

UNIVERSITY OF HRADEC KRÁLOVÉ
FACULTY OF INFORMATICS AND MANAGEMENT

DISSERTATION

SOCIAL SOFTWARE TO THE BENEFIT OF THE ELDERLY

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INFORMATION AND KNOWLEDGE MANAGEMENT

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DISCLAIMER

I hereby declare that the dissertation thesis is my own work and that I correctly cited literature and other sources I rely on.

In Hradec Králové, April 12th 2019

.....

David Zejda

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I could name researchers, developers, trial participants, or my supportive family. Due to the respect, though it was fully authored by myself, the first-person plural is used throughout the thesis.

ANNOTATION

The recent advancements in the science and industry, including the proliferation of digital technology allow paradigmatic shift from information society towards knowledge society, leading to the unprecedented prosperity. However, resulting benefits are not distributed fairly within the society across its dimensions, such as social status, nationality, race, or age; it leads to new challenges and tensions in the society. Seniors are among the groups endangered by the digital divide. Omnipresent technology, gradually transforming almost every economic sector and every aspect of human life, may make seniors feel side-tracked, lose self-esteem, limit their active participation, thus widen the generation gap. Technologies designed specifically for the elderly are not automatically beneficial; some even stigmatise. The root of the discrepancy between seniors' needs and products' functions lies in the missing or inadequate *knowledge* of product designers, service providers and others involved. Though they work with seniors as customers, they may still be lacking knowledge about seniors as *humans*, with not just limitations, but also needs and aspirations.

As a discipline of knowledge acquisition, processing and sharing, *the knowledge management* serves as a suitable principal foundation for the research. However, unlike traditional knowledge management which mainly targets business, technical or organisational goals (such as turnover, gain, productivity, length of development cycles, social network connectivity between individuals, etc.) the proposed *responsible knowledge management* leverages the organisation's potential to make positive impact on the society and the nature. As the thesis hypothesize, it may eventually lead into breakthrough or disruptive innovations, giving a new measure of benefit to its customers, and a substantial advantage to the organisation itself.

Responsible knowledge management involves treating consumers/customers as human beings. So, before reaching out to them with products or services, their behaviours and habits, needs and thinking are to be widely and meticulously examined, understood and eventually systematically targeted by products and services. To support the diffusion of knowledge management theory into practice and as an evolutionary step in human-centric design, *the in-depth human-centric design* is proposed to assist researchers, product designers and developers. Based on pillars of rational choice theory and cognitive science, it provides a set of principles and a toolbox of research and design methods focused on acquisition and utilisation of in-depth knowledge about consumers, potentially leading to truly beneficial products. The suggested principles and methods are experimentally applied through the following chapters.

First, explorative research into seniors' needs is presented with four identified clusters of deep needs as its results. Based on the acquired knowledge about their needs, a proposed novel type of *inclusive social software* could allow seniors, besides others, benefit from technologies of the digital world, meanwhile inaccessible for them. The proposed inclusive social software contrasts with widespread services and products, such as social media, which seemingly connect people, but in effect may even put people apart. Areas of architecture, functions, operation and deployment of the proposed inclusive social software are examined thoroughly and transformed into practical suggestions.

Based on the proposal, *a prototype* has been developed. It follows *good software design* and engineering practices including code reuse, maintainability, extensibility, scalability, etc. In harmony with the in-depth human-centric design principles, *creative design approaches* have been applied. Volunteers participated since the pre-development phase in a focus group with a user interface mock-up and in a game session. Ten participants were involved in the qualitative *in-depth usability testing*. During the trial, we combined semi-structured interviews, informal dialogues and user interaction data collected by the system. The in-depth methods have proven to be easy to perform, though time-consuming. A big majority of participants found the prototype both easy-to-use and beneficial. The trial further deepened the understanding of seniors in the role of digital technology users and suggested, that by appropriate products, the digital divide might be reduced not just gradually, but even almost suddenly.

The areas of responsible knowledge management, in-depth human-centric design, and the novel inclusive social software provide ample opportunities for both further research and practical applications, as examined in the concluding sections of the thesis.

Keywords: Responsible knowledge management, consumer behaviour, interdisciplinary studies, cognitive science, rational choice theory, seniors and ageing, in-depth human-centric design, inclusive social software, software architecture, in-depth usability testing.

ANOTACE

Nedávné pokroky ve vědě a průmyslu, včetně rozvoje digitálních technologií, umožňují paradigmatický přechod od informační společnosti ke společnosti znalostní, což vede k nebývalé prosperitě. Výsledné přínosy však nejsou ve společnosti rozdělovány spravedlivě napříč dimenzemi, jako je sociální postavení, národnost, rasa nebo věk, což vede k novým výzvám a růstu napětí ve společnosti. Senioři patří mezi skupiny ohrožené digitální propastí. Všudypřítomné technologie, které postupně transformují téměř každý sektor hospodářství a každý aspekt lidského života, mohou působit, že se senioři cítí být na vedlejší koleji, ztrácejí sebeúctu, omezují svou aktivní účast, celkově roste generační propast. Technologie speciálně určené starším lidem nemusejí být vždy prospěšné; některé mohou dokonce stigmatizovat. Příčina rozporu mezi potřebami seniorů a funkcemi produktů spočívá v chybějících nebo nedostatečných znalostech tvůrců a poskytovatelů služeb a produktů a dalších zúčastněných. Ti, i když pracují se seniory jako zákazníky, postrádají znalosti o seniorech jako lidech, charakterizovaných omezeními, ale i potřebami a aspiracemi.

Jako disciplína popisující procesy získávání, zpracování a sdílení znalostí je znalostní management vhodným teoretickým východiskem. Ovšem, na rozdíl od tradičního pojetí, kdy znalostní management sleduje především obchodní, technické nebo organizační cíle (např. obrát, zisk, produktivita, délka vývojových cyklů, sociální sítě mezi jednotlivci, atd.), navržený odpovědný znalostní management zaměřuje pozornost na využití potenciálu organizace k pozitivním dopadům na společnost a životní prostředí. Předložena je hypotéza, že zahrnutí těchto vlivů do sledovaných prioritních cílů znalostního managementu může ve výsledku vést k průlomovým inovacím, které přinesou zákazníkům zásadně vyšší užitek a zároveň podstatnou konkurenční výhodu samotné organizaci.

Jednou ze složek odpovědného znalostního managementu je vnímání spotřebitele/zákazníka jako lidské bytosti. Dříve než jsou navrhovány a vyvíjeny produkty, je třeba pečlivě prozkoumat a pochopit chování, návyky, potřeby a myšlení zákazníků. Poté je možné tyto znalosti systematicky proměňovat do charakteristik produktů a služeb. Aby se výzkum neomezil pouze na teorii bez vazby na praxi a zároveň jako evoluční krok v lidsko-centricém návrhu, navržen je hloubkový lidsko-centrický návrh. Ten na základě pilířů v podobě teorie přirozené volby a kognitivních věd poskytuje výzkumným pracovníkům, produktovým návrhářům a vývojářům soubor principů a metod výzkumu a návrhu zaměřených na získávání a využívání důkladných znalostí o spotřebitelích, jež mohou vést k prospěšnějším produktům. Navrhované principy a metody jsou pak experimentálně aplikovány v následujících kapitolách.

Nejprve je prezentován provedený explorativní výzkum potřeb seniorů spolu se závěrem v podobě čtyřech identifikovaných klastřů hlubokých potřeb. Na základě těchto znalostí je navržen nový koncept inkluzivního sociálního softwaru, který by mohl seniorům umožnit, mimo jiné, využívat těch technologií digitálního světa, které jsou pro ně z velké části nepřístupné. Navrhovaný inkluzivní sociální software kontrastuje s běžnými službami a produkty, jakými jsou např. sociální média, která lidi zdánlivě spojují, ve skutečnosti ale mohou rozdělovat. Architektura, funkce, podmínky provozu a nasazení navrhovaného inkluzivního sociálního softwaru jsou zkoumány a transformovány do praktických návrhů.

Na základě návrhu byl vyvinut prototyp. Vychází ze zásad dobrého návrhu software a souvisejících inženýrských postupů, vedoucích např. ke znovupoužitelnosti kódu, udržitelnosti, rozšiřitelnosti, škálovatelnosti atd. V souladu s principy hloubkového lidsko-centrického návrhu byly použity kreativní návrhové přístupy. Dobrovolníci byli zapojeni již do předvývoje např. formou fokusní skupiny. Deset účastníků se pak podílelo na kvalitativním hloubkovém testování použitelnosti. Během procesu jsme kombinovali data z částečně strukturovaných rozhovorů, neformálních dialogů s údaji o interakci uživatelů shromážděných systémem. Subjektivně zhodnoceno, hloubkové metody se prokázaly jako užitečné a poměrně snadno proveditelné, i když časově náročné. Pro drtivou většinu účastníků byl prototyp snadno použitelný a zároveň přínosný. Test prohloubil porozumění seniorům v jejich roli uživatelů digitálních technologií a naznačil, že pomocí vhodných produktů by digitální propast mohla být zásadně zmenšena.

Oblasti jako odpovědný znalostní management, hloubkový lidsko-centrický návrh nebo inkluzivní sociální software poskytují mnoho příležitostí jak pro další výzkum, tak i pro praktické aplikace, jak je popsáno v závěrečné části práce.

Klíčová slova: Odpovědný znalostní management, spotřebitelské chování, interdisciplinární studia, kognitivní věda, teorie přirozené volby, senioři a stárnutí, hloubkový lidsko-centrický návrh, inkluzivní sociální software, softwarová architektura, hloubkové testování použitelnosti.

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ABBREVIATIONS

2G	The second generation of broadband mobile network technology
3G	The third generation of broadband mobile network technology
4G	The fourth generation of broadband cellular network technology
AJAX	Asynchronous JavaScript + XML; techniques and technologies for client-side asynchronous Web
API	Application programming interface
ASCII	American Standard Code for Information Interchange
ASP	Active Server Pages
B20	FDD-LTE frequency band operating around 800 MHz; used by operators in many EU countries
CE	Consumer electronics; manufacturer's declaration that the product meets the standards for EEA
CORS	Cross-Origin Resource Sharing
CPU	Central processing unit
CSS	Cascading Style Sheets
CSS3	Cascading Style Sheets, version 3
DAL	Data abstraction layer
DOM	Document Object Model; interface that treats an XML document as a tree structure
EARFCN	E-UTRA Absolute Radio Frequency Channel Number
EDGE	Enhanced Data Rates for GSM Evolution
FDD	Frequency division duplex; a concept related to the LTE standard
GDPR	The General Data Protection Regulation (EU) 2016/679
GET	An HTTP request method; requests data from a specified resource
HIPAA	Health Insurance Portability and Accountability Act
HSPA	High Speed Packet Access
HTML	Hypertext Markup Language
HTML5	A markup language for content on the web; subsumes HTML 4, XHTML 1, and DOM L2 HTML
HTTP	Hypertext Transfer Protocol
HTTPS	HTTP Secure
IPS	In-plane switching; a screen technology for liquid-crystal displays (LCD)
JSON	JavaScript Object Notation (a lightweight data-interchange format)
LCD	Liquid-crystal display
LTE	Long-term evolution (a standard for high-speed wireless communication)
OEM	Original equipment manufacturer
PHP	A recursive acronym for 'PHP: Hypertext Preprocessor'; a server-side scripting language
POST	An HTTP request method; submits data to be processed to a specified resource
REST	Representational State Transfer
RSS	Rich Site Summary
SMS	A text messaging service of most telephone device systems

SQL	Structured Query Language
SSH	Secure Shell
SSL	Secure Sockets Layer
TLS	Transport Layer Security
UI	User interface
URL	Uniform Resource Locator
UUID	Universally unique identifier
Wi-Fi	A trademarked term meaning IEEE 802.11x
WSGI	The Web Server Gateway Interface
X.509	A standard that defines the format of public key certificates
XML	Extensible Markup Language

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1 INTRODUCTION

1.1 THE PROBLEM AND THE CONTEXT

1.1.1 INTELLIGENT TECHNOLOGIES – BENEFICIAL OR NOT?

The web has irreversibly transformed into Web 2.0. More than a matter of the technology behind, the web has redefined its meaning and sense. Its users are not only consumers but consumers and producers in parallel, 'prosumers' as defined by Klamma et al. (2007). Besides serving as a space for implicit socialisation (Wennerberg & Oellinger, 2006), current web, a whole ecosystem of complex and interconnected services running on millions of servers and clouds around the globe, offer variety of spaces designed to provide social services, such as dating sites, community portals, blogging and microblogging services, co-authoring wikis, and social media. Users perceive Internet and web in particular as a natural place to socialise, to interact, to share, to live. The evolution has not stopped, but the transition towards Web 3.0, a semantic web, is on the way, with some attributes of what some authors call Web 4.0 or Web 5.0¹. The emerging or ongoing trends involve Internet of things, a network of physical objects, such as devices, vehicles, buildings and other items, equipped with electronics, software, sensors, and network connectivity, that enables these objects to collect, exchange data and interact. Context-aware systems bring a general class of mobile systems that can sense their physical environment and adapt their behaviour to it, often as components of a whole ubiquitous computing or pervasive computing environment. Smart homes, offices, hospitals, or entire cities, equipped with own ambient intelligence are still in a stage of prototypes, but also offer promising opportunities on the horizon. Also thanks to modern technologies, we all belong to a global-world village. As expressed in the small world phenomenon, everyone is connected with anyone else through only several steps of relations (Pavlovic, 2009). The technologies allow to build these relations and maintain them fresh – find and meet friends from the other side of the globe, or to keep in touch with close despite the long distance. But on the other hand, the smart technologies, undoubtedly *beneficial in many areas*, also have their grim side.

The technologies which allow pushing content toward the consumer are emerging both on demand of Internet users and content providers. Major social media, created with a declared aim to connect people, have transformed into advertising platforms, making a fortune for their owners. As a logical conclusion, the monetary benefits serve as a significant incentive for the providers to keep the attention of their users as much as possible, so they spend vast amounts of time on their platforms – which may quickly become more than what is beneficial users. It leads the companies to employ psychologists and other professionals who help them to do it as efficiently, as possible. As a result, new problems arise. The technology overuse may lead to *social and psychological harm*. Several clinics now offer treatment for internet addiction disorder (Donnelly, 2013). Social media addiction is not a formal clinical diagnosis, or at least not yet. But social software plays a prominent role in addictive digital content. Many people spend far too much time on social media. Recently, psychology becomes increasingly interested in the impact that modern technology has on our lives, both positive and negative. Social software allows staying in contact with family and friends on the other side of the Earth. But on the other hand, people spend hours every day updating their status, uploading pictures, commenting, competing in silly games, reading updates, and searching for new so-called friends to add to the ever-growing list. Young people of today are losing real-life social abilities and healthy habits. New social strategies are necessary to cope with the social and information overload (Walter, Battiston, & Schweitzer, 2008), which brings new pressures, security, safety, and even health risks. Our cognition and behavioural patterns have changed in just a few years so rapidly, that we can't even think of a world without Google (Coupland, 2018). The impacts are yet to be fully assessed. Observing the effects of such addiction or experiencing them, it has led some former digital media consumers to radical steps, such as abandoning certain digital media, or digital media altogether.

The proliferation of digital technology is accompanied by a wide range of *breaches of trust*. Trust profoundly influences our social relations and social interactions. With trusted people, we usually deal

1 Consensus about the naming of web versions beyond Web 3.0 has not been reached yet.

differently than with strangers. Significant effort was rendered to make the Internet a safer space. We have security and trust authorities, security certificates, efficient algorithms, trust-related ontologies, trust processing and trust management. However, deceivers do not silently wait. Scamming, phishing, impersonating and profile hijacking, cyberstalking, trust authority compromising are some of the types of virtual attacks. Incidents recorded in a study by Loizou (2012) often involved harassment, cyberstalking, hate speech, trolling, assaults, sex offences, unauthorised access to accounts, privacy-related issues, and hacking. More than 100 categories of crime were recorded by the police, in which Facebook had been mentioned during the report. The study concludes, that although it is tough to assess the exact level of risk for the users, “it becomes apparent that criminal activity on Facebook is existent and growing.” If the elderly enter general purpose social media, such as Facebook, they are likely to be one of the most vulnerable groups, since in general, they have not adopted the necessary vigilant strategies to deal with the threats. Further, there is worldwide concern over false news being spread over digital technology, which may have a vast impact on political, economic, and social well-being. An extensive study of Vosoughi, Roy, & Aral (2018) has shown, that compared to truths, false news spread rapidly, like a snowball which may trigger an avalanche. According to the authors, the degree of novelty and the emotional reactions of recipients may be responsible for the differences observed.

Business models of big software giants, such as Google, Facebook, Amazon, or Microsoft, seem to be gradually converging. By a broad application of artificial intelligence methods, they accumulate vast amounts of personal data of their users. These assets of personal data have become a new type of a very lucrative commodity. But, as usual, governments are at least a step behind the big business. They are somewhat struggling to come up with efficient mechanisms able to protect essential rights in these newly emerged areas. It leads to *the disproportion of benefits from personal data*. Efforts, like the recent and European General Data Protection Regulation, which claims is the most critical change in data privacy regulation in 20 years (Trunomi, 2017), tries to solve some of the relevant issues, but remains controversial and some doubt that it tackles the problem in the right way or that it is sufficiently compatible with the whole ecosystem of various regulatory norms; refer, for example to Bräutigam (2016). New roles and jobs, like a personal data broker who would help citizens to share the benefit from the data which others keep about them, are still waiting to be revealed or occupied.

Intelligent technologies have improved our lives in many ways, and there is no space to enumerate them. But these benefits are accompanied by severe challenges. Some of them might even undermine the very roots of the whole modern human society if they would not be taken seriously. The dissertation thesis is trying to come up with a small piece of the entire puzzle of solutions.

1.1.2 DIGITAL SOCIALIZING AND THE ELDERLY

The proportion of elderly population grows steadily in developed countries. According to the statistics published by Eurostat, there was 15.8 % of people over 65 in 27 member states of the European Union in 2001, and the number reached 19.4 % in 2017 (Eurostat, 2018). And according to Cellan-Jones (2015), it is estimated that, by 2030, 19 % of the US population will be over 65 and by 2050, there will be one retired person for every two that are in work. But, age is not the only criterion for defining the elderly². Ageing may be viewed as simply getting more years, as a biological process, or, e.g. as a process of transition through certain life stages. The process of ageing is often indicated by the progress of age-related diseases, such as diabetes, arthritis, Alzheimer's disease and by gradual cognitive decline. By contrast, real old age brings a sharp decline in both mental and physical abilities (Degnen, 2007).

Our lives in the age of unprecedented prosperity are fast and hurried. It brings barriers for people who are not able or willing to adhere to the speedy and shallow way of life. Social relations are important predictors of happiness among the elderly, and perceived companionship is the best predictor of happiness among all social relations variables examined by Baldassare et al. (1984). While a typical social network of a youngster is broad, populated by users with hundreds of so-called 'friends' each, matured people usually select more precisely which relation they wish to keep. Seniors appreciate the depth of relations much more than the breadth of their social network. These dissonances in values, thinking and living, different opinions

2 The presented research uses a relatively wide definition of “the elderly” or “seniors”. More in section 4.1.

and abilities *widen generation barrier* between the elderly and youngsters. Children often live far, or pace of their life makes their visits less frequent, and the generation barrier causes, that even if people meet, they do not have much in common to talk about (Evjemo, Svendsen, Rinde, & Johnsen, 2004). The elderly don't wish to be sidetracked, isolated from the world of today. Sadly, often they are. In Japan, a new word, Kodokushi, has found its way into the dictionary to reflect the modern phenomenon of unattended death, when usually an old or sick person dies, and nobody cares, even for weeks or months (Tamaki, 2014). But even not going to the extremes, health risks of social isolation are similar to the dangers of smoking cigarettes and obesity (Cornwell & Waite, 2009). And just seeing crowds of youngsters walking in streets or commuting, with their sights buried in displays of newest smartphones, ignoring the world around, makes the generation of grandparents feel, that they must be living in a different world. As a result, the technology with potential and aim to connect people and bridge gaps may even deepen them. Youngsters may feel as digital natives, while the elderly as immigrants to a hostile world (Prensky, 2001). To prevent the social exclusion of seniors is one of the challenges for today's society. To help seniors to stay independent and active in their community by the modern technology, it is even an official goal of the European Commission (European Commission, 2016).

As a parallel, in retirement institutions, there might be an excellent level of assistance and care available. But, discussed later, the high level of care is not the primary source of contentment for those who perceive the institutional setting as beneficial. Instead, users commend if the environment allows them to, e.g. overcome their loneliness through meeting new people. On the other hand, the elderly often prefer ageing in place, in their familiar surrounding, near to family, despite the weaker tangible support there. Many perceive the move to an institutional setting as a loss. As one cause of negative feelings, *professional care often mutates into control* (Mynatt, Rowan, Craighill, & Jacobs, 2001). People do not wish to be controlled, and the elderly are not an exemption. Further, previous heterogeneous social connections comprising people of all generations are often damaged, disturbed or even destroyed in retirement institutions (Mynatt et al., 2001), emphasising the feeling of being very old and powerless. Similarly, intelligent sensory monitoring systems aimed at fall or other crisis detection, or cognitive support systems, such as reminders pushing users to take medication timely focus on assisting caregivers rather than care receivers. Such systems may be dehumanising, making care receivers feel just like mere objects in the process of elderly care. No surprise that such systems often do not make the care-receivers rejoice (Miyajima, Itoh, Itoh, & Watanabe, 2005).

Seniors form a *significant market group* with specific needs and preferences that designers, developers, and engineers should take into account (Sustar, Pfeil, & Zaphiris, 2008). The market is ripe for the proper type of innovation. Sherwood (2015) quotes Lisa Gundry, director of the Center for Creativity and Innovation at DePaul University. "*It's really worthwhile to look toward the senior market,*" she says. "*It's a market that's ready and waiting for innovative products and services. And it's willing to pay for it.*" But, the cost of development grows with the complexity of intelligent products. Thus, such a development should not be hit and miss. Sadly, as Rogers & Mynatt (2003) note, many computer systems have been designed with insufficient regard for older users. As mentioned by Cellan-Jones (2015), nowadays there is no shortage of technology designed for seniors. From hearing aids that adjust volume according to the current geolocation data from GPS to robots that can carry the elderly around and wireless sensors everywhere, even on mattresses. Sherwood (2015) asks a relevant question: "*But do older people want any of this when many have not got to grips with the more basic technology most of the younger generation take for granted?*" Ian Hosking, quoted in the article relates his experience from research and design for the elderly: "*There are some very tech-savvy older people around, but there is clearly a large cohort of people who feel excluded by technology. They find it a bit impenetrable.*"

The technology has potential to suppress negative aspects of the process of ageing, improve safety and health conditions of the users. But, sadly, many such projects tend to be more technology-centric than human-centric, in the way how are they designed or presented, which leads to disappointment both on sides of developers and potential users. How to increase chances for a positive reaction of potential users to an intelligent product? Or even better, how to develop intelligent products, which would be very likely positively accepted and which would bring significant benefit to users' lives? New product design and engineering approaches and methods are needed to let designers and engineers gain and apply the appropriate knowledge.

1.2 KNOWLEDGE MANAGEMENT PERSPECTIVES

Knowledge management serves as a principal foundation for the thesis, which in return contributes to the knowledge management on both conceptual and practical level.

1.2.1 KNOWLEDGE MANAGEMENT EVOLUTION AND CHALLENGES

As described more than 50 years ago, an organization's ability to process information belongs to the core of organizational and managerial competency, thus the strategies shall improve information processing capability (Richard M. Cyert & March, 1959). *Information management* concerns the life cycle of information within the organisation, from its acquisition, through distribution and utilization, to archiving or deletion. More recently, researchers shifted their attention to various categories, dimensions and contexts of business information within the organisation. New approaches, such as business process management (Hammer & Champy, 2009; Johansson, McHugh, Pendlebury, & Wheeler, 1993), intellectual capital management (Edvinsson & Malone, 1997; Kar & Khavandkar, 2013), or knowledge management (I. Nonaka, 2008; Wiig, 1995) emerged. After receiving substantial attention from researchers, they eventually evolved into distinct disciplines, though until now there is still no general consensus about their exact scope and objectives and they often overlap. Efforts to shed light on relationships between the fields could be tracked well back to the past (Wiig, 1997). But until now, e.g. intellectual capital management may be either viewed as just one of knowledge management perspectives (Choo & Bontis, 2002), or as a broader field which involves knowledge management as one of its components (Khavandkar, Theodorakopoulos, Hart, & Preston, 2016; Stewart, 1997). For our research, we adopted the view that knowledge management leads to leveraging intellectual capital (Pasher & Ronen, 2011), which puts knowledge management in a good position to serve as a theoretical foundation for our research.

Contemporary *knowledge management* stems from various disciplines, such as management, information technology, social sciences, complexity science (Snowden, 2002), information theory (McInerney, 2002), or philosophy (Spender & Scherer, 2007). It comprises of mainly creating, sharing, using and managing *knowledge*, and doing so in a multidisciplinary manner. Knowledge, described e.g. as a step from information towards wisdom (Ackoff, 1999, p. 170), has become the modern-age commodity of primary importance. Early works distinguished between tacit knowledge and explicit knowledge and described the conversion processes between them, such as the famous SECI model and knowledge spiral (Ikujiro Nonaka, Takeuchi, & Umemoto, 1996); others argue that such a process provides blurred and oversimplified view explicit knowledge, represented in language and symbols as mere information (Wright, 2005). The so-called organizational knowledge creation theory is still evolving, incorporating the academic discussion, attempts to infuse it to management practice and the feedback received (I. Nonaka & von Krogh, 2009; I. Nonaka, von Krogh, & Voelpel, 2006).

Links between knowledge management, competitiveness, and innovation have been examined, e.g. by Carnero (2000). And, for example, Darroch & McNaughton (2002) completed a study of how knowledge management specifically contributes to *innovation*. They measured innovation on the three-dimensional scale involving incremental innovation, the innovation that changes consumers' behaviour and innovation that destroys existing competencies. They have concluded, that knowledge acquisition and responsiveness to knowledge are both vital and more important for innovation than knowledge dissemination. According to some, appropriate knowledge management, which involves all fundamental business processes in a company, may lead to the *creative and innovative organizational climate*, which has a potential to deal with challenging and complex issues of today's society (B. Gupta, Iyer, & Aronson, 2000).

Researchers differ in their focus on various aspects of knowledge management. Some focus on information technology which enhances the knowledge capture, sharing, and utilisation (Alavi & Leidner, 1999), including e.g. social media (Zammit & Woodman, 2013). Others highlight the system aspects of an organisation, such as its structure and processes (Addicott, McGivern, & Ferlie, 2006). Personal knowledge management (Wright, 2005) sets an alternative area for systematic dealing with knowledge. Bray (2007) look beyond the organisational boundaries and involve the surrounding *environment*; in his view, the interaction of different people and their knowledge within the organisation and its environment compose a complex adaptive system which could be related to a natural ecosystem. In a synthetic view of these various

works, the core components of knowledge management include people and their culture, the organisation as a system, and underlying or supportive technology.

As a new proposal, the areas of knowledge management may be structured, besides else, according to (1) different central objects of knowledge (the knowledge *about* something, e.g. about customers, the staff, research and development, production, the market and competition, marketing, etc.), according to (2) subjects of knowledge (*who* primarily carries the knowledge, e.g. engineers, designers, developers, managers, or even information systems, or organisation structure itself), or (3) perspectives (primary *quality* of concern, e.g. applicability, performance, flexibility, safety, openness, availability, scalability). More dimensions might be identified or examined, such as representation (e.g. tacit vs. explicit), or usage (invented, tested, applied, refused). Figure 1 illustrates the idea of three main conceptual dimensions of knowledge management; circles of different size at intersections of dimension values mean different amounts of knowledge.

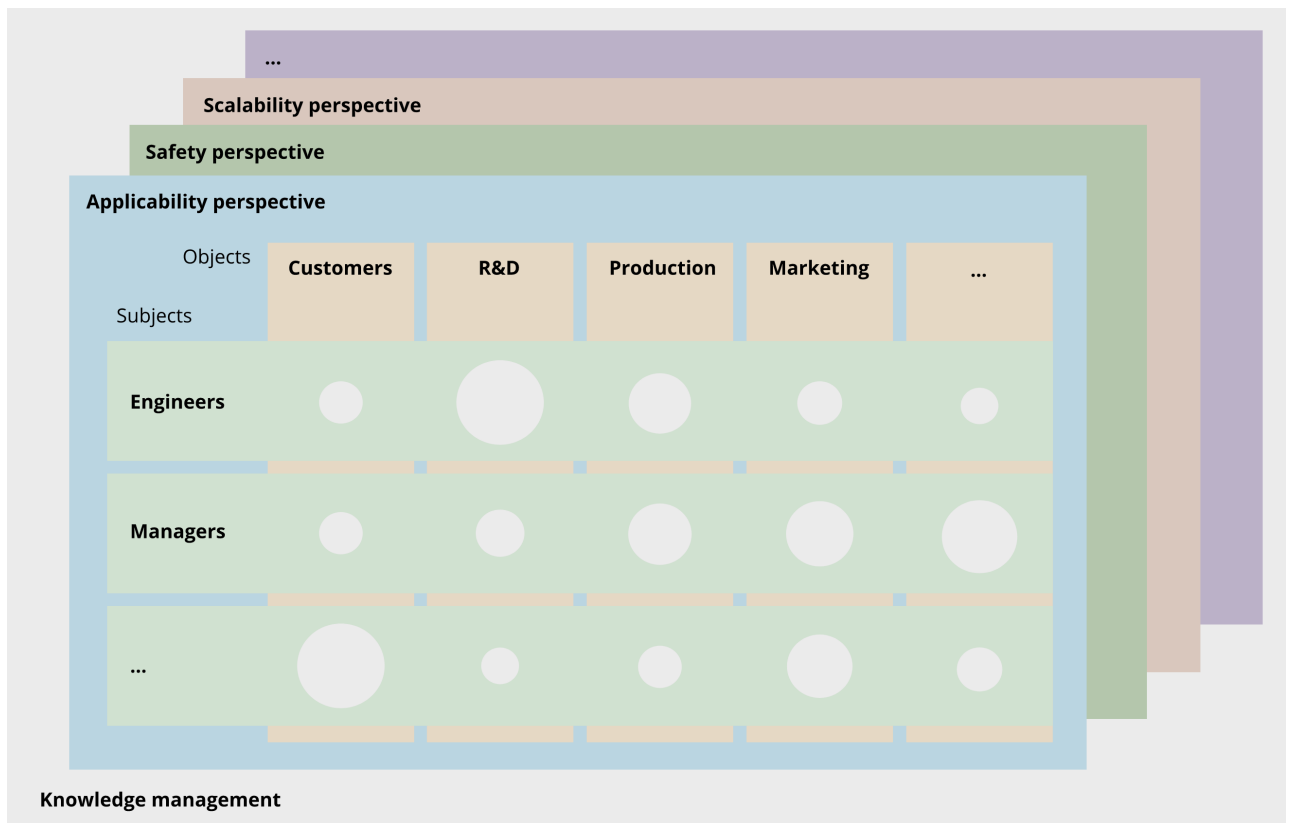


Figure 1: Knowledge management dimensions

1.2.2 KNOWLEDGE MANAGEMENT OBJECTIVES

Knowledge management as a part of business administration is closely related to the economy, because, from strategic point-of-view, their objectives complement each other or even overlap and converge. Friedman (1970) claimed that creating profit is the only *social responsibility* of a company. But, the sentiment is shifting (Nunn, 2017). As a survey of directors of Australian companies conducted jointly by the AICD³ and KPMG (2018) found, only 3 % of directors felt that corporate Australia had no role in supporting social inclusion, 89 % of felt that the inequitable distribution of benefits eroded social cohesion, half of the directors felt that the social contract needed to be renegotiated and only 18 % disagreed (Nunn, 2017).

The problem also has its *macroeconomic* perspective. OECD countries inequality is at its highest level in 30 years (OECD, 2015). The dangerous trend is evident not only in regards to wealth, but also education,

3 Australian Institute of Company Directors

employment, health, and human rights. When the gaps between rich and poor widen, it increases the tensions in the society. Unequal distribution of welfare highlights the division line between the North and the South. Migration waves catalyse of the rise of xenophobia and nationalism around the world. The shift in moods is strong for example in Central-Eastern Europe (Cave & Roberts, 2017).

In parallel to the shift in sentiment toward profit as an only goal from the microeconomic point-of-view, also pure economic growth does not seem a satisfactory objective anymore, at least for some. New economic models have been constructed to involve values, such as environmental quality, social protection, food security, or equity of health (Hasmath, 2015). The term of *inclusive growth*, promoted, e.g. by Ianchovichina & Lundstrom (2009), eventually found its way into official strategic documents of important stakeholders. For example, a draft paper issued by European Commission in 2010 envisioned Europe of 2020 as a cradle of smart, sustainable and inclusive growth (European Commission, 2010). The time is ticking fast. While certain progress towards the vision has been achieved, the overall trend of increasing economic inequality does not seem to reverse any time soon. It emphasises the need to work more on the ways how products, including those adopting advancements in technology, could be delivered *to the benefit of all* – both poor and wealthy, men and women, young and old. Though Friedman repeatedly defended his stance (e.g. 2007), the ‘shareholder primacy’ which, according to (Nunn, 2017) has dominated the structure and regulation of markets since the industrial revolution and which leads to prioritizing short-term gains over long-term sustainability, seems no longer as a sole and ultimate goal of all business.

Similarly, knowledge and its proper management have a wider impact than just making businesses more competitive in terms of market share, turnover, or profits. It also has its *social and ecological dimension*. Sustainability and knowledge management are key components in a complex process of product development (Trotta, 2010). Melville (2010) highlights the role of information systems in the knowledge-rich innovations leading to sustainability. From the microeconomic point-of-view, improvements in the knowledge-acquisition and knowledge-processing may not only lead to a distinct competitive advantage, but also to the reduction in wage inequality (Garicano & Rossi-Hansberg, 2006). And from the macroeconomic side, regional smart specialisation strategies may lead to both sustainable and inclusive growth (Carayannis & Rakhmatullin, 2014). However, primary *scope of knowledge management objectives* is still mostly limited to the *organisation* (Alavi & Leidner, 1999; Girard, 2015; J. N. Gupta & Sharma, 2004). For example, according to Snowden (2002) knowledge management objectives typically include facilitating and managing innovation and organisational learning, leveraging expertise across the organisation, making increased knowledge in the development and provision of products and services available throughout the organisation, achieving shorter development cycles, increasing network connectivity between individuals within the organisation or elsewhere, or managing collaboration environments to support insights and ideas emergence.

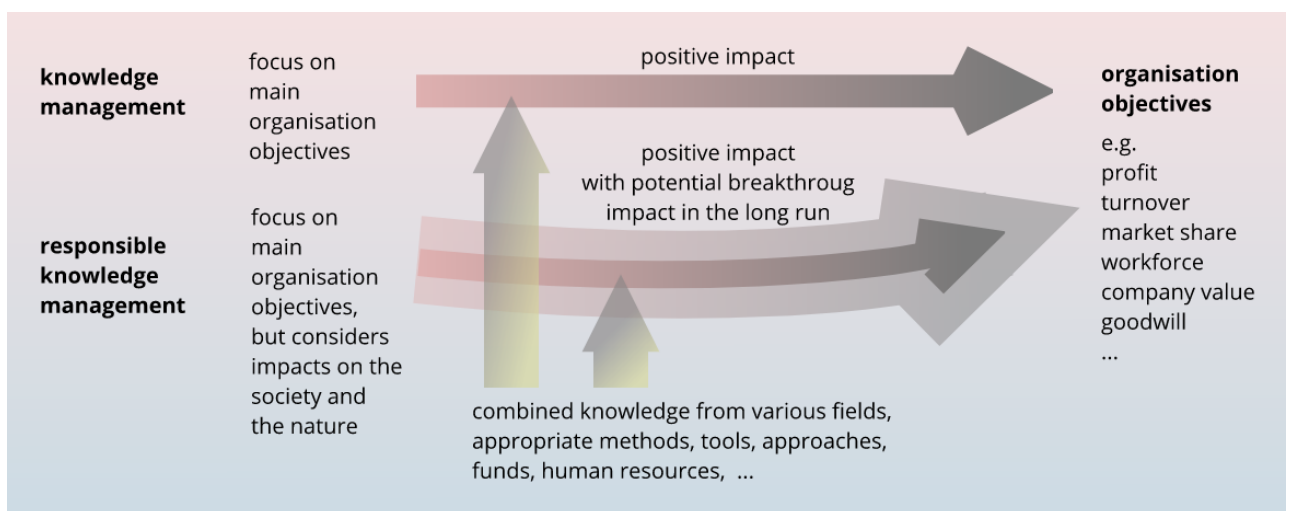


Figure 2: Hypothesis of the impact of responsible knowledge management on organisation objectives

The thesis joins the voices calling for a shift from the rather technocratic knowledge management to more holistic, creative, human-centric approach (Andriessen, 2004; Bray, 2007; Melville, 2010; Thomas, Kellogg, & Erickson, 2001; Trotta, 2010). Knowledge management should not merely follow the organisation's objectives; humans and their needs should be considered thoroughly. Employees and customers are of primary concern, but the needs of the surrounding community, wider society, or even future generations should be part of *responsible knowledge management* considerations. As a hypothesis we suppose, that making knowledge management responsible, it may in effect contribute to the organisation's economic objectives better, especially in the long run. Figure 2 illustrates the hypothesis – the potential strong impact on the organisation's objectives. The thesis does not intend to provide any definitive answer, but rather start evaluating the hypothesis practically on the problem of accessible and beneficial software for seniors.

Figure 3 offers a holistic view of a company, broken down into concepts such as economy objectives, impacts objectives, assets and goodwill, marketing and customer management, management. Interactions between concepts are denoted as arrays. The view involves core economic objectives, such as market share, profit, or turnover, enhanced by impact objectives of environmental, social, and cultural responsibility. Knowledge is considered both as an asset and an object of knowledge management, a mediator through which knowledge management influence the system. All concepts are used in a broad sense, such as that objectives mean both goals and their fulfilments, both in short and long run. The view goes beyond the company itself, involving its environment and relevant influences, however it does not intend to be exhaustive; it serves rather as a mental map to show a company from a broader perspective, including the position and the role of knowledge and knowledge management. It also illustrates the role of the beyond-economy objectives and highlights the need to not lose the whole picture when dealing with particularities.

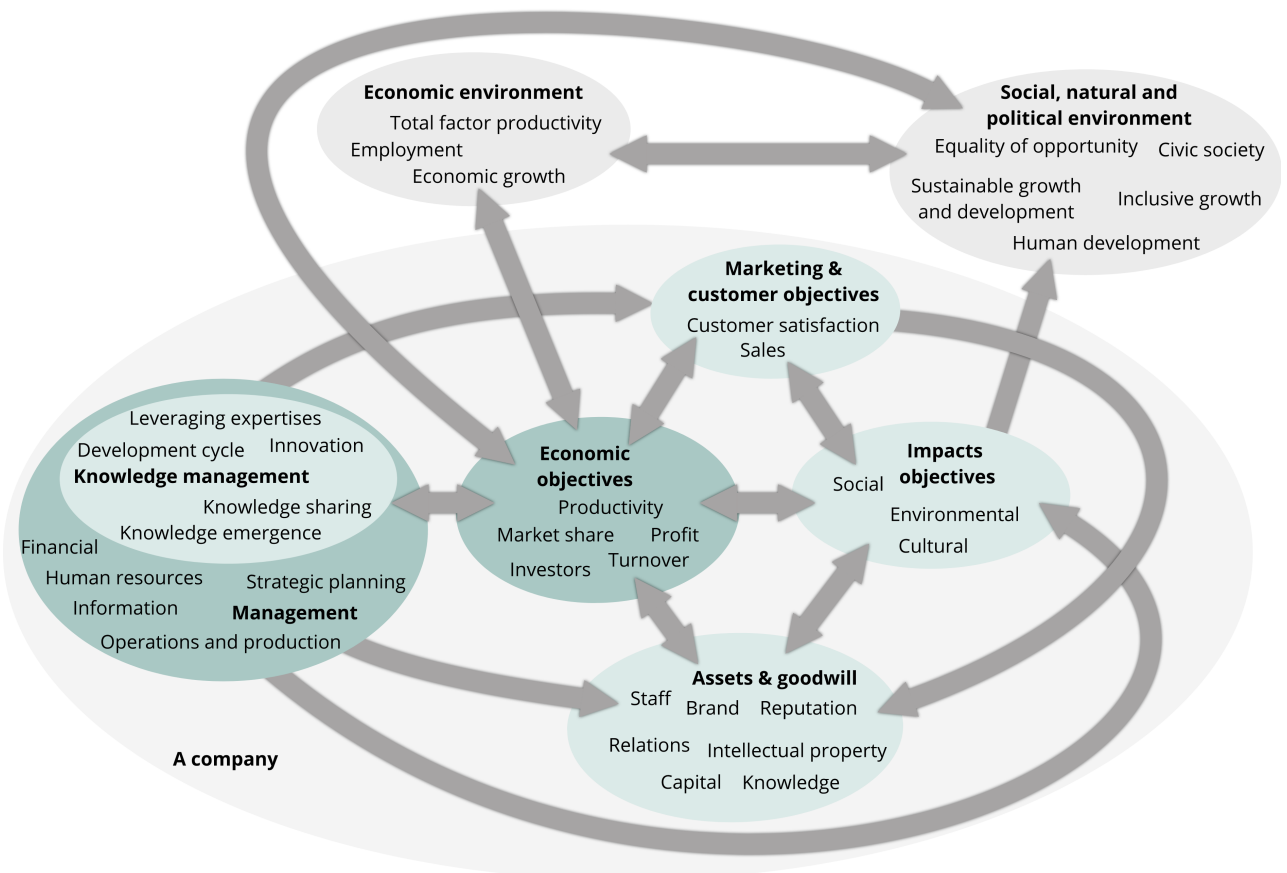


Figure 3: Holistic view of a company calling for responsible knowledge management

programmes and research areas, but without the necessary thoroughgoing reform. Interdisciplinary research centres usually do not host cohesive groups tackling well-defined problems, but rather loosely connected individuals searching for intersections. But she also notes a positive shift in the increase of public spending dedicated to interdisciplinary research and relevant growing awareness⁴.

Current knowledge management challenges the orthodoxy of scientific management (Snowden, 2002). Non-rigorous, but creative approaches lying on the boundaries of science and art, such as *creative science* (Callaghan, 2013) may have big innovative potential. New and innovative approaches are needed to move forward, such as complex adaptive systems theory to model behaviours of individuals and communities, including the natural flow of knowledge creation, disruption and utilisation. Knowledge is seen paradoxically, as both a thing and a flow requiring diverse management approaches (Snowden, 2002). Broad context, including economic, psychological, sociological, and cultural aspects, has to be considered to deliver truly beneficial products (Singh, 2010). Tokoro (2010) in his proposal of *open systems science* emphasises the interdisciplinarity as a key aspect of the science of the future, the science able to deal with the big, global and open issues of the present and the following days. Rhoten (2004) quotes Wilson (1998) who claims, that 'consilience', the "jumping together of knowledge" across disciplines "to create a common groundwork of explanation", is the most promising path to scientific advancement, intellectual adventure, and human awareness. According to Rhoten (2004), Wilson (1998) and other interdisciplinary advocates contend that the breaching of scientific boundaries will lead to other breakthroughs as critical as the cracking of the DNA code.

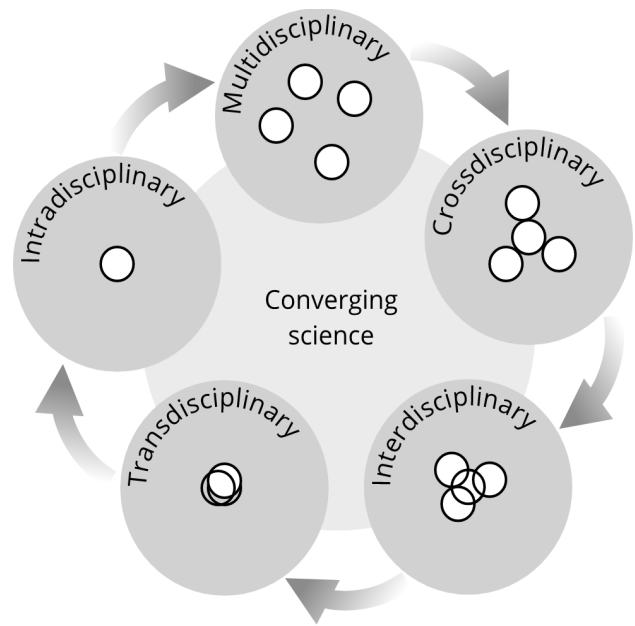


Figure 5: Converging science; inspired by Jensenius (2012)

But, with a long history of research in distinct areas science researchers may feel challenged to absorb sufficient amount of multiple-domain-specific knowledge. Adopting the interdisciplinary approach requires a *shift in epistemological values and intellectual interests* (Rhoten, 2004). It may seem as an unpassable cognitive barrier. Research in intersections of distant fields can be likened to the work of prospectors who survey vast areas to identify not-yet-known deposits of resources. Similarly to the prospecting, the initial exploratory research work is likely to be less rigorous in comparison with research in well-established distinct fields of study where research problems are usually precisely defined and well-known. The ambivalent and hard-to-grasp nature of explorative interdisciplinary research may add to the qualms or even trigger criticism towards those explorers.

Though challenging, the multidisciplinary approach is *worth of the effort*. The intersections between fields of science represent the white areas on maps of scientific knowledge, such as those created by Boyack et al. (2005). Fields of science are sometimes also illustrated in the form of a pie chart, where each section of the chart represents a distinct field or area of research. As a contribution to the debate about interdisciplinary research, Figure 6 provides an alternative 'windmill' view to the common pie chart. The fact that the middle part of each field is more distant from the centre illustrates that the horizon of knowledge is most likely

4 The doctoral programme 'information and knowledge management' provided by the University of Hradec Králové is an example of still relatively scarce interdisciplinary study programmes offered by universities. The program characteristic reads: "In today's practise we need more than just the Internet and related technologies. We need to use software tools that change the information to knowledge and use them to fix the problems of the real world." (University of Hradec Králové, n.d.) The program also stresses creative approach to research. Students have to combine various methods to exploit synergistic combinations of information and communication technologies with an innovative and creative capacity of human individuals.

farther in purely distinct areas of science, such as mathematics, or linguistics, than at boundaries between fields. Coming up with important or even *breakthrough results* (Rhoten, 2004; Singh, 2010; Tokoro, 2010; Wilson, 1998) might be less-elaborate and more likely *in interdisciplinary areas*, than in distinct domains. The third part of Figure 6 illustrates the idea; to make similar progress in an intersection of disciplines (same shift in distance from the centre) smaller area has to be pushed forward than in the case of distinct fields.

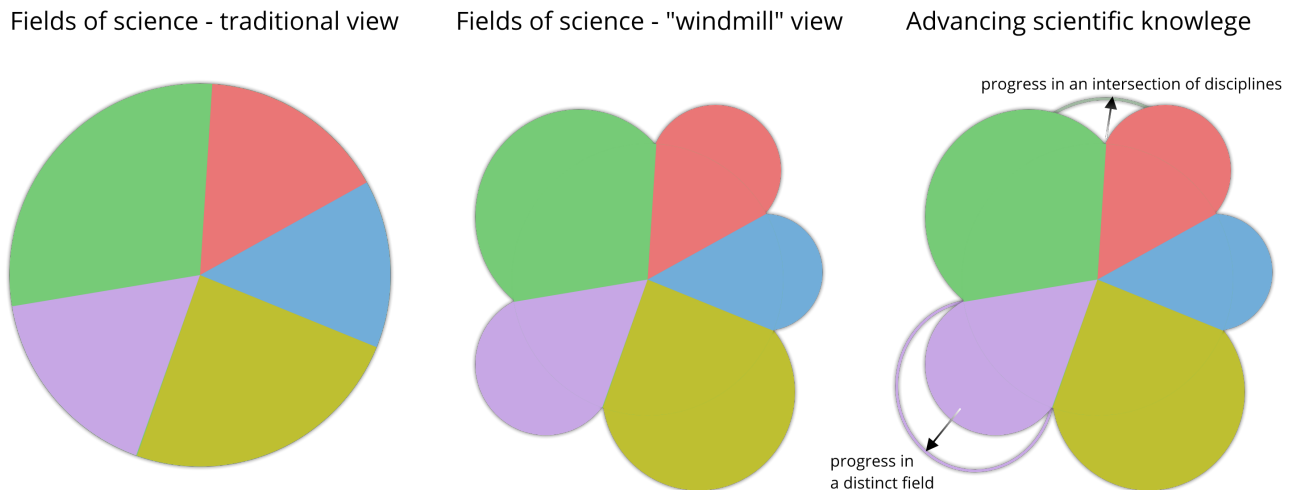


Figure 6: Scientific fields – a common pie chart representation and an alternative 'windmill' representation

The heavily multidisciplinary nature of the whole thesis, from the newly proposed in-depth human-centric design methods (Chapter 3), through their experimental utilization in the proposal of a new software concept (Chapter 4), developing its functional prototype (Chapter 5), to the concluding usability testing (Chapter 6), may be viewed as an additional push towards even stronger multi- and interdisciplinary nature of knowledge management, leading to intense diffusion of ideas, angles-of-view, concepts, methods, and tools between disciplines.

1.2.4 PRACTICAL APPLICABILITY OF KNOWLEDGE MANAGEMENT

Researchers are in danger of *losing connection with both humans and companies* and their 'ordinary' problems. Though having one of its roots in business and despite the excitement and recent advancements in the field, knowledge management research is perceived by some as quite detached from business reality; as if there are two relatively distinct knowledge management tracks, one of the academics and of the practitioners (Andriessen, 2004; Booker, Bontis, & Serenko, 2008; Ferguson, 2005; Sembel, 2015). So, scientific knowledge shall be confronted and compared with the knowledge from relevant businesses fields. Diffusion of ideas between science and practice is not for-granted and shall be given enough attention (Khavandkar et al., 2016).

Cognitive, social and organisational aspects of are among the most critical for successful practical knowledge creation, dissemination and application and are essential to the success of any applied knowledge management strategy (Morey, Maybury, & Thuraisingham, 2000, p. 451). So, in order to merge both worlds, researchers should shift their attention more from technical and organisational aspects of knowledge management back to people. It may involve peoples' behaviour, thinking and motivations, habits, routines, cultural norms. Even researchers from the rather technically oriented knowledge management camp conclude, that *"knowledge is inextricably bound up with human cognition, and the management of knowledge occurs within an intricately structured social context"* (Thomas et al., 2001).

The role of humans and their interaction in knowledge creation has been examined from various perspectives before, starting decades ago. One of them is *a community of practice* (Lave & Wenger, 1991), either physical or virtual (Dubé, Bourhis, & Jacob, 2005); for example, McLure Wasko & Faraj (2000) distinguish knowledge embedded within individuals from knowledge embedded in a community. But, the

continuing dissonance between the theory and practical application suggest that it is still not enough. Human aspects of knowledge should be examined more thoroughly and what is even more important, meticulously reflected in the way products and services are designed, developed and produced. Following the path, not only existing knowledge can be fully exploited, but also completely new knowledge, potentially leading to breakthrough innovations, may emerge (Bray, 2005). Some recommend to reverse the research process – take the business perspective first, but solve it using scientific methods. It may mean e.g. doing knowledge management research *as a design science* (Andriessen, 2004).

On the practical level as a contribution of the thesis to the often lacking diffusion of the knowledge management theory into practice (Andriessen, 2004; Booker et al., 2008; Ferguson, 2005; Khavandkar et al., 2016; Sembel, 2015), a simple in-depth human-centric product design methodology is outlined and subsequently evaluated in a software prototype and in the following usability testing. Though the software prototype developed as a part of the experiment has features of a knowledge application and good software development principles have been meticulously applied, it did not divert the primary focus of our research, which was not on the technical aspects, but on humans; we wanted to help the elderly truly benefit from the digital technology, despite any cognitive, tactile, social or other limitations they may be facing. The whole process from gathering and synthesizing relevant knowledge from multiple disciplines, through market research, application of creative and human-centric design and development methods, leading to implementation and in-depth usability testing with participants may serve as an example or a case study showing the *practical potential* of responsible knowledge management methods.

2 GOALS AND METHODS

2.1 BRIEF OUTLINE OF THE THESIS

The challenging central research area of the thesis is the usability and real benefits of modern information technologies for the target group of elderly users. The proposal of responsible knowledge management serves as a conceptual foundation of the research. Both theoretical and directly applicable results are delivered. First, the multidisciplinary pool of related knowledge in human-centric product design, consumer behaviour, economy, and psychology is explored; the knowledge is synthesized into a practical contribution to human-centric design approaches. Then, the needs of the elderly and their expectations towards the technology are specifically examined and compared with available products and services. Based on the findings, a novel type of inclusive social software is proposed and conceptually distinguished from available products. With the help of proposed in-depth human-centric design methods, a prototype of inclusive social software is developed. Finally, the prototype undergoes an in-depth usability trial, which evaluates not just the prototype, but also the proposed concept of inclusive social software, as well as the in-depth human-centric design toolbox itself. Though the research leads to substantial theoretical and practical results, its nature is rather exploratory – it does not intend to provide definitive answers; rather, a direction for further research and development is hinted wherever possible.

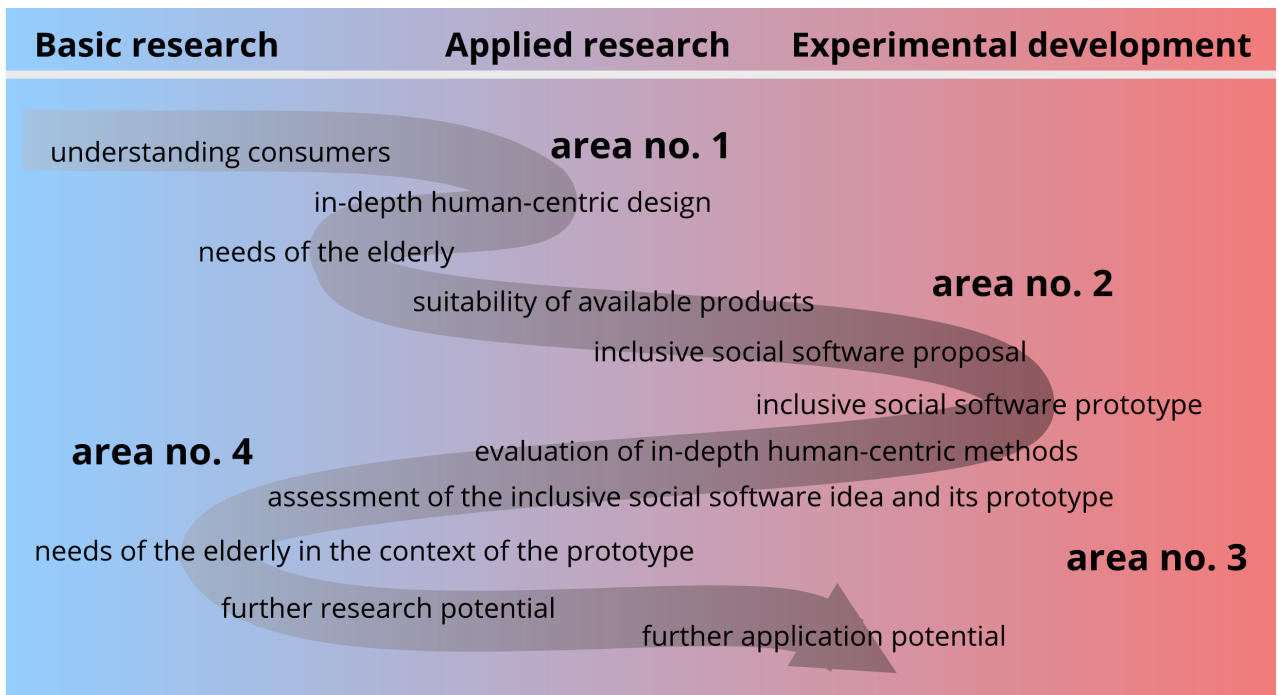


Figure 7: Key research areas covered in the thesis

Figure 7 illustrates the structure of the thesis. The concepts are put in chronological order and in relation to the prevalent nature of research. The arrow shows the order in which they have been solved and the main direction of the knowledge flow. The following sections present goals, structure, main contents, research questions, methods, and a specific relevance to the area of knowledge management of all four main areas of the thesis.

2.2 EXPLORE CONSUMERS' THINKING

Goals: The goal of the research covered in chapter 3 entitled Consumers as Humans is to propose an extension to the human-centric design which would more tightly respect consumers' needs, feelings, and reasoning.

Structure and contents: First, a state-of-the-art in human-centric design is surveyed. Then, two conceptual frames are chosen, the rational choice theory, a subfield of economics, and cognitive science, the current leading stream of psychology, multidisciplinary itself. The rational choice theory seems to be superior in the area of precise formal models and tools describing rational reasoning in a variety of life situations. But, as cognitive science reveals, humans are not mere rationally-reasoning machines. We often do not think, recollect, decide, or behave precisely, logically, and deterministically. The share of irrationality in our reasoning tends to be stronger in more complex, long-lasting and less-conscious tasks. Various other perspectives are considered, including technical, medical, or sociological. Our research in the area of consumer thinking and behaviour led into the construction of several semi-formal analytical models of consumers' thinking, but those go beyond the thesis and are just referenced.

Research questions: Which theoretical foundations could be used to describe consumer's reasoning about a product? Which specific applicable concepts can be identified in the underlying theory? Which distinct product evaluation stages might be identified? Which implications for product design might be derived from the knowledge about consumer's thinking? Which methods may researchers, designers, engineers or knowledge managers use to understand consumers better?

Methods of research: Induction – exploratory research in published works from various fields. Synthesis – comparing the results of various experiments, clustering, deriving conclusions. Triangulation – more methods used to check results of the same subject. Hypothesizing – proposing new design principles and relevant tools and methods which may undergo testing and verification. Modelling – formalising the findings into conceptual models, usable for further reasoning on the subject matter.

Relevance to the knowledge management: Product design and development belongs in typical core business processes. Knowledge about customers needs in relation to products, their functions and properties belongs to the organisation goodwill and translates into the economic results of the company. Because of its value and importance, the knowledge about customers should be managed responsibly. The in-depth human-centric design toolbox is widely applicable in a variety of businesses, not limited to those dealing with the elderly.

2.3 PROPOSE A SOFTWARE TO THE BENEFIT OF THE ELDERLY

Goals: The chapter 4 entitled Towards Inclusive Social Software presents research to (1) deepen our understanding about needs of the elderly in relation to the information technology which might contribute to the better satisfaction of the needs (2) and propose a kind of software which would harmonize with the needs. (3) Application of relevant in-depth human-centric design methods contributes to their evaluation and verification.

Structure and contents: Resources from technical, medical, economic, social, and psychological resources revealed several clusters of essential needs of the elderly with specific attention given to the areas where information technology might help. Market research summarizes the social media, mobile applications, smart electronic devices for seniors and relevant service providers and systems integrators and analyses them in relation to the needs of the elderly. Previous research in consumers' thinking and behaviour allowed to reveal the fundamental limitations of current social media and other intelligent technologies in regards to seniors. Based on both the research in the needs of the elderly and the market research, particular requirements for software beneficial for the elderly are formulated. It eventually leads to a proposal of an inclusive social software, conceptually different from available kinds of so-called social software.

Research questions: What are the essential needs of the elderly which information technology might help to satisfy? How are the available products and services in line with the revealed needs of the elderly? Which qualities should a software possess to satisfy the needs of the elderly users and respect the variety of their cognitive, sensory and motor impairments?

Methods of research: Induction – extensive interdisciplinary exploratory research; market research in relevant products and services. To keep the line between the science and practice, both scientific resources and knowledge of entrepreneurs is considered. Triangulation – more methods used to check results of the same subject. Synthesis – comparing the results of various experiments, clustering revealed concepts and ideas. Hypothesizing – identification of the needs of the elderly, formulating them in a way which may

allow further testing and verification; formulating requirements on the software aimed at the elderly users, proposing a concept of inclusive social software.

Relevance to the knowledge management: The findings about the needs of the elderly may directly extend and enrich the knowledge in organisations aimed at this specific target group. The way how some of the previously proposed in-depth human-centric methods are used may inspire researchers, designers and knowledge managers to adjust their procedures.

2.4 DEVELOP A SOFTWARE PROTOTYPE

Goals: The chapter 5 entitled Inclusive Social Software Prototype Design presents applied research and experimental development, which intends to show, (1) how the inclusive social software might be developed in harmony with the previous findings and (2) how further in-depth human-centric design methods might be applied in the process.

Structure and contents: The chapter presents builds upon the inclusive social software proposal from chapter 4 and continues in the formulation of particular function ideas and requirements. Specific attention is given the area of user interface. Several creative and user-oriented pre-development methods from the in-depth human-centric design toolbox are applied, including wireframing, a focus group, brainstorming and a game session. Finally, the chapter is concluded with a choice of suitable technologies and a brief description of the overall architecture of the prototype. The previously gathered knowledge enabled us to design the prototype to overcome a potential lack of users' interest, their anxiety, fears and other barriers, and fully leverage the positive forces, such as curiosity, positive surprise, or habit. Appendices 11. and 12. describe the architecture and functions of the developed prototype in detail with an explanation for crucial decisions we have taken, accompanied by diagrams and small samples of source code where necessary. The attention and focus we have given to the prototype are related to the unique features and significant potential it has. The appendix 13. explains how an execution environment for the prototype has been prepared and how the software might be deployed in the future if it reaches a productive stage. These additional rather technical details are important to satisfy the falsifiability criteria, allowing other researchers to follow the steps of our research or even participate on the further prototype development; besides this, the application of good software design and development principles and innovative and creative solutions of various technical issues makes the appendices valuable from the point-of-view of applied informatics.

Research questions: Which functions and services might inclusive social software provide? Which principles should be considered when developing a user interface for the elderly users? How various methods from the in-depth human-centric design toolbox can be applied and combined in a software design project? Which technologies to choose, how to design the overall architecture and how to deploy an inclusive social software?

Methods of research: In-depth human-centric methods applied in the experimental design and development, namely collection of ideas, wireframing, a focus group, brainstorming with volunteers, a game session.

Relevance to the knowledge management: The research extends the knowledge in the core-process-area of product design and development. The practical application of the proposed in-depth human-centric methods contributes to the diffusion of theory into practice, which is one of the areas of interest in contemporary knowledge management research. As presented in the concluding chapters of the thesis, the developed prototype itself may be used to further extend and deepen the knowledge about users, thus extending the corpus of knowledge which is relevant to the knowledge management.

2.5 PERFORM A QUALITATIVE USABILITY TESTING WITH THE PROTOTYPE

Goals: As a logical climax of the research, the goal of the research covered in chapter 6 entitled In-Depth Usability Testing with the Prototype is to (1) let users who suffer certain cognitive, sensory, or motor evaluate the prototype in regards to the perceived benefits and ease-of-use. (2) The trial, an experimental application of the proposed in-depth usability testing method, should evaluate the method itself, thus contribute to its verification.

Structure and contents: The in-depth usability trial combines several data sources – the kick-off questionnaires, detailed user interaction data collected by the program itself, post-trial questionnaires and every even irregular interaction with participants, such as a support call or a support visit. The chapter opens with a description of the trial preparation – the formulation of research questions, its structure, procedure, setting. Then, each participant is introduced and characterized, in line with the in-depth usability testing recommendations; all data gathered during the trial is presented in the context of individual participants. Then the research questions are evaluated based on the synthesis of the data, namely the perception of the prototype and the homogeneity and/or heterogeneity of the group. Valuable insights into participants' minds which emerged during the trial, such as their different problem-solving strategies, are presented and discussed. The chapter concludes with a brief analysis of “bad clicks”, based on the recorded coordinates of users' interactions with the touchscreen, which did not trigger any action. Technical details related to the trial, such as about the selection and preparation of the testing devices, are in appendix 13, namely in section 13.4. Finally, the concluding chapters 7. Results and Potential, 8. Summary do not only summarise the research also outline new perspectives for follow-up research and application.

Research questions: Is the developed prototype perceived as beneficial and easy-to-use by the involved participants, thus has the concept of inclusive social software potential to become beneficial for the elderly? Which functions and content are the most important and/or interesting for the participants? Which challenges the participants encountered during the trial and which strategies did they use to deal with them? What else can we learn about seniors from their interaction with the software and from their impressions? How homogeneous or heterogeneous group do they form in regards to their needs, values, opinions, abilities, or habits? Do the proposed in-depth human-centric design methods prove their practical value for the processes of product design and development? How the research, from its explorative stage to the usability trial, demonstrate the potential of knowledge management to deal with the current society-wide problems and challenges?

Methods of research: The trial is qualitative by its nature and uses various methods to capture and analyse data, including the in-depth human-centric design methods introduced in chapter 3.3.3, such as the following. Experiment – a trial with participants. Questionnaires combined with an adjusted structured interview. Observation of participants and their environment. User interaction capture. DREAM Dynamic real-time ecological ambulatory data collection (The Pennsylvania State University, 2015) for subjective assessments from within the application. Description and analysis of the collected data. Synthesis and comparison. Inductive reasoning to draw conclusions from the data. An in-depth qualitative analysis based on the combination of answers, observation, and the data gathered by the system.

Relevance to the knowledge management: The trial evaluated in-depth human-centric methods, designed and intended for application in core business processes of product design and development and in related knowledge management and consumer behaviour research areas. The research contributes to the understanding of the elderly, namely in their position as customers and users of information technology; organisations with products or services for the elderly may benefit directly from the knowledge. The research highlights the importance of the human dimension of knowledge management.

3 CONSUMERS AS HUMANS

3.1 INTRODUCTION – UNDERSTANDING AND MISUNDERSTANDING

Different upbringing, background, environment, experiences, etc. resulting in different needs and manifested in the form of habits, behaviours, decisions, language, etc. may lead to a completely different perception of oneself and the world. It may create a deep misunderstanding between people (Figure 8). From the misunderstanding today's huge divisions in the society stem. Similarly, misunderstanding may also cause a complete failure of a product. Reasons for refusal of a product may be quite trivial, such as using a metaphor which does not fit their mindset, placing or framing of the product, or even a detail of its design, as shown, e.g. in an experiment with photo frames (Swan & Taylor, 2008). Or, as Gross, CEO of a company which sells medical alert systems says, “*the largest challenge probably is the perception of these systems. Our clients don't want to be old.*” (Sherwood, 2015) Yes, the elderly only seldom perceive themselves as being old; instead, they tend to view themselves as ‘getting old’ (Lindley, Harper, & Sellen, 2008).

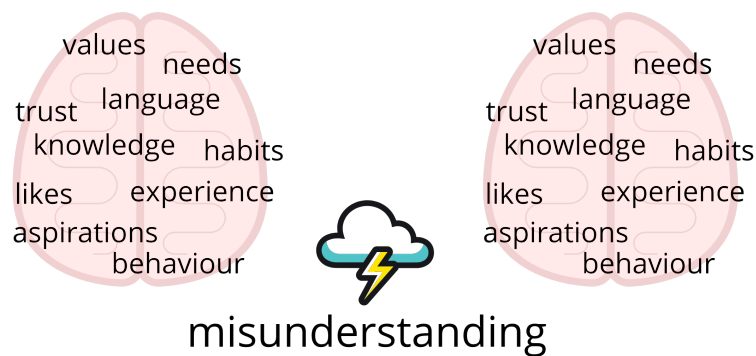


Figure 8: Dissonances between the young and the elderly, between designers and users, etc.

Before making a technology beneficial, researchers, designers, engineers, knowledge managers have to know their target group first. To deliver products perceived as beneficial by the elderly, they have to understand seniors' patterns of thinking thoroughly (Veldhoven, Vastenburger, & Keyson, 2008). It involves not just how they decide, handle, interact, etc., but primarily how they *think* and *feel*. The understanding should go beyond just a surface, mere decisions and behaviour, to the roots; to *needs*, *aspirations*, *values*. It may require to understand and perhaps adopt metaphors, *the language* of their target group. Further, customers deserve *respect and dignity*. They are not just customers, but *humans*. It may require a big deal of modesty to break deeply rooted stereotypes. But the rewards are worth of such an effort. The technological product *truly* respecting consumers' needs may help to tackle some of the burning pains and challenges of today's society. And, as a consequence, they may also lead to business success and higher economic gains – that's the 'shareholder primacy' inside out we propose.

3.2 THE FOUNDATION FOR IN-DEPTH HUMAN-CENTRIC DESIGN

3.2.1 CONTEMPORARY HUMAN-CENTRIC DESIGN

Though gaining *knowledge about consumers* and their behaviour has always been an important part of business administration, with the emergence of the whole new area of knowledge management, the efforts to shed more light on the area have intensified. Great challenge designers and product managers face is not how the market or different technologies work, but how humans work. Often, what users say versus what users do are two entirely different things (Bank & Cao, 2017). Hartikainen (2008) mentioned that effectiveness-focused usability as defined in ISO 9241-11 cannot explain which technologies will be adopted by users. People are more complicated beings than physical and cognitive processors, able to carry out work. Jordan (2002) pointed out that task-centric approaches may be profoundly dehumanising. We have

hopes and dreams, sorrows and fears, desires and aspirations and actually, that make us human. These and other works motivated other researchers to work on the formulation of various human-centric design approaches.

Behaviours-centric approaches. Callejas et al. (2009) suggested taking users more seriously into account even in the early phases of design. To understand humans better, it may be advisable to move the design to users' everyday context. Kikin-Gil (2006) recommended instead of focusing on tasks and functions to look on people and their behaviours. Hartikainen (2008) favours human-centric in-place testing to lab experiments. Various specific methods and techniques have been developed for human-centric and mind-centric design, e.g. Vogiazou et al. (2006) introduced 'design for emergence' where users are being observed in their daily activities to reveal unpredicted behaviours. Unexpected use cases may become a fruitful source of ideas for iterative design. Technology probes, an approach from the same family of design approaches promoted, e.g. by Hutchinson et al. (2003), bring a high level of serendipity, possibly leading to breakthrough ideas.

Emotions-driven approaches. Norman (2003) examined the primary role of emotions in our ability to understand the world and to learn new things. Kano (1984) has brought marketing technique used for measuring customer content, known as kano satisfaction model. Products should be designed to be a joy to own and use them. The pleurability acts as a necessary prerequisite of acceptability (Veldhoven et al., 2008). Even appliance with usually negative appeal may be accepted if designed with emotions in mind, as shown in an experiment with wheel-chair (Desmet & Dijkhuis, 2003). Emotion-driven design approaches focus on immediate factors, which is not enough. According to our findings and in harmony with conclusions of Carroll et al. (2002), designers need new design techniques, more sensitive to the lasting psychological and sociological nature of the appropriation criteria and reinforcers. In a later work, Carroll et al. (2002) offer scenario-based participatory design technique. The behaviour-focused approaches target the forces driving the short-term evaluation stage and eventually may lead to higher acceptance even in long-term.

The relevant research also includes, for example, both positivist and interpretive approaches of social sciences (Hudson & Ozanne, 1988).

3.2.2 RATIONAL CHOICE THEORY

The process when a user is evaluating a product could be split into several consequential phases. A successful product has to pass all of them. Reversely, refusal in any phase fails. The evaluation process can be seen from various, as hinted in the introduction. Each of the approaches may be beneficial. If we have a goal to construct a model formal enough to allow inferencing, the rational choice theory is a good potential candidate. Since the rational choice theory is a subfield or descendant of the economy, it provides an excellent palette of diverse, but internally coherent formal models. Becker et al. (2008) have proved, that economy-based models may help to understand and describe various aspects of human life and behaviour, including discrimination (2010), crime and punishment (1968), addiction (1988), beggary and compassion (2009), human capital (1975), love, marriage and family (1991). According to the theory, nearly all human behaviour may be explained as rational reasoning. The theory of economy suggests that people are economy beings and they do what makes sense to them and what brings the highest possible utility for the lowest possible cost. So, users balance costs against benefits (Friedman, 1953). Of course, the elderly are not an exception. People usually do not like to change themselves. Apparently, the benefit of an evaluated product has to significantly outweigh the relevant costs, where the costs involve not only or necessarily a financial value, but also, e.g. an anticipated effort necessary to master a complicated user interface. The rational evaluation applies step-by-step in all phases of the acceptance process. First, in an immediate decision, when a user is comparing expected benefits with expected costs. Last, in the long run, when a user is getting familiarised with the product and when he compares the real benefits with the actual costs.

Another dimension of the reasoning about a product is the context of its competitors. The product which is being evaluated has to succeed in comparison with the best time-spending alternative available, maybe something habitually rooted and immediately convenient, or something which does not require effort to learn or change any habits. The idea of competing activities in the area of product evaluation has been examined in a study on love-promoting technology published by Pujol et al. (2009).

3.2.3 COGNITIVE SCIENCE

Psychology developed considerably during the last century. Where previous theories, such as Freudian psychoanalysis or behaviourism, failed to explain significant phenomena in our reasoning, cognitive science, based on precise scientific methods including rigorous statistical examinations in reproducible scenarios, markedly deepened our understanding of ourselves (Baars, 1986). Since cognitive science significantly overlaps the boundary of psychology, it is sometimes called an interdisciplinary scientific study of mind, consists of multiple research disciplines, including psychology, artificial intelligence, philosophy, neuroscience, linguistics, and anthropology (Miller, 2003). Thagard (2008) claims, that "*thinking can best be understood in terms of representational structures in mind and computational procedures that operate on those structures.*" The theory covers many mind-related processes, from simple mechanics of learning and decision mechanisms to complex logic, planning, reasoning and decisions in complex tasks.

To compare the two, rational choice theory brings right answers on the question how we *should think and act* (its nature is naturally normative), whereas cognitive science is much more descriptive, aiming to capture how we *indeed think and act*, thus reflects many of the inconsistencies, biases, flaws of the reasoning machines in our heads. As human beings, we are not rationally reasoning machines. We do not think, recollect, decide, or behave precisely, logically and deterministically. Our mind shows more biases and less rationality than what we would like to believe. Cognitive science concluded, that there are flaws in our reasoning even in simple isolated tasks, as described further. Many more irrationalities influence our thinking in tasks which are complex, challenging and spanned over a long period. Some of these 'principles of mind' (Zejda, 2011c), revealed by cognitive science, are briefly introduced on the following lines:

Steps of Evaluation. A lot of current scientific understanding of human reasoning is based on studies of behaviour in highly controlled simple tasks, where participants decide between well-defined options, such as single gambles. Real world situations are usually both not so much controllable, and also more complex, requiring sequential decisioning. Evaluation of a new product is an example of such a complex and dynamic task. Efforts to explain chains of successive related decisions may be traced somewhere to a study of Damasio et al. (1997) on the performance of brain-injured patients. Other researchers followed the path, e.g. Lejuez et al. (2003) examined, how participants think and behave in a sequential balloon inflating task. As a conclusion, it is quite natural for the human mind to break a complex problem into distinctive steps or episodes, framed due to the character of the task, such as single blows in the balloon experiment, distinct days, or weeks in longer-lasting evaluations (Hastie & Dawes, 2009, p. 314).

anchors or Reference Points. The boundary between rational choice theory and cognitive science is not entirely sharp. Various scientists made an effort to merge the two, such as behavioural finance or a prospect theory (Kahneman & Tversky, 1979). One of the conclusions from such studies is a tendency of our mind to closely attach itself to a certain fact for further reasoning. Kahneman and Tversky (1979) described this as a phenomenon of anchor, or reference point. Instead of thinking rationally in absolute quantities and final outcomes, our mind tends to think in relative comparisons and in shorter time frames. Both positive and negative consequences of our decisions have diminishing returns proportionally to the distance from the reference point. Though initially introduced by an economist for money-related choices, the concept of labile, vague, adaptive reference points which is not always rational has never been adopted by the mainstream economy, respecting its primary focus on the normative description of rational aspects of human reasoning. The relative approach of our minds, though tenable in certain situations, when applied in tasks with utility, contradicts with traditional diminishing marginal utility law known in the economy, and rational choice theory as well. With these findings, Kahneman and Tversky (1979) refined the theory of utility and called it the prospect theory. As subsequent research revealed, a palette of various reference anchors exist, either related to the problem, such as status quo or aspiration level or irrelevant (Tversky & Kahneman, 2000). Some of them are more prevalent and more influential, such as the status quo. Lopes and Oden (1999) concluded that at least three reference points play a significant role in our evaluations under uncertainty. They act in parallel: the main reference point (usually status quo), aspiration level, and security level (danger of loss). According to Hastie and Dawes (2009, p. 274), a model built around the concept of reference points may do pretty well and may compete with the prospect theory in its ability to explain our reasoning.

Gradual Adaptation. The concept of progressive adjustment is nothing more than an application of the idea of mental anchors in complex problems with successive decision chains. Specific examples of this phenomenon are mentioned, e.g. by Hastie and Dawes (2009, p. 204). When we respond to stimuli, such as loudness or temperature, the past and present context of experience defines an adaptation level or reference point, and stimuli are perceived in relation to this point. Cyert and March (2005) revealed that we tend to search for alternatives in the neighbourhood of our previous try. In complex schemes with successive steps, we tend to follow an *anchor-and-adjust strategy*, which leads to successive adjustment on-the-fly. E.g. Slovic et al. (1982) confirmed the effect in pricing and choice in successive virtual gambles. Kahneman and Tversky (2000) pointed out that justification for reasoning on consequences with status quo on the mind is present in the general principle of adaptation – the stepwise adjustment of the mind anchor allows to adopt our mind to the always changing environment. On the other hand, it may quickly lead to illogical flaws in our reasoning, such as “money pump” described by Hastie & Dawes (2009, p. 77), which contradicts with rational (economic) choices.

Two Chains of Reasoning. Neuroscience (also called neuroeconomics) examine the neural substrates of our judgement and behaviour (Hastie & Dawes, 2009, pp. 295, 196). One of the conclusions made by neuroscience is that our reasoning runs over internally in two trails (chains, circuits). While the dopamine-mediated system is responsible for assessing positivity, the acetylcholine-mediated circuit ensures negativity. From the relevant works we may mention, e.g. Damasio (2000). So, any evaluation or assessment runs over in parallel tracks. User evaluates benefits, utility, rejoice, pleasurable surprise etc. on one hand and negative aspects such as costs, pain, anger, disappointment on the other hand, at the same time.

Linear Model. According to many studies, if the task is to make a decision based on a set of cues, we could hardly name anything better to describe our reasoning, than a very simple linear model. Even improper linear models with weights not based on statistical techniques (e.g. with random weights, where the only direction of relation is explicitly assigned) outperform experts in many expert tasks (Dawes, 1979). Simple linear model executed by a dumb computer program achieves same or better results in medical diagnosis tasks (Einhorn, 1972), in prediction of bankruptcy (Libby, 1976), in an assessment of applicants (Wiesner & Cronshaw, 1988), in estimations of real estates values, in stock investments and many other areas. Since the first notable book on the topic has been published more than 50 years ago (Meehl, 1954), many studies concluded again the same. So-called “expert insight” can't outweigh inconsistency, incomplete memory, and plenty of other flaws. According to March quoted by Hastie & Dawes (2009, p. 63), the fact that we still rely on experts despite their real incompetence may serve a purely social function. As a conclusion, if we wish to formally describe our reasoning in situations based on a set of cues, there is no need to seek for anything more sophisticated, than a simple linear equation. Most likely, our mind won't do better.

Not so many authors have tried to describe reasoning of prospective users about products by means of the cognitive science. We may mention at least Carroll et al. (2002) and their work providing insight into the minds of young people and the way they evaluate novel technologies. Their research was based on questionnaires, scrapbooks, observation and online diaries. They use a term *appropriation* to describe both the final state of a successful evaluation of a product and the process leading to it. Their findings allowed them to construct an informal *model of appropriation*. Within the model, attractors, repellents and appropriation criteria, sets of forces which together act their respective roles during the process. Attractors and repellents take effect in the initial evaluation. A prospective user is positively motivated if a product is cheap, convenient, seems to be controllable, usable, fashionable, familiar, “our stuff” and dissuaded if it is costly, inconvenient, controlled, frivolous, unfashionable, unfamiliar, “their stuff”. Repellents and attractors keep their role in the following phases, but some more permanent sets of forces, appropriation and disappropriation criteria, start influencing the user. The user continues using the technology if it supports what matters to him – his social life, leisure, management of information and when the technology, e.g. brings safety and security. A critical mass of usage has to be reached early enough. A user, on the other hand, turns away if he finds out, that there is a hidden cost in using the technology, if the technology negatively affects his life, or if it is somehow unusable or non-learnable. Finally, yet other forces called higher order positive or negative reinforcers turn the scale. While attractors and repellents are immediate factors, higher order reinforcers stem from deep needs.

3.3 PROPOSING IN-DEPTH HUMAN-CENTRIC DESIGN

Cognitive mental processes in the minds of potential users determine success or failure of a product, regardless to wishes of developers, designers or engineers, and irrespective to the intelligence, forwardness or “smartness” of the product. Development of a new technology-rich product is a vastly complex task since features and functions of such systems can neither be comprehensively predefined nor anticipated because of various emergent or synergistic effects (Olsevicova & Mikulecky, 2008). Though being much closer to humans' needs, the ideas of both emotion-driven and behaviour-centric design are still not sufficient to hit the very virtue of the appropriation process. Some of the other aforementioned human-centric approaches are getting relatively close to the idea of a design aiming to harmonise with most inner needs of users, their “deep needs”. One of them is an approach proposed by Kikin-Gil (2006), which takes social structures into account, so products are being designed to increase the social effectiveness of users.

A comprehensive design or engineering approach, which would systematically lead designers to reveal and target the deep needs of prospective users, appears to be a challenging goal. Dix (2007) even argues that it is virtually impossible to design directly for long-term appropriation, because, as he says, appropriation is something unexpected or even unexpectable. Designing for appropriation indeed may look like an oxymoron. However, our opinion is, that if there is a product within reach of prospective users which genuinely reflects their deep needs, it will likely become not only enthusiastically accepted, but also adopted and gradually appropriated. So, if we both sufficiently understand the process of appropriation and identify the correct deep needs of users, serving as high order reinforces, we *may* design intentionally *for* appropriation. And that's what the idea of “in-depth human-centric design⁵” (Zejda, 2010a) is all about. It recommends treating the customer or consumer as a human being and keeping close attention to him and his needs throughout the design and development process. It requires to reveal deep needs as a source of user's interest in a product first and reflecting them systematically.

The Focus	Methods	The Target
task	use cases, goals, scenarios, ...	effectiveness, efficiency,
human	usability testing, prototyping, ...	usability, utility, accessibility
emotions	kano model, emotion-driven design, affective computing, ...	immediate emotional benefit, pleasure
behaviours	technology probes, design for emergence, emphatic design, ...	unspoken, tacit behavioural patterns,
deep needs	in-depth human-centric design and its methods	harmony, long-term acceptance, perceived quality of life

Table 1: Comparison of different design approaches

The in-depth human-centric design may be viewed as a logical climax of previous human-centric design approaches as it highlights the innermost needs of users as a fundamental foundation for subsequent design.

5 The similar term 'deep design' has been used by Wann (1995) as an approach to developing high quality and high-performance processes for industrial and community activities. As mentioned in the book review, Wann rejects obsolete patterns of the industrial revolution and adopts practices which can help preserve the world's biological and cultural wealth. Observable patterns of systems in nature should be mimicked. Natural systems' characteristics of feedback, diversity, and flexibility can be incorporated into design principles, including social or community arrangements. He proposes that such a transformation will make life more satisfying for people because they will have better quality products, services, and physical infrastructure, and more time in which to enjoy these things with their families and friends. According to Wann, people can maintain their quality of life only if they reject the importance of material goods grounded in traditional supply-side economics and embrace a more comprehensive philosophy on the whole of human life. In-depth human-centric design as understood in our work, though applied in a different field, harmonise with Wann's deep design in its emphasis on redefining theoretical grounds of the design process. In both Wann's and our in-depth human-centric design, true and universal needs of humans are in the centre of attention. The term deep design was also used by Hugh (1997) in the area of large-scale real-time control systems in aviation. Hugh argues that the actual control task should be re-analysed, the human operator should be provided with a satisfying task appropriate to his natural abilities. The system should understand human failures and process them accordingly.

Table 1 captures the fundamental differences between different design approaches from the author's subjective view. The table is grouped by the focus of each of them and is ordered from more mechanic and shallow to the deepest, so the approaches mentioned close to the end of the table have more in common with the principles of the in-depth human-centric design. Higher-level approaches either involve or imply results of lower-level approaches, such as that emotion-focused product has to be reasonably usable in parallel.

Human beings have relatively stable hopes and dreams, sorrows and fears, desires and aspirations, which drive or fuel both our emotions and behaviours. Affinity towards a pleasurable appliance is typically derived, stemming from these deeper grounds. We do not value old grey photos per se (Swan & Taylor, 2008). Our souvenirs serve as a proxy to the related memories. Communication devices have high psychological value for both teenagers and adults. The value may derive from its ability to keep the person in touch with his close, from the perceived addition to the social status a device may provide to its owner, etc. The things which people usually like most are those with perceived psychological or social extent, either hidden or apparent.

In-depth human-centric design approach recommends following the real needs, wishes, desires or passions as sources of affinity at first, as the most important target. For example, according to an extensive study about integrating intelligent technology in senior citizens' home (Mohammadi, 2010), needs, perceptions, environmental and personal attributes of the senior determine the attitudes towards the technology. They conclude, that too much automation is undesirable, innovation by addition often results in sub-optimal solutions. Their results confirm that the integration of intelligent technology in a house needs to be a synthesis of the user's needs, technology, the living environment and healthcare.

3.3.1 STAGES OF PRODUCT EVALUATION

Successful products have to attract attention first, show rewards soon and become an integral part of user's habits. If a product fails on this way, it leads to its refusal (Veldhoven et al., 2008). The purpose of models of evaluation is to provide a formalisation of mental processes behind. Such a model may assist researchers and designers to not lose sight of psychological aspects of technological concepts or products. It may also help to introduce, advertise and advocate novel products and technologies efficiently using terms and arguments relevant to the prospective users. With the help of the models, we may not only bring more acceptable products but also deepen our understanding of ourselves. As suggested earlier, both rational choice theory and cognitive science provide useful conceptual models. We introduce two stages of evaluation in the following lines.

Acceptance. First, a technology has to succeed in the immediate evaluation, when a prospective user decides, whether to give it a try or not. Various immediate emotions take place during the stage, such as anxiety of the unknown, lack of concentration on one hand and excited curiosity or wish to adhere to a positive recommendation on the other hand. According to Vastenburg et al. (2008), for the elderly, the direct anticipated short-term emotional benefit of a product must be substantial and immediately apparent to outweigh the anticipated short-term cost regarding both its price and also, e.g. effort necessary to master complex interface. Compared to the whole process of evaluation it is rather a short process under stable conditions. The user is aware of the fact he is making a decision, and he knowingly intends to make a rational one. So, the model for the initial stage should be based primarily on rational choice theory, with possible overlaps into other fields. Though usually quick in nature, it may influence the final success in a high degree, because if a product fails in the initial stage, no further stages follow.

Appropriation. If benefits are clear and strong, resulting enthusiasm (euphoria) positively fuels also following short-term evaluation. But, even a technology keenly accepted first may fail soon, if it does not bring anticipated benefits quickly enough. Level of initial euphoria determines timeframe available. Symptoms of the described acceptance process arisen in various studies. For example, in an experiment aimed to increase social connectedness among patients, family, and caregivers in a spinal cord lesion rehabilitation centre, amount of photos shared gradually decreased (Biemans, Dijk, Dadlani, & Halteren, 2009).

Table 2 shows possible forces driving particular stages of evaluation. The word appropriation has been used by Carroll et al. (2009) in a study on technologies in the hands of young users. We understand it as a mental process which succeeds initial acceptance. Compared with technology adaptation or adoption, the idea of

appropriation (Magnus & Higgins, 1996) is more focused on the strengths which cause, that particular technology is getting used in a daily routine manner. In the process of appropriation lasting aspirations of the user, his desires, valued social relations or other deep needs have to be hit by the technology, and the user has to either explicitly or subconsciously but above all perpetually perceive, that they have been hit. While acceptance usually takes something between seconds and days, the appropriation has to be much longer, typically weeks or months. We may say that a product has been appropriated if it has become an integral part of user's daily activities, failing with the product is rejected, e.g. if it does not fulfil user's initial expectations. In the following paragraphs, we call the acceptance and the appropriation *stages*. The acceptance consists of several *phases* of reasoning, but within the appropriation stage, we use *steps*. In the following sections, we suggest novel methods which we view useful both in research which aims to reveal the deep needs of a particular group of consumers, and methods for product design and development.

Stage	Positive Forces	Negative Forces	Covered by
acceptance	appeal, excited curiosity, wish to adhere to a positive recommendation, apparent short-term benefit, low cost, etc.	the anxiety of the unknown, lack of concentration, anticipated usability issues, high cost, etc.	models of acceptance based on the rational choice theory
appropriation	enthusiasm, euphoria, truly perceived benefit, joy and pride for managing the interface, etc. dignity, self-worth, social needs, etc.	usability issues, disillusion, adverse side effects, hidden cost, etc. deep needs not satisfied or deep needs affected	models of appropriation based on cognitive science

Table 2: Technology evaluation stages

3.3.2 RESEARCH METHODS

In-depth explorative research. We assume, that it is possible to get a deep insight into the feelings and needs of virtually any group of consumers from the published research. But it requires an exploratory work with sources from diverse fields of science, such as sociology, psychology, economy, biology, or technical fields. Either conclusions or even side findings of relevant studies should be compared, central concepts related to the deep needs of subjects from the target group should be listed, and clustered into semantically compact groups. From these, practical recommendations for product design may be inferred. Specific methods to perform the search, analysis, extraction, clustering or inference depend upon the context. In comparison with the systematic review, the in-depth explorative research method does not require using all available and relevant sources based on the assumption of diminishing value of resources – the contribution of every additional relevant resource is likely to add a smaller bit of knowledge because of the overlap with the knowledge gathered so far. It has an analogy in the economy (the theory of marginal utility) or in usability testing (Nielsen, 2000). It also does not involve meta-analysis review or other related formal methods.

In-depth modelling. Findings revealed by the explorative research may be formalised into models of consumers' feelings and behaviour. Relations between concepts may be expressed in form of formulas, charts, or by other means. The formulations may be based on language, methods and tools from psychology, economy, operations research and other fields may be used. To allow innovative ideas to appear, we recommend a creative mathematical approach, followed by subsequent validation of the models. For validation, techniques and methods, such as programming, simulation, or questionnaires may be used. The research in human-centric design, rational choice and cognitive science allowed us to construct semi-formal models of consumer reasoning for stages of acceptance (Zejda, 2011a, 2012) and appropriation (Zejda, 2011c) of technology-rich products⁶.

6 The models allowed us to better understand, for example, the role of enthusiasm in the evaluation process. Enthusiasm induces a higher level of patience. But it is primarily derived from expectations, and with higher expectations, there is a higher chance of disappointment. As a consequence, higher initial enthusiasm does not necessarily mean a higher success rate (or lower probability of rejection; two are complementary) in appropriation. A high level of enthusiasm induced in the initial evaluation stage may even lead to a lower chance of success in the following appropriation stage. The optimal level of

3.3.3 DESIGN METHODS

Using the knowledge management terminology, the proposed in-depth design methods help designers illicit and externalize knowledge from participants, designers themselves and volunteers from the target consumer group, or even from strangers who may come up with novel or breakthrough ideas.

Collecting ideas. Upon the inception of a new product idea, as a very first pre-development stage, we recommend dedicating a period during which the work on the prototype is not the main priority of involved designers, but is being kept on the mind as a near-future project. During this time, if any of the involved designers come up with a relevant idea, he makes a note, perhaps just on a sheet of paper or in an electronic notebook on a portable device. It is good to have the means to make a note always at hand during the whole collection period so every relevant idea may be captured, and since recorded, it no longer puts a load on one's cognitive facilities. Applying the method, ideas may appear even in unpredictable ways, as loose associations or sudden surges of inspiration. Regarding the length of the collection period, it may span from just a few days to several months, depending on the schedule of the project, its complexity, and other circumstances. We recommend the method especially for non-trivial projects, where serendipity ideas may lead to a significant positive shift in the quality of the result. Section 5.2.1 reports about how we applied the method.

To introduce the following recommended methods, we have to explain specific terms first. A *wireframe* is a visual representation of the functional structure. Wireframes visually communicate what functional pieces are present and their relationship to each other. A *prototype* is instead a representative model or simulation of the final system. Prototypes go further than wireframes and tell and let users experience the design (Warfel, 2009). According to Merriam-Webster dictionary (2018), *mock-up* is a full-sized structural model built to scale chiefly for study, testing, or a display, or a working sample for reviewing format, layout, or content. It is also important to make a difference between user testing and usability testing. For example, according to Burke (2016), during the *user testing* phase, the goal is proving that people needed a product, whereas *usability testing* reveals if users can indeed use the product as intended. User testing may also mean an idea validation. Wireframing, with use of a mock-up, belongs under user testing. Because we involved a group of users in the user testing stage and gradually shifted them into usability testing with the developed prototype, we also use a word *trial* to cover the full participation of users in our research and experimental development. For both user testing and usability testing, *persona approach* (Idoughi, Seffah, & Kolski, 2012), based on a structured description of several typical but diverse members of the target group, representing typical or significant subcategories of the target group, might be applicable.

In-depth user testing. In a stage of product pre-development, we recommend what we call in-depth user testing. While a commonly used term user testing refers to proving that people needed a product (Burke, 2016), in-depth testing serves the same purpose but stresses users' deep needs. Once the needs are revealed by other methods, a mock-up of a product user interface is created as part of the *wireframing* method. But, unlike in user testing, in in-depth user testing, before actually presenting the mock-up to users, questions are asked to learn more about participants. *Focus group* which gather several participants in a comfortable environment may be a good setting for in-depth user testing, in contrast to an unfriendly-looking testing lab and individual user tests. Especially, feelings in situations relevant to the intended product, participants' relevant struggles, or wishes have to be revealed and named. During the presentation of the mock-up, questions targeting participants' impressions are asked. It is possible to make notes during the session, but not to an extent which would affect a friendly atmosphere of a free discussion. Similarly to brainstorming, all ideas are welcome, and nobody's opinions shall be corrected. In-depth user testing is less-formal and more user-centric than ordinary user testing. Sections 5.2.2 and 5.2.3 report about how we applied the method.

In-depth usability testing. In the particular stage of development, usability testing reveals if users are able to use the product as intended (Burke, 2016). It usually involves product prototyping, and usability tests are performed on such a prototype. Typically, usability testing is being performed in a dedicated testing lab, which is equipped with eye-tracking technology and specialised software, which allows to record and analyse the sessions. More common are individual usability tests, collaborative user testing is an emerging

enthusiasm is probably even below the level not inducing disappointment, but this is just a hypothesis, yet to be examined.

field (Rymešová, Benešová, Hradecký, Pavlíček, & Bock, 2013). In-depth usability testing may be performed both in an individual, or a collaborative form. Its primary goal is not to reveal how users are able to use a product, but rather what are their impressions, how they feel about the product, its functions, its content, the layout of the user interface. To evaluate the user's acceptance, just a session may be sufficient. But to assess appropriation, it is typically necessary to start with a kick-up meeting, but give users enough time for subsequent testing in their own time and their own way. So, in-depth usability testing typically combines both moderated and unmoderated testing phases. More meet-ups with researchers or designers are likely to be needed to collect the changes in user's impressions and feelings. It may be useful to let them rate, for example, their enthusiasm, or boredom, forces which influence the appropriation likelihood. As a principal analytical method, we prefer qualitative analysis based on semi-structured interviews conducted in a friendly manner, observation of individuals. Quantitative analysis may be used as a supplementary method. Chapter 4 covers how we applied in-depth usability testing on our prototype software.

The core idea of in-depth human-centric design is to treat the customer or consumer as a human being and keep close attention to him and his needs throughout the design and development process. The list of methods to implement the idea presented above is not exhaustive; other user-oriented or creative methods such as brainstorming, technology probes, or direct field-research may provide valuable results in certain stages of in-depth human-centric design. To be able to involve users thoroughly during the development, we recommend short cycles of development and testing.

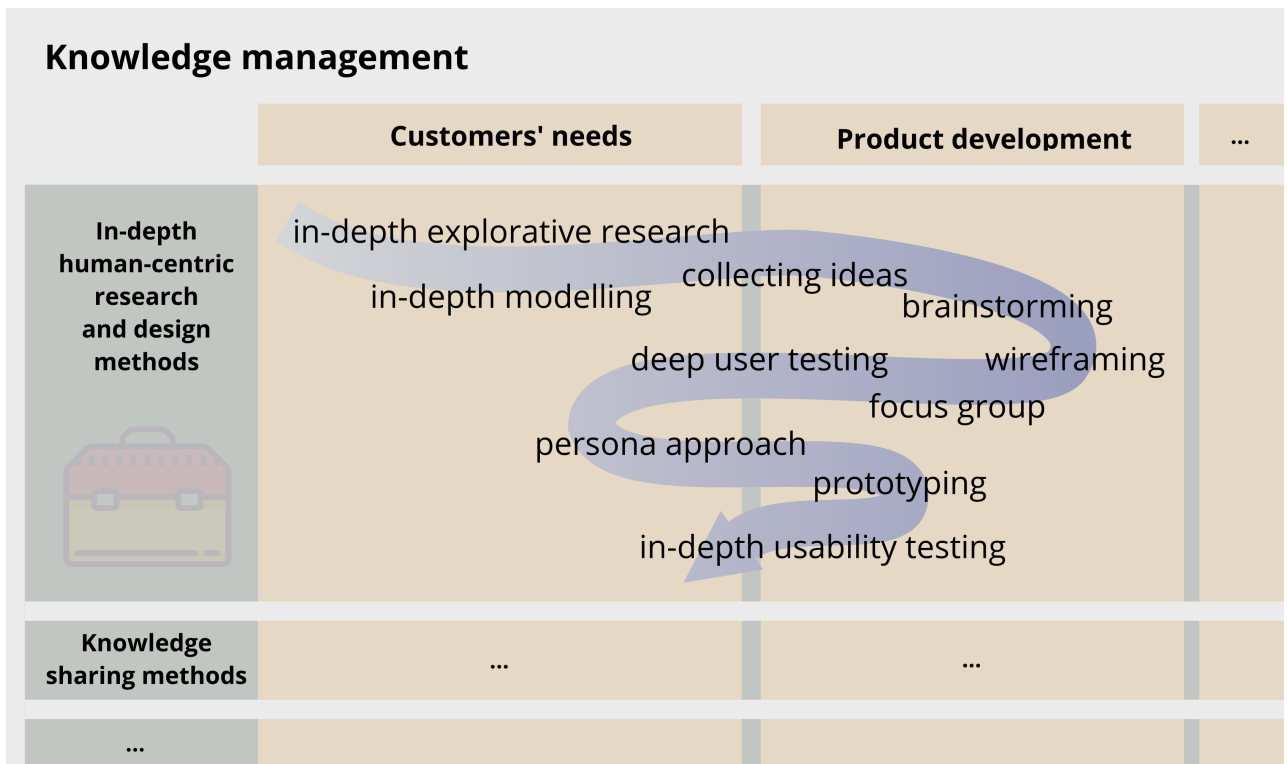


Figure 9: In-depth human-centric research and design in the context of multi-dimensional knowledge management

Figure 9 shows the toolbox of in-depth human-centric design and research methods in the context of knowledge management. Dimensions of *objects* and *methods* are considered in the figure. As shown, the methods are meant to contribute mainly to the knowledge about customers and enrich product development. The placement of methods relates to their proximity or relevance to these areas of knowledge management with some methods related more to one of them and other methods at the borderline. The methods may be applied in the order denoted by the arrow, though it may depend on the nature of the project. The convergence of methods to the borderline between the object areas reflects harmonising of design and development (and in effect functions and qualities of the product itself) with the growing understanding of its future users.

4 TOWARDS INCLUSIVE SOCIAL SOFTWARE

We were able to investigate consumers' thinking, behaviour and the forces behind in general, leading into advancements in human-centric design including new, potentially practical tools and methods. As a logical further step, the research has to return back to the central research idea, shift our focus to the group we are concerned with, the elderly. To not lose its connection with the real world, the research has to involve more of experimental development and lead to a practical evaluation. Chapter 4 covers the research into the needs of the elderly, market research and the initial analysis of requirements. Chapter 5 follows with the pre-development and development of the prototype and chapter 6 with the concluding in-depth usability trial conducted with the prototype. Figure 10 summarises the information flows between the stages.

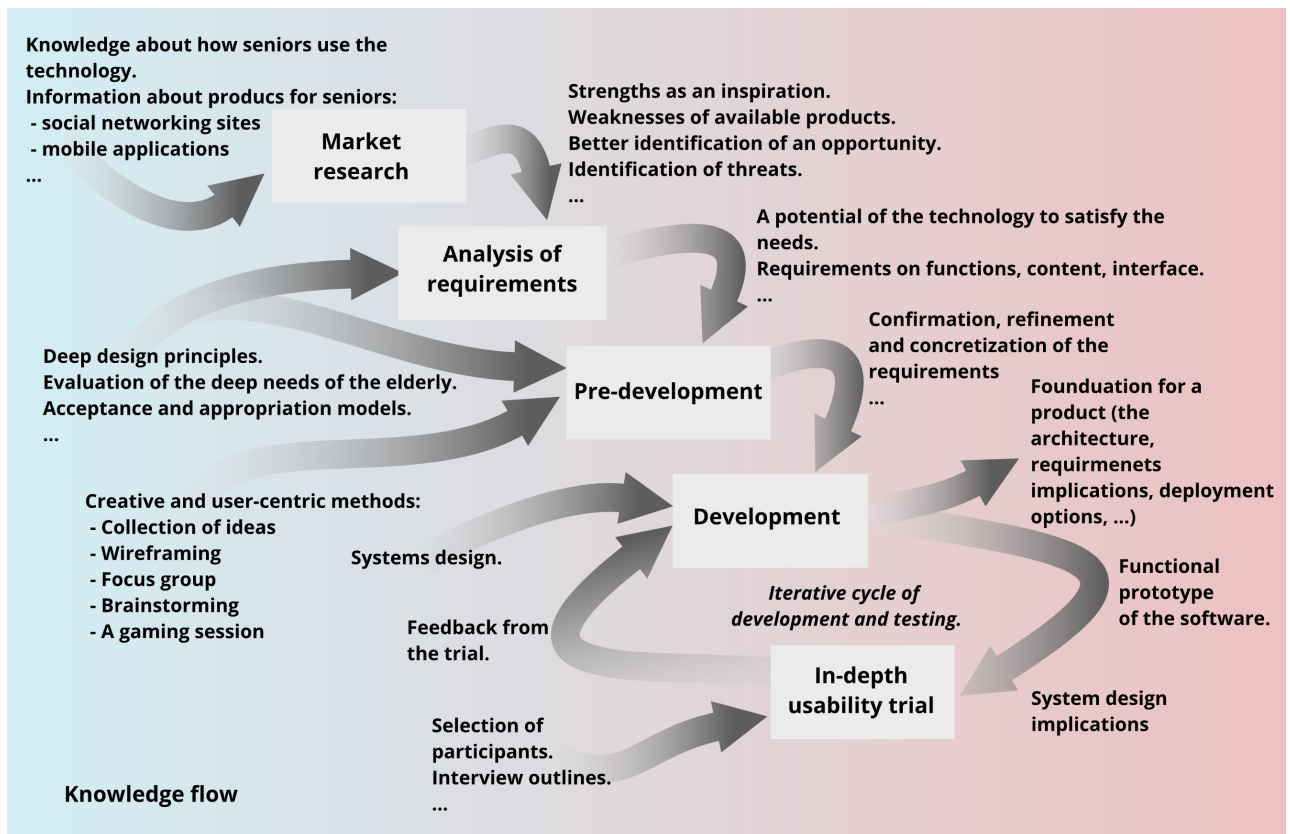


Figure 10: Steps in the applied research and experimental development and the knowledge flow between them.

4.1 EXPLORING NEEDS OF THE ELDERLY

The target group. Terms such as old people, the elderly, seniors, senior citizens, or older adults are used as synonyms, depending on the language dialect (British or American) or the field of science. There is no consensually accepted age limit for “old age”. Setting the age limit anywhere between 50+ and 65+ (World Health Organization, 2019) or even between 40+ and 70+ (Encyclopedia Britannica, 2019) is acceptable and the choice depends on the context⁷. Some gerontologists prefer a wider age range, recognizing the diversity of old age by defining sub-groups (Forman, Berman, McCabe, Baim, & Wei, 1992). Senescence (biological ageing) of humans is accompanied by gradual changes in psychological, social (Phillips, Ajrouch, & Hillcoat-Nallétamby, 2010), and developmental (Wattis & Curran, 2013) dimensions of ageing. Old age is rather a social construct than a biological stage and its precise definition varies both culturally and

⁷ For example, in Britain, pension scheme require 60+ years for eligibility, however the Friendly Societies Act defines old age as “any age after 50” (Roebuck, 1979).

historically. In general, old age refers to the final stage in the life course of an individual, usually associated with declining faculties, both mental and physical, and a reduction in social commitments (Kent, 2007).

The thesis focuses on individuals (1) *older than 50 years*, (2) *who retired from any full-time job*, (3) *are facing physical and/or cognitive decline which may be related to their age either objectively, or in their own self-perception*, (4) *but have not yet reached the “real old age”* (Rubin, 2007), *identified by a sharp decline in both mental and physical abilities* (Degnen, 2007). So, all “young olds” (Newman & Newman, 2012), i.e. the reasonably healthy individuals 50+ who do not need assistance and can complete their daily tasks independently together with the less-affected from the group of “old olds” (Newman & Newman, 2012) who depend on specific services due to declining health or diseases are involved. Chosen definition allows to consider both heterogeneity and homogeneity of the target group consisting of individuals each with his own personality, social background, health state, religion, cultural heritage, place of residence, wealth or social status, hobbies, knowledge and experiences, digital literacy, etc., however, with certain similarities in needs, aspirations, requirements, or habits.

The method. To find deep needs of the elderly, which might play pivotal roles in the evaluation of products, we performed research presented further, based on available published sources, ranging from fields of ambient intelligence for the elderly, through more general design and engineering methods, to sociology, psychology and gerontology. Having heterogeneity of the sources on the mind, we decided to apply the in-depth exploratory research method (3.3.2) based on a free cognitive method of mental mapping and subsequent assessment of the findings. The procedure was to take down both main conclusions and edge results and findings related to the area of interest, intuitively group the results to logical clusters and follow ideas in each cluster to conceptualise the key theme behind. Carroll et al. (2002), though they have focused on youngsters, provided valuable inspiration regarding the methods, approach, as well as revealing fundamental forces playing a role. Among youngsters' deep needs, power, identity, and fragmentation were identified. For the group of the elderly, our research has led us to four interrelated clusters of deep needs: social touch, autonomy with anticipated support, feeling of being competent, feeling of helpfulness and self-worth. In each of the following sections, we present the findings first in the context of intelligent technologies, turning them into guidelines for design afterwards.

4.1.1 THE SOCIAL TOUCH

Probably the most apparent desire of the elderly in most of the papers examined was to keep their social connections alive and healthy. How to capture the essence of the need as precisely as possible? There were many terms invented to capture various modalities of social relationships, such as a ‘social presence’, ‘*the ability of a communication medium to emulate face-to-face presence through its capacity to carry interpersonal communication cues; different media or systems can be directly evaluated with respect to how close they emulate the experience of face-to-face interaction between humans*’ (Short, Williams, & Christie, 1976) or ‘*social connectedness*’, ‘*a positive emotional appraisal, characterised by a feeling of staying in touch communication medium, in the context of social and within ongoing social relationships*’ (Romero et al., 2007). Seniors tend to be more and more isolated as they grow old. A study conducted by the Administration on Ageing (2017) shows, that about 29 % (13.6 million) of all noninstitutionalized older persons in the US lived alone (9.3 million women, 4.3 million men) in 2016. They represented 35 % of older women and 20 % of older men. The proportion living alone increases with advanced age. Among women aged 75 and over, for example, almost half (46 %) lived alone. Isolation and loneliness may lead to depression (Cacioppo, Hughes, Waite, Hawkley, & Thisted, 2006), cognitive problems (Cacioppo & Hawkley, 2009), or even increase in mortality rates (Steptoe, Shankar, Demakakos, & Wardle, 2013).

The elderly particularly appreciate deep relationships with strong positive emotional content and prefer them to wide but shallow relations. They wish to stay in touch with their close and with family members in particular. They wish to look in the lives of their close but do not want to be looked upon (Lindley et al., 2008). The mixture consists of

1. awareness of daily life, ‘*daily contact between family members, as opposed to the lack of an alarm*’ (Mynatt et al., 2001) (focus on information),

2. feeling of closeness, ambient intimacy, *'being able to keep in touch with people with a level of regularity and intimacy that you wouldn't usually have access to, because time and space conspire to make it impossible'* (Java, Song, Finin, & Tseng, 2009) (focus on persistence),
3. affective awareness, *'the general sense of being in touch with someone's friends and family'* (Liechti & Ichikawa, 1999) (a connection in an ambiguous sense).

Summarizing these modalities, the elderly yearn after closeness, they wish to perceive that they have a valuable social role, they wish to be updated with ongoings of their close. This is what we call the social touch. Keeping in social touch brings comfort and peace of mind (Mynatt et al., 2001) and lowers a pain of cognitive decline (Morris, Lundell, & Dishman, 2004).

Design guidelines. Designers should focus on relationships which already exist first rather than building new (Lindley et al., 2008). Vastenburger et al. (2008) recommend to leverage relations instead of supplanting them, and similarly, Neustaedter et al. (2006) suggest not to replace existing awareness-gathering techniques but augment them. Sadly, the elderly often have unmet their communication needs (Hutchinson et al., 2003). Technology should provide 'mediated awareness'. It should surrogate or re-establish natural social structures disrupted by distance, current pace of life, or by dehumanising technology (Mynatt et al., 2001).

4.1.2 AUTONOMY WITH ANTICIPATED SUPPORT

Family and other caregivers should be at hand, willing to offer assistance when it is required, but 'ageing well' means, that the support is nearly never drawn (Adams & Blieszner, 1995). Seniors desire to feel autonomous and independent (Kawamura, Umezu, & Ohsuga, 2008). They wish to stay in touch with children's lives but imposing no intrusions on them. Children should avoid over-protectiveness, which brings stigmatising and a loss of perceived independence (Lindley et al., 2008). Krause (2007) brings exciting insight into the deep feelings behind various types of support provided to improve the quality of life of the elderly. He distinguishes four fundamentally different types of support - emotional support, tangible support (e.g. cleaning, cooking), informational support (providing information), and anticipated support, the confidence that help will be provided if necessary. Both emotional and anticipated support improved the perceived quality of life. Informational support had no evident effect. Most interestingly, tangible support caused a decrease in perceived quality of life. According to Krause, the inability to reciprocate tangible support results in the sense of dependency, or implies incompetence. Monitoring technologies, such as intelligent fall detection systems, are likely to be accepted, as long as they help seniors to live independently without putting a massive stigma of being old. It means besides else that they should be at least unobtrusive, or ubiquitous.

Design guidelines. According to the findings, supportive technologies managed by relatives could be perceived negatively, increasing a feeling of dependence. On the other hand, intelligent supportive technologies mainly or entirely controlled by the elderly themselves, lowering need of tangible support from relatives or others, could be accepted much more. Easy-to-use pervasive communication devices could increase positively perceived emotional and anticipated support.

4.1.3 FEELING OF BEING COMPETENT

Besides the most valued relations (typically family relations), social links within a local community are desired too (Gaver & Dunne, 1999). Particularly the elderly in an early phase of cognitive and physical decline appreciate diversity in relations and extensiveness of ties besides relation deepness. While asymmetry in relationships with close family is desired – the elderly prefer to watch instead of being watched – with social peers (contemporaries, various people in a local community) they wish to feel competent, equal (Lindley et al., 2008). For the relations, it is vital if the elderly are acknowledged with their impairments and if they do not strive too much to hide them. Rather than if they are pretending competence, they are likely to feel happy if they may exploit most of the remaining abilities (Morris et al., 2004). On the other hand, the acknowledgement should not overgrow into a feeling of incompetence.

Design guidelines. The desire to feel competent could be reflected in technologies augmenting or extending the social network of their users. For example, intelligent technologies might be used to provide novel and convenient interfaces to social media for those who are struggling with common user interfaces based on

metaphors, which may be confusing for those, who are not used to them, such as menus, windows, dialogues etc. The feeling of competence could be further supported by higher adaptability and intelligent customisation while keeping it as simple and usable as possible.

4.1.4 FEELING OF HELPFULNESS AND SELF-WORTH

Reciprocity in relations is not always necessary, or even desirable by the elderly, especially when dealing with children. We already mentioned positively perceived asymmetry in communication patterns (look at but not being looked at). A desire to keep a similar pattern in the field of support and care has been observed too (Lindley et al., 2008). In general, the elderly do not wish only to stay autonomous, but they want to influence others (Morris et al., 2004), to be and to feel helpful and important for their close. They wish to feel that they are indeed perceived as helpful and important by those who receive their support. Cultural and religious heritage further supports the virtue of pleasurable giving⁸, which makes the giver feel even more dignified.

Design guidelines. In the case of those whose opportunities to help and influence others have been limited by their impairments, we should focus to support a renegotiation of roles of importance (Adams & Blieszner, 1995). Hofmeester et al. (1999) show how, by thinking of older people as active participants in society rather than as needy and dependent, innovative designs have been developed for systems that help seniors remain a vital part of the community. They, supported by appropriate technology, may use their memories, experience and time to take various valuable roles. They may act as a living memory of the community, as a guide, commentator, or a valuable and cherished family member, of course.

4.2 MARKET RESEARCH

Moran concludes that seniors 65+ are living longer, are more active, and becoming increasingly literate online (Moran, 2013). According to a report from the Pew Research Center commented by (Sherwood, 2015), while nearly 60 % of American seniors use the Internet, only 37 % of those over age 80 get online, as of 2014. Only 18 % used smartphones, while another 18 % owned tablets. Regarding the situation in the Czech Republic, according to Srb, big majority, 92% of seniors people under 65 years old own a mobile phone as of the date of the publication. Majority of them also cannot imagine life without one (Srb, 2012). The fact that use of the novel technology by seniors is on the rise is no surprise. For example, Hrdinová (2017) whose article based on data published by Czech statistical agency covers the consumption of television content in the form of Internet streaming among the elderly in the Czech Republic. According to the article, in 2010 only 2 % of citizens aged 65+ were used to watching TV on the Internet, whereas in 2016 the number increased to 12 %. The increase of consumption is even stronger among the cohort of consumers aged 55 – 64. In contrast, use of TV content on the Internet among consumers aged between 16 and 24 years have risen only by 18 %, which harmonises with the assumption, that vast majority of youngsters are used to the digital content, so the market is well saturated. We have also noticed an interesting phenomenon of emails being mass-forwarded among communities of senior users. The emails usually contain PowerPoint attachments about exciting places, historical events, pictures of landscapes or pets, opinions on current affairs, links to various resources on the web, or even conspiracy theories and hoaxes. We perceive this as an example, how some senior users fulfil the needs of social touch, autonomy, feeling of being competent, and feeling of helpfulness. But more research would be needed to confirm both the significance of the phenomenon and its causes and implications.

The upward trend in the adoption of technology by seniors is well-documented. But, on the other hand, seniors are still at least a step behind the younger generation. As covered by Hrdinová (2017), even though the involvement of seniors has proliferated, it is still just a fraction of the whole population. She also notices that seniors in the Czech Republic are not willing to pay for Internet content. According to Srb (2012), they use the phone primarily for calling, so they prefer hardware buttons. According to Klímová et al. (2016), proper integration of older people into the present information society without help is almost impossible. In their study which focuses on adoption of digital technology by seniors in the Czech Republic they conclude that the digital divide (J. A. G. M. van Dijk, 2002; J. van Dijk & Hacker, 2003) between the young and old is

8 For the western culture, for example (*Holy Bible, Giant Print Presentation Edition*, 2000 Acts 20:35)

apparent, though, thanks to the younger seniors, this gap is narrowing. Nevertheless, only a fraction of seniors can go beyond the very basic exploitation of ICT. As Klímová et al. summarise from several other studies, the situation in the Czech Republic is similar to other EU countries. According to Hrdinová (2017), for example, consumption of TV content on the Internet among Czech citizens aged 16 – 74 is roughly an average in comparison with other EU countries, but in comparison with seniors in other EU countries, more Czech seniors use computers than mobile phones.

Systems designed specifically for the elderly are doing better regarding usability, legibility. On the other hand, as Williams (2014) conclude, users may feel stigmatised using them. Opportunities for creative self-expression, for social network enhancement, or for self-education have been sacrificed to keep the system as simple as possible. Younger users may feel awkward using them, undermining the potential for bolstering essential family ties. On the other end of the spectre, general purpose social media do not bear the mentioned drawbacks, but on the other hand, usually lack usability, thus possibly bring anxiety, confusion, disillusion, feeling of incompetence. Further, the systems follow youngsters' patterns of thinking, such as the preference in shallow relations.

The following sections provide an overview of the digital technology available mostly in the form of products, either directly targeting seniors, or which offer relevant functions. The market research does not have the ambition to be exhaustive, but it instead gives a perspective view on the matter. It illustrates the diversity of problems which have to be solved to satisfy needs of seniors successfully and the variety of possible solutions. The market research does not have a summary, but we provide comments on selected individual products. First, the area of social media is covered, then we present our findings of available mobile applications and senior-friendly electronic devices. Finally, relevant service providers and systems integrators and their products are presented. Because we found two providers the most interesting in connection with the topic of the thesis and most inspiring for the subsequent development, we cover them in more detail.

4.2.1 SOCIAL MEDIA

As discussed in other parts of the thesis, current mainstream social media reflect the shallowness of social relations of youngsters and high pace of life of the middle generation. Though being called “social”, it may even widen social barriers. On this background, niche sites specially made to meet the needs of the elderly emerged as well (Clifford, 2009).

Senior-crafted social media. SeniorMaze (SeniorMaze, n.d.) is an example of a web-based social and matching system aimed at seniors, allowing them to connect with others around the world and develop new friendships in the free time. The communication on the site may revolve around the types of content the site supports, such as blogs, photos, forum, polls, videos, quizzes, events, music, or marketplace. Interestingly, they involve in their definition of senior people aged 40 and over. The idea behind is that the site is targeted towards those in the second half of their lives. But, the site did not catch up or is in a decline – it is not even in the list of sites tracked by alexa.com service (Alexa, 2018). Other social media aimed to attract seniors appeared, but have been either abandoned, such as eons.com or mywayvillage.com or transformed into a different kind of product, such as senior.com.

Mainstream social media. We can't forget the mainstream social media, with Facebook on the most prominent position with more than 2 billion active users as of now (Statista, 2018), followed by YouTube (1.5 billion), WhatsApp (1.3 billion), Facebook Messenger (1.3 billion), WeChat (980 million), QQ (843 million), Instagram (800 million), Tumblr (794 million), Qzone (568 million) and other services. According to Facebook Demographics and Statistics 2010 (Corbett, 2011), US audience of age 55+ grew by 923 % in 2009 from 954 thousand to almost 9,8 million, which was in comparison with 145 % overall growth including all ages a high figure. Now, according to Pew Research Center surveys covering the US population, some 88 % of 18- to 29-year-olds indicated that they use any form of social media. That share falls to 78 % among those ages 30 to 49, to 64 % among those ages 50 to 64 and to 37 % among Americans 65 and older (Smith & Erson, 2018).

Social networking 'new wave'. A new wave of social media is arriving in response to the darker side of Facebook and other major providers. Nakmeister (2015) enumerates and briefly describes some of them. *Ello* (Budnitz & Berger, n.d.), created in 2014, an invite-only ad-free alternative, created by a small group of

artists who'd grown tired of clutter, negativity, data mining, and ads, with Alexa global rank 33,383 as of the time of writing the thesis. *Diaspora* (The Diaspora Foundation, n.d.), launched in 2010, a non-profit, user-owned and distributed social network that, unlike to Facebook, gives its users full ownership and control of all the data that they post, ranks 406,939 as of now. Relatively popular among the newcomers, *FourSquare* (Foursquare Labs, n.d.), launched in 2009, unique with its stress on geolocation-relevant data, ranks 2,511 as of now. *Ning* (Ning Interactive, n.d.), a platform founded in 2004, allows individuals and organisations to create their own custom digitally supported social networks, ranking currently 4,941. According to *Path* (Path.com, n.d.) which emerged in 2010, we tend to have 5 best friends, 15 good friends, 50 close friends and family, and 150 total friends, so the service allows you share with the people who matter most in your life, they intended to nurture quality relationships. The idea of a cap for social relations around 150 is well founded – as Dunbar (1993) has shown, it is just the limit biologically entrenched in us, and it applies across cultures and eras, from ancient Mesopotamian villages, nomadic !Kung San people of Botswana, or, as a new trend, even in modern offices (Gorvett, 2018). Path ranks 87,019. Founded in 2012 as Harnu, now called *Aware.world* (Aware, n.d.), its mission is to bridge gaps between countries and cultures, currently not indexed by Alexa.

4.2.2 MOBILE APPLICATIONS

*ConnectedLiving*⁹ (Connected Living, n.d.) connects seniors living in retirement homes with their families. Their mobile application for Android and iOS phones correctly reflects on the fundamental difference between a typical social network of a senior and a network of a youngster: “*Share news, photos, memories and inspirations that you want to keep between only your family and closest friends (not with your 450 contacts on other public social media sites).*” The functions include geolocation and geofencing¹⁰, scheduled rides, sensors, and real-time alerts and notifications. The interface has been simplified with people with memory or cognitive losses on the mind, but still, it is necessary to deal with menus, relatively small buttons, and more than just basic touch strokes, so we find it useful rather for seniors in early stages of decline. Besides this, the company provides a web-based platform for elderly-care institutions to manage relevant information like events, surveys, notices, photos from one point of entry. Recently they extended their focus on improving productivity at workplaces by delivering well-being for employees by connecting them with their families. It keeps them happy by assisting with work/life balance and reinforces the company's reputation as a family-friendly workplace.

Oscar Senior (Oscar Senior, n.d.) is an Android and iOS compatible mobile application which helps seniors to stay in touch with family and friends through video, text, calling and photo sharing. It has a simple interface with large elements and big fonts. Instead of trying to be an all-inclusive solution for all needs, it provides simplified access to other applications and services. It adds protection from scams, unauthorised pop-ups, and uncalled-for alerts and remote access for family members who may configure the device and guide the user.

KeepTouch (Geolives Belgium, n.d.) and *Family Locator* (Sygic, n.d.) are examples of simple geolocation and geofencing social applications. They allow to locate friends and family and for example, get a notification, when a family member reaches a destination or leaves a specific place. It may be useful also for seniors and their families to stay updated on one another's whereabouts.

Clevermind (Clevermind, n.d.) is a voice-activated iPad app to help stimulate the cognitive abilities of seniors and people with Alzheimer's or Dementia. It includes a chatbot, allows search on the Internet, in an encyclopaedia, in a dictionary, and in health-related resources, a collection of resources about nutrition, exercise and healthy lifestyle. It also allows connection with friends and family via Facebook, Twitter, Google+, and Pinterest. A memory-training section prepared by experts on dementia contains tasks such as answers to questions from general knowledge, problem-solving, grammar and language. It also has games, such as tic-tac-toe, games based on matching, or simple puzzles. The application provides access to news published by mainstream online media houses, music and video from Vimeo, Vudu, YouTube, B&W Movies, Jango, eBooks and YouTube audiobooks. Finally, it has a function which allows writing notes and taking pictures, connected with services such as Flickr, Gmail, Outlook, YahooMail. The application

9 Formerly on www.connectedliving.net, but now on www.connectedliving.com.

10 Allows triggering a notification when a mobile device (held by a family member) leaves certain geographic boundary.

provides a vast palette of functions which are all accessible from one place. But, on the other hand, the richness makes the interface quite complicated. The application also does not shield the user from the technical aspects of the underlying services much. So, it is suitable for relatively experienced users or users with relatively minor cognitive problems.

FlipBoard (Flipboard, n.d.) is an iOS application which connects with major social media accounts and with some news and content sites. Then it turns everything into a digital magazine, in which user 'flip' the pages, where content from various sources is combined. The application has major drawbacks. For example, it pushes advertisements in the content excessively, and the flipping on a touchscreen is not as comfortable compared to swiping when it comes to larger amounts of content. But, it is an interesting example of a mash-up application which presents an available content in a new way. There was a similar project called *Prismatic* for Android, iOS and web, but it was discontinued in 2015 (Novet, 2015).

4.2.3 SMART ELECTRONIC DEVICES FOR SENIORS

GreatCall (GreatCall, n.d.) sell senior-friendly mobile phones and portable mobile medical alert devices together with a pack of services, which include urgent response (an immediate contact with an agent which will assess user's situation and provide help), urgent care (voice consultation with a doctor), link (updates about the well-being of a person using a GreatCall phone or device sent to a caregiver), medical coach (prescription schedule with a reminder). Their smartphone uses a launcher with big icons. The default menu has a limited number of applications. Voice-to-speech technology substitutes the software keyboard as a default input method.

grandPad (GrandPAD, n.d.) is a 7" Android tablet designed for seniors aged 75 and older. It comes with a stylus, a charging stand and LTE connectivity data plan. It provides a simplified menu, big colourful icons, big fonts. Its functions are limited to phone and video calls, voice emails, taking and viewing photos and videos, listening to personalised music, checking the weather, few games. It does not offer web browsing or other ways to consume internet content. It also provides an instant connection with remote assistance with the tablet functions. An excellent idea which may help to promote connectedness is the weather function which covers not only user's location but also positions of his family members.

OwnFone Mobile (Anywhere Care Limited, n.d.) is a radically redesigned mobile phone with functions stripped to the very minimum, only sends and receives calls. It is of a size of a credit card, wearable, and brandable.

Doro (Doro AB, n.d.) phones have large print and big buttons, while other phones come with a built-in panic button.

But to some seniors, these devices can seem a bit old-fashioned and somewhat stigmatising, according to Prof Hosking. "*They don't deal holistically with the problems of ageing because often older people have multiple impairments,*" he says (Cellan-Jones, 2015).

Savi (MobiSoft Infotech, n.d.) is a project of a senior-friendly tablet with buttons and icons that are easy to access, easy to navigate, along with fonts and colours that count with people with vision impairments. Unlike many devices targeting seniors, it has a stylish look. The layout of the user interface of the application launcher and functions such as music play, email, camera, calendar, has been radically redesigned. Though the project went quite far in a proper direction, more work would have to be done to make the product look-and-feel entirely coherent and intuitive and to transform the results into a real product.

RealPad (AARP, n.d.) was a tablet offered by AARP, a non-profit organisation with a mission to empower seniors based in the US. It had a senior-tailored launcher, a chosen set of pre-installed applications and in default, its settings were adjusted to the needs of seniors. It was affordable and with a 24/7 hotline support. As a highlight feature, it came loaded with more than 20 step-by-step videos as a replacement for a manual. It also had a pre-installed tool which assisted users with common problems. The project launched in 2014, but has been discontinued.

Jive (Arent, 2009) is not a product, but an inspiring proof of concept for a set of innovatively augmented electronic devices aimed to keep the elderly in touch with their friends through the Internet. As a central

idea, it uses specially designed physical cards to identify friends and family members. For example, when a user wants to send a message, he puts the card in a specific position, a new message dialogue appears, and the user pulls out the keyboard and types the message contents.

4.2.4 SERVICE PROVIDERS AND SYSTEMS INTEGRATORS

Keystone Technologies is a US-based technology service provider focused on elderly-care institutions. Their goal is to deploy engagement-promoting technologies to senior care communities. They deploy a variety of configurable products, such as a program which helps prevent falls and frequent illnesses, by sensor-based health monitoring and artificial intelligence, or an integrated pack of software which provide social functions and keeps users informed and entertained (Keystone Technologies, 2018).

Moran (2013) notes that also elderly-care providers, such as Merrill Gardens and The American Association of Retired Persons, are increasingly more active in the area of software for the elderly.

4.2.4.1 CLARIS COMPANION

Claris Companion is a product aimed to connect older seniors with family and caregivers, combining software and suitable electronic devices offered by Claris Healthcare, based in the US (Claris Healthcare, 2016). It targets older seniors, according to its website an average age of their users is 86.

Hardware. It is available in variants as a tablet, either with Wi-Fi or 4G connectivity or as an IP phone with a big screen. It is designed to be always on.

User interface. Authors claim that the product has been designed with visually impaired, seniors with arthritis, Parkinson's disease, or dexterity issues. As control elements it consistently uses large colourful buttons with textual captions, big fonts, and as far as we may understand from the available information, clear and easy-to-understand layout. There is no need to type any passwords and the senior does not have to set-up anything. Only basic touch gestures are used, no swipe. All content is pushed to the device and displayed in full screen without the user having to do anything. It can be even configured to show no buttons on the home screen and notifications appear automatically.

Interaction. It allows the family to connect with seniors using email and text messages, photos, and video calls. A function which adapts to both needs of seniors and their younger family members is a '*call me button*'. When clicked by the senior, his family member receives a notification to call at a convenient time. It also uses a concept of '*checking-in*' every day as a first user's interaction with the system which helps to keep caregivers and the family updated, that he is all right.

Content. It also provides access to external material, for example, exercise videos. Family or caregivers may also define a set of web pages which are then made accessible to the senior via an integrated web browser directly from the product. Because the device is always on, any reminders, messages and notifications are displayed at a real time.

Monitoring. Caregivers and family can receive alerts and observe compliance with medications, treatments, and appointments. The system sends a notification if anything is out of the ordinary, such as a missed medication reminder. Alerts are configurable, and various events may trigger them, including interactions of the user or system events, such as if the system goes offline. Besides real-time notifications, a daily summary may be sent via email too. The system also presents an activity (intensity of the user's interaction with the product), compliance (response to medication and other scheduled reminders), wellness (self-assessment) scores. Because these scores are recorded over a period, trends may tell the family and caregivers when the user needs additional help.

Administration. It has a web-based management interface, accessible by caregivers and the family. It allows to select functions and adjust their settings. Authors recommend that most users start with only one or two buttons, more may be added gradually. The management interface also allows the family and caregivers to schedule questions remotely. The system then asks the user according to the plan.

Authors recommend to get started with the product early before seniors need it, so when it comes to manage medications or implement a detailed care plan, the product is already part of their daily routine. If we were asked to assess the product, we may conclude that it is promising. Its functions, user interface and

recommended usage patterns are in good harmony with the needs of seniors which we have revealed in our research and show a good insight of authors of the system into problems and feelings of both seniors and their families. The product also has its drawbacks. It keeps almost all control out of the hands of its users, which may make seniors feel even older and dependant. The monitoring functions may lead to a feeling of being watched by a big brother (Orwell, 1949). It also provides very limited access to the content which is available online. Though it is possible to enable selected websites, it does not make the websites automatically accessible to users with various impairments. Interaction with user interfaces of different sites may lead to accessibility issues. But, despite these issues, we view Claris Companion as a good product for a specific subgroup of seniors.

4.2.4.2 BREEZIE

Breezie is a product of That Device Company based in the UK (That Device Company, 2018). They offer mainly a solution for elderly-care providers, which allows them to deploy tablets, tailored to the needs of senior users, among their clients. According to Pratt (2017), approximately 70% of their clients among providers serve seniors in their own homes, with the rest providing care for seniors in residential care facilities.

Hardware. As the main client device, they use tablets. Integrating third-party hardware such as IoT, biometric devices and wearables allow them to deliver smart apartments, remote patient monitoring and innovative home care services. The integration has been implemented in collaboration with Samsung and T-Mobile and supports, for example, Fitbit, Amazon Alexa, Samsung SmartThings and iHealth monitoring devices.

User interface. According to the limited information publicly available (That Device Company, 2017a), it uses a clean and synoptic layout, legible captions, bright colours which may help users to remember its functions. According to a Breezie Case Study, the interface allows personalisation (Samsung, 2017).

Functions. Breezie offers benefits ranging from stronger connections with friends and family, increased mental engagement and independence, to support for post-surgical recovery (Samsung, 2017). According to Kazimi quoted in another Samsung article, their tablets have five major benefits for seniors (Samsung, 2015). 1. Social media which helps them to keep in touch with friends and family, through Facebook and Skype, 2. content, such as information for leisure, learning and emergency preparedness, 3. commerce, such as convenient online shopping and access to user reviews for informed decision making, 4. entertainment, which involves games and content that promote mental engagement, 5. health, namely medical information, care plans, health apps and wellness content. The product website mentions also facilitating ordering services such as transport, meals, groceries and care visits.

Content. It allows to integrate various online content, using many supported APIs, micro-services and predefined templates, such as dining menus, activity calendars, appointment requests, or medication reminders, into a holistic, often custom-branded and senior-friendly digital solution.

Architecture. At the back end side, they use a scalable architecture based on containerised microservices architecture (That Device Company, 2017b). The system internally uses HTTPS and REST. A single sign-on OAuth 2.0 integration automatically logs users into the organisation's systems without any username and password being entered.

Deployment. As an Android EMM Partner, the company may take control of any Android device at its setup screen by entering a registered email address or an AFW code. Google then automatically installs and runs their Device Policy Controller application, which then connects the tablet to their back end. It involves replacing the start screen app and applying various settings that make the tablet easy to use. It also automatically installs a set of curated and personal groups of applications and bookmarks configured for the user by their organisation. User account details are set as well during the process, so, when the user launches the tablet, he gets greeted by a name, and his tablet is immediately ready to work with email, contacts, content, curated and personal apps. This solution allows the company to deploy and support thousands of tablets (That Device Company, 2017b). To automate the set-up of tablets, the company uses Samsung Knox Customization API (Samsung, 2015, 2018), which allows them to perform tens of customisations of the original tablet software by running a small script. It also lets them capture sensory data for digital profiling, provide remote access to devices, and report analytics for the company, insurance providers, and elderly-

care institutions where the residents are living. Remote access may be used to adjust settings, install new applications, provide training, or technical support (Sherwood, 2015).

Management. Tablets get connected to elderly-care organisations and managed via the so-called admin portal and also to the user's friends and family via the so-called family hub. The company monitors the tablets too and may provide some assistance if needed.

If we were asked to assess the product, it has many advanced features, especially if it comes to the deployment, management, and architecture. It helps to make the digital world more accessible to seniors. We commend that the device does not stigmatise its users. The product directly and primarily targets wishes and needs of seniors, which is commendable and in harmony with the principles of in-depth human-centric design. On the other hand, though simplified and designed with the elderly on the mind, the user interface seems to be still too complicated for many seniors. Most of those who never used smart electronic devices need the training to learn how to operate the functions. It is also not clear, how well it is doing for users with significantly worsened vision, with sensory impairments or tremor. A simpler interface would make the product accessible to a larger group of seniors.

4.3 INITIAL ANALYSIS OF REQUIREMENTS

Inclusive social software. Terms such as social networks, social media, social networking software, social networking platform or even social software often refer to Facebook, Twitter, WhatsApp, Instagram, etc. That's a common perception – a system which just allows people to interact with one another in some or other way. But, as mentioned in 1.1.1, many mainstream social media evolved (or degraded) into advertising platforms, sometimes even putting people apart instead of bringing them together. Some view the technology giants in even more negative light (The Economist, 2018). So, instead of developing just another clone of Facebook, we would like to come up with something *fundamentally different*. We are focused on different purposes. We do not want to primarily give both old and young means to communicate, as other applications do. But instead to help them to rediscover *topics to talk about*. Also, to help them *understand each other* again. Even just comprehending the social media vocabulary may help seniors to feel more confident, less lonely and more involved. We aim to help to bridge mental, social and emotional gaps between generations, or to merge two principally distinct worlds – the world of speedy YouTube / Facebook / Twitter / Instagram generation with the world of their mature grandparents. Also, we want to open doors of the Internet and its vast pool of resources to the elderly and do it in a pleasant manner and to seniors' benefit. That is the inclusive social software in the in-depth human-centric design sense.

Acceptance and appropriation. Various emotions and strengths take their role in the process of technology evaluation and successive appropriation. People are economy beings; they wish to feel rewards for efforts (J. B. Lopes, 2001). Successful products have to pass all the stages and steps – attract attention first, show rewards soon, and gradually break into habitual usage. Failure in any of the steps effectively means the refusal of the product (Veldhoven et al., 2008). At first, some shallow emotions such as visual appeal, curiosity or euphoria drive the process. But finally and above all, deep needs are the forces which may turn into high order reinforcers and keep the product in use in the long-term (Carroll et al., 2002). To overcome the anxiety of seniors and motivate them to learn new things, it is even more important to target their needs as precisely as possible. We are fully aware of it and determined to apply the knowledge in the software design and development.

Successful ageing refers to a combination of physical, mental and social well-being in older age. The concept emerged in the middle of the 20th century as a result of changing views on the process of growing old in an attempt to find a dignified place in the society for seniors. They should not be viewed as a burden on society, but rather as a source of valuable knowledge and a precious connection with the past. Interventions needed to increase the proportion of the population ageing successfully are offered, e.g. by Rowe and Kahn (1997). The same authors reviewed the concept of successful ageing after almost 20 years later and came up with a term Ageing 2.0¹¹, perhaps as a reflection on the now popular versioning of various concepts from the web, to the industry. They recommend to re-engineer core societal institutions, help seniors to adopt a life course perspective, and focus on human capital in the context of the modern

11 Or 'Ageing 2.0' in the original article written in American English.

technology-rich society. Some try to think even further. The term Ageing 3.0 was used for example, by organisers of a scientific conference entitled “*Wise ways of living, working, and thinking towards 2050*” (Tsuzuki, Kon’no, & Ikujiro, 2014). Regardless of the evolving terminology, a contribution to the successful ageing is what the proposed inclusive social software is aiming directly and inherently.

4.3.1 RELEVANCE TO CLUSTERS OF DEEP NEEDS

Intelligent software products and smart portable electronic devices may improve the quality of life of seniors in various ways. According to Jackson, the right infrastructure may enhance the quality of life of seniors, advance the quality of care, increase length-of-stay in place at lower levels of care for longer, prevent adverse health events from illnesses or falls (Jackson, 2017). And for example, according to Belval, smartphone and tablet applications may allow seniors to keep their minds active and engaged, to stay connected with friends and family, stay abreast of news and world events, set reminders for physician appointments and to take medicines, pay bills online, get quick and to-the-point medical information, listen to their favourite music, stay well read, quickly take and save notes, and be entertained (Belval, 2015). In the following paragraphs, we outline, how inclusive social software¹² might contribute to the fulfilment of the clusters of needs revealed and described earlier.

Social touch. Although relations are crucial for elderly, their social network, as well as frequency and quality of their social activities, diminish rapidly with age, resulting in feelings of loneliness and needlessness. One of the most inner desires of the elderly is to *keep in touch with their family*. They do not wish to be monitored, but they want to follow their close and also happenings on their side. Local information sources, such as current weather, local news, webcams from city street may bring the feeling of connectedness and raise topics for discussion (Ejemo et al., 2004). Though in general, they prefer deeper relations, the interest is not limited to the family only. They wish to extend themselves to meet others. They want to meet *contemporaries*, but also people of *all ages to not feel as to die soon*. The software should help the elderly to keep their social connections alive and healthy, with emphasis on several relationships with strong positive emotional content rather than to a vast array of shallow “friends”. The software should help to keep its users aware of the daily life of their close friends and family, provide them with feelings of closeness, ambient intimacy and affective awareness. The goal is to focus on relationships which already exist first, rather than building any new. Technology should not be used as a means to replace real social engagement, such as meetings and group activities, but it should enhance the chances for vital and beneficial socialisation (Keystone Technologies, 2018). Instead, it should help to surrogate or re-establish natural social structures disrupted by distance, current pace of life, or by dehumanising technology. Pettigrew (1997) identified five categories of most severe obstacles for the socialisation of the elderly – they are not physically accessible, they keep to themselves, the fact of moving, changes in a community and isolation of illness. The software might help to overcome these barriers. For example, as research conducted by Oswald and Cotten shows, seniors who use the Internet even moderately feel less lonely and are less prone to depression (2014). Nimrod (2013) studied how an access to digital technology may reduce the depression. He clustered online seniors into three groups: information swappers, socialisers, and those into ageing-oriented pursuits. Socializers enjoyed most the time online with family and friends, which lead to the feeling of connectedness, which in turn have decreased signs and symptoms of depression. As he concludes, seniors who are active online feel more connected to their family, friends, and community.

Autonomy with anticipated support. Studies have proven, that ability to control raises interest (Zaad & Allouch, 2008). Seniors wish to be masters of their own lives and to keep their environment under control – to feel competent, empowered, *no more dependent*. They want to use their stuff without having to ask for support (Bambina, 2007). The software should help the user to keep his autonomy but enable close friends and the family to provide valuable and meaningful support, e.g. with remembering daily routines, scheduled events, etc. The feeling of closeness should likely lead to a higher level of positively perceived emotional and anticipated support, not making the user feel unnecessary dependent. The software might be able to help

12 We prefer 'inclusive social software', or general 'software' at this stage because it is not yet clear how the program should be implemented from the architectural point-of-view. It might be called 'an application' because it belongs to application space rather than operating system space. But we prefer to avoid the term 'application' because it might evoke a compact program running on a single piece of hardware in contrast to distributed application architecture, which will most likely fit the proposed purpose.

its user to free his family and close friends from worries, e.g. if the user follows routines prescribed by a physician. The software should make its users feel, that it is under their control. For seniors, it is frustrating when they have to call their children or grandchildren for technical support (Sherwood, 2015).

Feeling of being competent. The software should also help its users, to be competent within a local community and friends, including those of the same generation. Users should not be forced to pretend higher competences than they possess, but they should be able to exploit the abilities they have. The user interface should not be based on confusing metaphors, should not be excessively changing its layout, functions should be precisely defined, control elements should be connected with the functions in an understandable, stable and intuitive way. Feeling of competence could be further supported by higher adaptability and intelligent customisation, but still keeping it as simple and usable, as possible. It may happen that the elderly will use a system specifically designed to go about their disabilities. But it is not likely that they will *like* to use it. It is a matter of *dignity* – seniors *do not wish to be stigmatised*. To accept and like a product, seniors should feel, that it is *under their control*. For example, based on years of experiences with delivering technology solutions to elderly care institutions, people from Keystone Technologies (2018) conclude, that residents should be able to '*independently pursue their own unique online interests with a flexible schedule.*' They give an example: '*Once the recreation staff has headed home for the evening, residents can still jump on Instagram to check out their college granddaughter's photos for the day, or Skype their son from across the country.*' This pursuit is not bound by a calendar set by the institution but can happen when, and how often, the resident prefers.

Feeling of helpfulness and self-worth. The software should make its users feel helpful and important for their close, not necessarily bringing new ways they support their close, but leveraging the actual ways, e.g. via better communication. Users should also feel, that, they can influence others, e.g. by sharing their opinions and comments, memories, experiences or even expertise. The elderly would appreciate a space to *express themselves*, maybe organise memoirs, reuse experiences into pieces of advice, prove themselves as dignified, valuable and be recognised. The elderly may be highly willing to *take a dare*. As shown in experiments with micro-learning (Fuchsberger, 2008), they *wish to learn* if they may keep the feeling of competence in the process. It applies both to the system itself (appropriate learning curve of system mastering) and to opportunities to learn new things *through* the system. As Sherwood (2015) covers in her article, it might be the emotional driver of social media that appeals to seniors, but they quickly learn that photos of their grandchildren are not the only worthwhile content online. She quotes Kazimi from Breezie company: "*We often forget that seniors have aspirations – things they never got to do because they were working or looking after kids. In retirement, they have the time and mobile devices can help them do these things.*" As an example, he relates a 100-year-old lady who makes her own videos. "*Wearing my preconceived lens about what seniors do online, I assumed she was enjoying videos her family posts on Facebook. But it turns out that she always wanted to be a movie maker, so she's interviewing people and making short films.*"

4.3.2 ADOPTING SOFTWARE TO USERS, NOT THE OPPOSITE

For example, according to Washington, to ensure that older adults' needs are met, it is necessary to make older individuals a part of the design of mobile devices (Washington, 2015).

Subtle details matter. Swan et al. (2008) studied the usage of photos in a home setting. The study showed that each photo in home captures something - an idea, emotion, place, or event. The virtue of idea highly influences connotations which people feel towards each photo. The emotional charge further influences where people tend to place it, how they frame it, how they combine it with other photos. Placing, framing, glazing, combining reflect what do people feel to photos, such as perceived formality or importance. Framed photo usually captures something persistent; different kinds of photos hang on walls, lie on a bedside or stand on a mantelpiece. Photos are being also used for photo-sessions with relatives (Evjemo et al., 2004), for story-telling, or as a way to keep close emotionally at hand (Counts & Fellheimer, 2004). The study of Swan et al. resulted in findings useful for design, e.g. that cycling function of photo frames distorts perception of photo persistence, or that remote control distorts positive feeling of closeness. Interesting concepts, unisonant with inner feelings, have been introduced as a result, such as photo-cube and photo-matrix. A well-designed system may awaken enthusiasm, such as when users of bulletin board prototype revealed personal items shared by their valued family members (Veldhoven et al., 2008).

Linear media consumption. According to Hrdinová (2017), while young users often choose content from video library or digital archive, seniors prefer linear broadcast even on the Internet. The channels from which seniors are typically used to consume content include TV, radio, or printed media such as news, newspapers, or books. Also, the discussion in our focus group (5.2.3) was in harmony with the assumption – seniors who participated talked about TV and printed magazines as a familiar source of information for them. All these types of media are designed primarily for linear consumption. Of course, there is also a certain level of interaction but typically limited to mere switching queues of linear content, such as a selection of a channel to watch or listen to, or navigating to a chapter in a book. On the contrary, a vast amount of digital content on the Internet is typically accessible *on demand*. With this kind of media, users are often expected to set-up their preferences, to choose specific options in menus, to formulate searches, to browse through lists of results, etc. In general, these types of media require a much higher level of necessary interaction and more complex selection algorithms than just switching queues. The difference is illustrated in the following Figure 11.

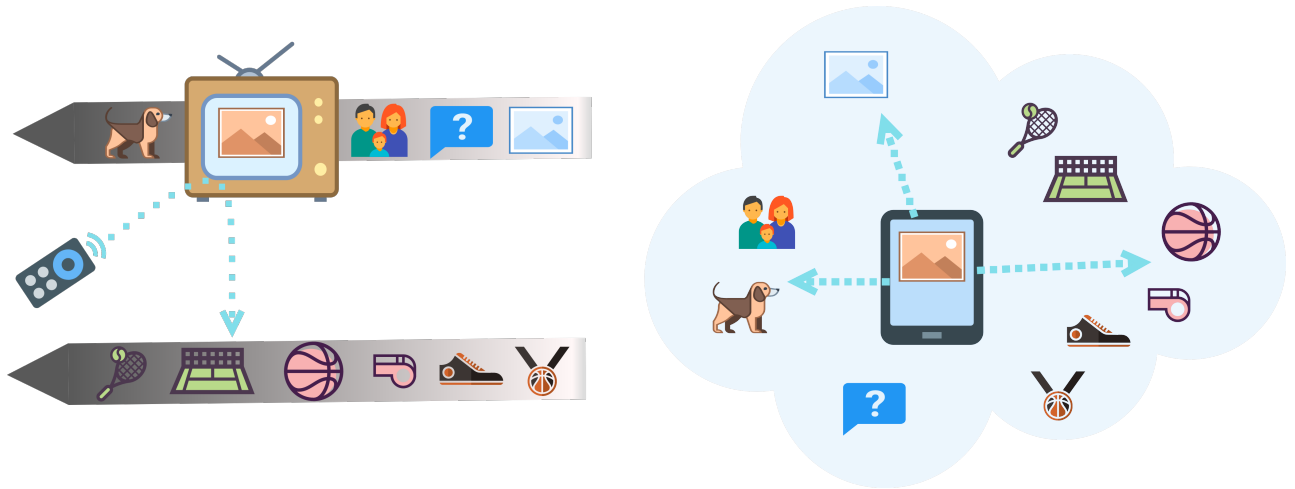


Figure 11: The conceptual difference between linear and on-demand media

The distinction between media designed for linear and for on-demand consumption is not clear, and they converge from both sides. Traditional media are becoming less linear and content on the Internet is increasingly more ready for linear consumption. Recent digital technologies are involved in this ongoing trend of convergence. So, pushing content even from web applications is possible. For example, playlist-generating algorithms on YouTube which allow virtually indefinite playback. But still, in general, the differences prevail.

5 INCLUSIVE SOCIAL SOFTWARE PROTOTYPE DESIGN

5.1 PRELIMINARY IDEAS AND REQUIREMENTS

5.1.1 DESIRED FUNCTIONS

An appropriate content granularity. The suggested software shall provide access to a variety of contents, but it should serve them to the user in a fine-grained manner – a picture, a short video, audio, a text or a simple combination (such as an article with a text and an image) at a time. The contents might be sourced from the system, or be fetched from an external source (e.g. RSS, web pages, digital photo galleries).

Content adaptively relevant to the user. Each user shall be served with materials according to his interests (“a personal feed”). User's preferences should be configurable. The algorithm should be gradually adapting to his preferences and the way he uses the system.

Navigation and feedback. The user should exercise control over the context. There should be controls which would allow him to navigate to a next content item. He would also have means to express his satisfaction or dissatisfaction, which might be implemented e.g. as 'interested'/'not-interested' and/or 'like'/'dislike' control elements. The software should keep track of items a user is interested in and, perhaps, provide him means to re-access the liked content.

Content creation and intra-system and cross-system interactions. The software might allow the user to create new content in various forms (written, a recorded voice, or a photo), either in relation to other content (as a comment), or not. Users might be given means to share the content they have created – for example, to send it to someone in his circle. One-directional or bi-directional connections with other systems and services will allow users to interact with users outside of the software. For example, a content by a user or his interaction will be forwarded to an e-mail, or to a social media (e.g. Facebook, Twitter, or Instagram). The person who receives a content from a user of our software shall be given means to respond. The response will be conveyed back to the original user.

Safe, secure, trusted. Though a fully-fledged inclusive social software should have a well-thought-of and precisely crafted security and trust model, the suggested software prototype won't need it, because it won't be dealing with many users and it won't be open for registrations beyond the testing circle of persons. Specifics of perception of trust and distrust among the elderly in their role as information technology users should be considered; our previous research may provide relevant insight and direction (Zejda, 2010b, 2011b).

Extensible. The software should not provide just a limited set of functions or sources of content, but it should be readily extensible. One idea of an extra feature is a calendar with a shared reminder function. It would allow both user and his family members to keep watch of scheduled appointments or daily routines, such as medications. Both textual and audio reminder might be stored. The remainder should bring the user's attention.

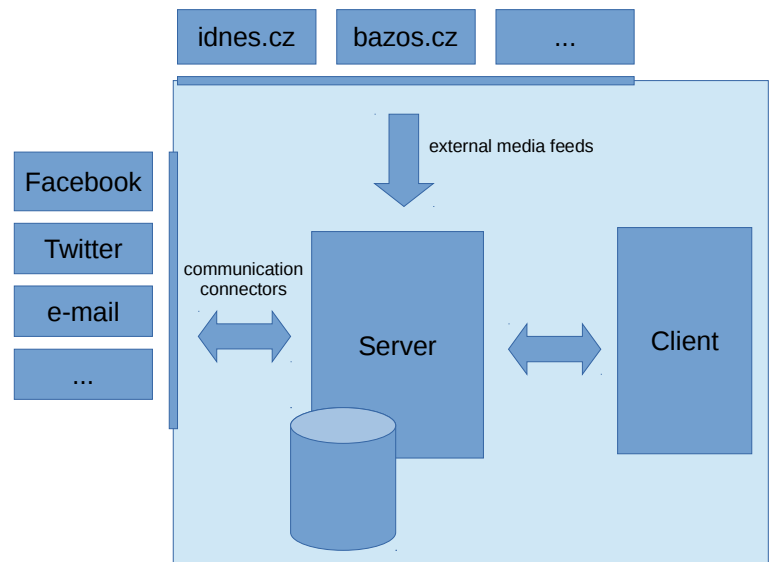


Figure 12: A preliminary concept of the proposed program

The architecture. In the early stage, we considered several architectural options, for example, a personalised façade for one of existing social media systems. With both function and user interface ideas, we decided instead to implement new software, but able to interact with other systems. We suppose that the software will have a client-server architecture, with data stored in a database. A draft of the architecture is in Figure 12. The server part of the software shall have a web interface for the management and configuration.

5.1.2 USER INTERFACE

Inclusive social software may help the elderly to overcome disabilities and enrich their social relations, but the same limitations make the task difficult. We have to consider impairments (Apted, Kay, & Quigley, 2006), such as *visual losses* (reduced visual acuity, loss in colour perception, increased sensitivity to glare), *cognitive losses* (declining performance of working memory and learning) or *motor skill impairments* (slower movements, poorer coordination, difficulties with fine motor actions). Other researchers have examined related usability questions. It is widely known, that for example, tiny control elements are not suitable for seniors. But a user interface suitable for the elderly does not merely mean bigger buttons. E.g. Becker (2004) targeted the usability of the web by older adults, Lopez (2001) examined the suitability of interfaces for severely handicapped. Newell et al. (2006) described different viewpoints and misunderstanding between prospective users, experts from web industry, and researchers during the design of a portal for older users. Based on the research, we may identify critical usability-related requirements, some obvious, but others often neglected or overlooked by user interface designers. But, we should not be concerned with all the disabilities and impairments to lose the *primary focus on benefits*. A product which primarily focuses on the troubles related to an advanced age is likely to miss the target and not likely to be well accepted and appropriated. We like the perspective given by Leung et al. (2012) that mobile devices can assist older adults in becoming more independent as they experience declines in perceptual, motor, and cognitive abilities because of the ageing processes. They put the benefit (becoming more independent) as a primary objective and the decline in skills serves as a constraint.

Simple. While gradual ‘upgrading’ is a trend, ‘downgrading’ may be more appropriate for users with impairments (Veldhoven et al., 2008). After discussing various advanced technologies for the elderly, Cellan-Jones (2015) quotes Ian Hosking, who says, that *‘we need to get the basics right first’*. Not only the elderly appreciate simplicity, but it is welcomed by most users, as shown, e.g. in an experiment with a photo sharing system (Counts & Fellheimer, 2004). Any kind of overwhelming should be avoided. E.g. Evjemo et al. (2004) showed that people like to see short videos of their close, not the whole party. Users also welcome if they may act immediately, without waiting and remembering. To provide the right amount of functionality, we recommend a *disruptive approach* (Christensen, Raynor, & McDonald, 2016). We should use the means we have, the computation power, artificial intelligence, connectible services, embeddable content, high screen resolution, Internet bandwidth, etc. not to primarily add more options, functions, buttons, menus and make things complicated, but the opposite – *to simplify*. There should be less. Fewer buttons, fewer menus, fewer components, fewer settings, fewer distractions and less frustration. A lot of work should be done behind the scenes by the means and resources we have, to provide a plain, but *smooth user experience*. Things should just work. Before adding anything, it has to be considered very carefully if the benefit outweighs the increase in requirements on the user skills, more confusion, clutter and lost focus.

Reliable. The user interface should also be responsive and platform neutral, if possible. In the case of a technology failure, especially inexperienced users doubt their own skills, which raises negative feelings, such as their anxiety (Veldhoven et al., 2008). The system should be reliable to be acceptable. It should be fault-tolerant, for example, run both online and offline. It should prevent faulty user interactions or recover from them reliably.

Adaptive. The user interface should gradually and intelligently accommodate the needs, preferences and skills of each user. There should be only a very short learning phase, not longer than a few minutes before even an inexperienced user can operate the essential functions of the software. He should feel confident almost instantly. The essential functions should give him a sufficient glimpse of the benefits which the software may bring him. More features may gradually appear, as his skills are growing. The user interface may also accommodate in other ways – if he is struggling with buttons, they may grow up a bit. There should not be a distinct separation between phases of learning, using, or setting. Combined, they should be part of the aggregate experience. The software should be growing like a plant in symbiosis with its user. The

pace of education of seniors should respect their individual capabilities, should be reasonably slow, clear, and visual (Rovný, Fižová, & Skalová, 2004); exactly the same recommendation applies to the user interface. The fact that motor, tactile and cognitive faculties, experiences with information technology and level of digital literacy vary within the group of seniors adds one more argument for user interface adaptiveness. The interface should support both slow and steep learning curve, starting with minimum functions, but adding more swiftly if the user wants them and if he is skilled enough.

The design ideas mentioned above harmonise with findings of Callejas and López-Cózar, who recommend making user interfaces for seniors non-intrusive, proactive, adaptive, customizable, friendly, easy-to-use, joyful and useful (Callejas & López-Cózar, 2009). Also, general recommendations for user interfaces, including Nielsen's famous usability heuristics¹³ (Nielsen, 1994) have a lot in common with our user interface ideas.

Regarding the choice of proper *modality*, studies such as (J. B. Lopes, 2001), (Apted et al., 2006), or (Torres, 2006) have revealed, that a tactile device is well suitable for people with impairments. So, we will implement the user interface primarily for a class of tactile devices, most likely for *tablets*. A study by Werner & Werner (2012) made us feel more confident about the decision. They assessed that the acceptance and usability of tablets may reduce the barriers for the elderly, mainly because of the non-technical look and feel of the touchscreen in comparison with other types of conventional devices. Beyond tablets, we may consider support for a wide range of interface modalities, from mobile and desktop integration (Counts & Fellheimer, 2004), IPTV (Fuchsberger, 2008), ambient appliances, such as screen at the kitchen wall (Evjemo et al., 2004), audio-based interfaces (which may promote feeling of closeness more than written word), from highly discrete, up to open audio zone (Evjemo et al., 2004), or multimodal interfaces (Salces, England, & Llewellyn-Jones, 2005). But we view these as a potential add-on, not a substitution to tablets.

While the previous ideas were applicable to any modality of a user interface, the following ideas are more related to the chosen primary modality – a tablet device with a touchscreen.

Static. Though dynamic sounds better, the interface intended for seniors should be mainly static. There should be no hidden parts, which appear only as a result of a user's action, such as context menus, portions of interface sliding from sides of the screen.

Self-explanatory. Everything should be clear as much as possible. For example, we should not rely on icons or other symbols except those, which are very familiar to people with no previous experience with any smart electronic devices. It does not mean, that symbols should be avoided entirely, but a textual caption or explanation should be shown or provided. We should use known metaphors, if possible. As inspiration, we may consider, e.g. a model for evaluation of metaphors from the perspective of user's cognitive and memory load introduced by Yousef (2001).

Unobtrusively assistive. Prioritize functionality and ease-of-use. Colours and other graphical features of the user interface should be used intentionally to help them to distinguish pieces of the interface, different concepts, and to remember how to use various functions. For example, green would always be used for a positive, and red for a negative answer. Consistency is important.

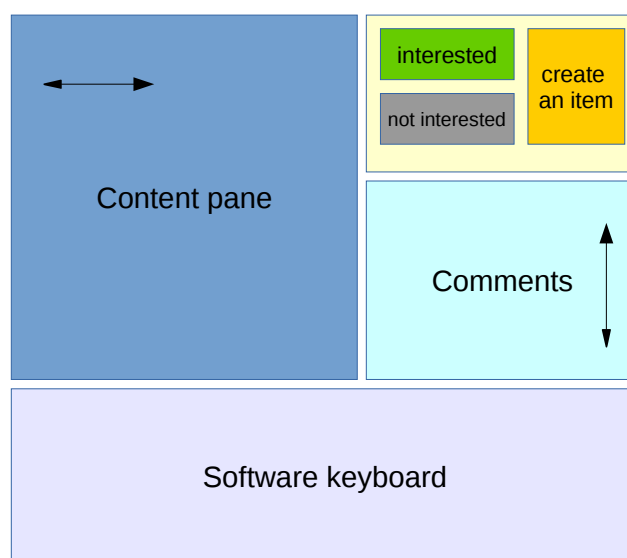


Figure 13: Preliminary layout of the user interface

13 Visibility of system status, the match between system and the real world, user control and freedom, consistency and standards, error prevention, recognition rather than recall, flexibility and efficiency of use, aesthetic and minimalist design, help users recognise, diagnose, and recover from errors, help and documentation.

Consistent. Interaction patterns should follow uniform scheme through the whole system (Vastenburg et al., 2008). In our case, control elements, such as buttons, should always be rendered in a similar, consistent way and no parts of the user interface should resemble control elements if they do not possess a control element function. The same control elements should always have the same or very similar function; contextual changes should be avoided, if possible.

Accessible. The touchscreen-based user interface should be easy-to-operate even for people with motor skill impairments. As (Cellan-Jones, 2015) points out, the response time for icons on an Apple screen is 0.7 seconds, but seniors have a response time of about one second, so using touchscreens may come naturally enough to a toddler but not necessarily for an older person. The nerves in fingers become less sensitive with age. So, even a touch may become a challenging task. If an older person has a slight tremor, it can be interpreted by the device as a swipe rather than a touch. As Chris Bignell quoted in the article says, these subtle issues may erode confidence and confuse. As an implication for our software, only basic strokes should be used. Probably nothing beyond a plain and simple touch. Before relying even on anything else, we should perform sufficient usability testing to evaluate, if it is not too discriminatory for some.

Generous. The user interface does not have to be concise. Unlike when targeting experienced and skilled users, the user interface of our software may use the available screen size generously. It is not necessary to fill every piece of the screen. Space on the display may be sacrificed if it helps to make the design easy-to-understand and easy-to-operate.

Guided. Washington in an extensive qualitative and quantitative analysis concludes, that older adults welcome instructions and tutorials for mobile devices. According to her, a mobile device tutorial would be a much-needed value-add enhancement to the older adult's well-being (Washington, 2015). A graphical wizard might be a good concept. A wizard guides users step-by-step to perform specific goal. Typically, it gathers user input in a series of simple questions. In our case, for example, to share or send a media to others, the user might be required to click 'interested' button first, since only an item a user is interested is likely to be intended for sending. Then a dialogue would appear asking “*Would you like to share the item with someone?*”, if the user agrees, “*Would you like to share it with your family?*”, then “*Would you like to share it with others?*”, etc. Similarly to create content, rather than providing several buttons for various content types, the user will click 'create', then the system will series of questions about the content type, purpose, etc. A good example of related research is a mixed static and video tutorial system that automatically generated step-by-step instructions from user demonstrations (Chi et al., 2012). Figure 13 provides a draft of a possible layout of the user interface.

5.2 CREATIVE AND USER-ORIENTED PRE-DEVELOPMENT METHODS

Before proceeding to the development of a prototype, to avoid taking a wrong direction and to maintain the focus on users needs and achieve a quality result, we combined several *creative* and *user-oriented* methods and techniques. We involved users since the very beginning, and we kept in touch with them during the development and the subsequent trial. More details follow on the lines below. We decided to cover the choice of methods and techniques and the results quite thoroughly in the text, because it serves as an example, how the principles of in-depth human-centric design (3.3) may be applied on a real-world software project.

Margolis suggests not to make usability testing excessively long; he advocates so-called *research sprint* which lasts only 4 days (Margolis, 2014). Such short user tests fit well into our preferred iterative development approach. Making things simple and less elaborate, it is possible to gather the necessary feedback as quickly as possible and move on with the development. With users directly involved, the risk that the project will go out of sync with their needs is reduced. The research sprint consists of five successive steps – 1. a set of questions and assumptions, 2. intentional and selective recruiting, 3. a realistic prototype, 4. five 1-on-1 interviews combining broad discovery questions with task-based evaluation of a prototype, 5. real-time summarization of findings. Researchers learn from facial expressions, gut reactions, and body language. They should ask follow-up questions and follow any interesting tangents. During the sessions, it is possible to identify critical patterns of behaviour, which may signalise bottlenecks or blind spots in the design. We did not apply the technique of research sprint directly, but indeed it has given us a valuable inspiration and confirmed our initial plan to prefer more iterations of quick, short and small tests

with potential to be directly and immediately reflected in a short development cycle. The pre-development steps with the involvement of user testing are covered in sections 5.2.2, 5.2.3. The whole chapter 6 is dedicated to the usability testing of the developed prototype.

5.2.1 COLLECTING IDEAS

Approximately 3 months of pre-development have been dedicated to collecting ideas (3.3.3). During this period, the work on the prototype was not our main priority, but we kept it on the mind as a near-future project. Anytime we came up with a relevant idea, we made a simple note on a piece of paper. Some ideas appeared as unexpected associations, other when we came across a source of inspiration. During the three months, we collected about two hundred of such notes, some in the form of just a few lines, other accompanied with simple sketches or diagrams. At the end of the period, we organised the notes into categories such as user interface, architecture, functions, algorithms, related research, etc. The records have proven as a useful source for the subsequent development phases.

5.2.2 WIREFRAMING

To create the mock-up which served as a working sample for the wireframing, we used draw.io (Draw.io, n.d.), a free and open web-based tool for creating diagrams and simple vector graphics which also provides collaboration functions via G Suite¹⁴ and Confluence / Jira¹⁵. The mock-up helped us to organise our thoughts about the overall layout of the user interface and also about the main functionality of the intended software. The mock-up covered in total 21 screens, interconnected with links to simulate transitions.

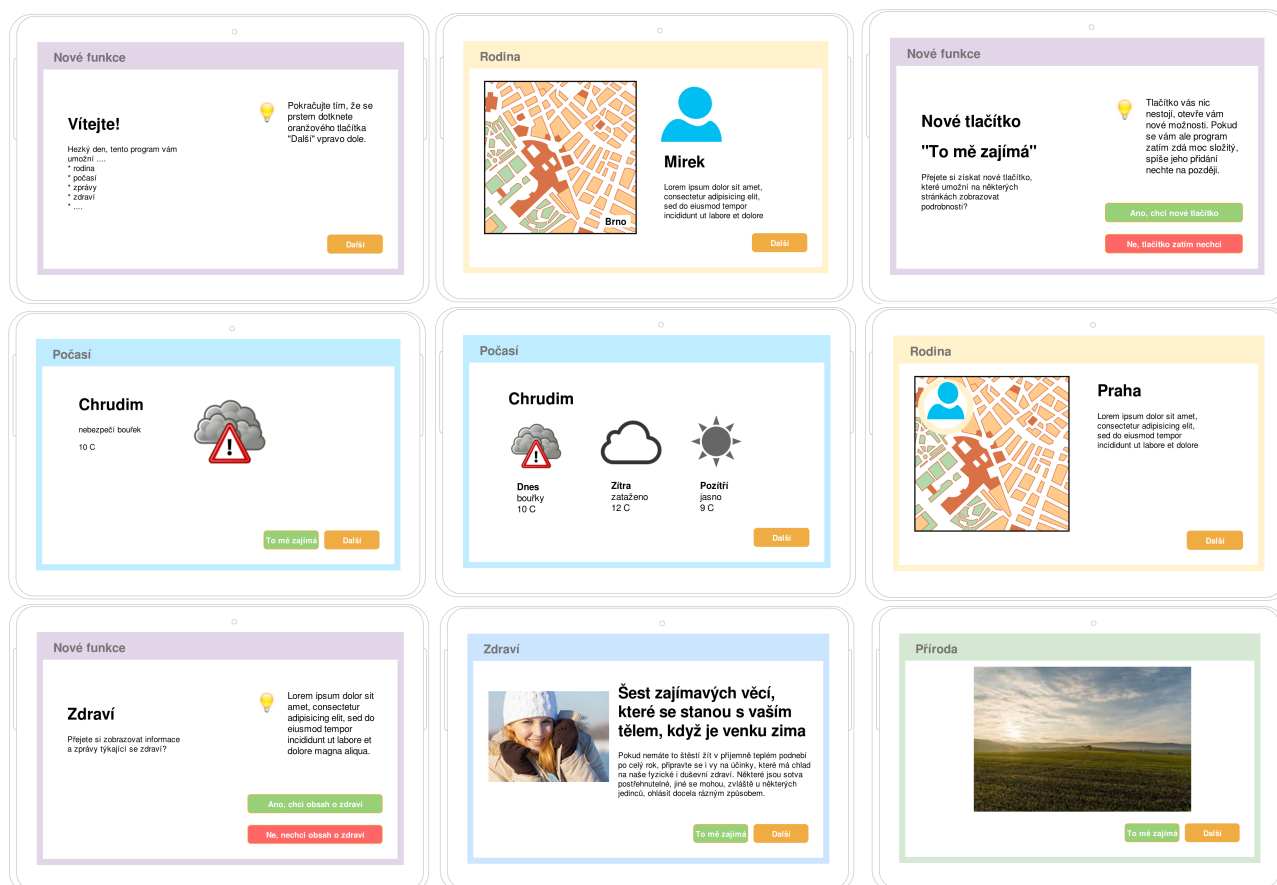


Figure 14: Example screens of the mock-up design¹⁶ (texts and other details not important)

- 14 G Suite is a brand of cloud computing, productivity and collaboration tools, software and products developed by Google (Google, n.d.-b).
- 15 Confluence and Jira are pieces of a team collaboration software product by Atlassian (Atlassian, n.d.).
- 16 The primary language of all participants involved in all stages of the prototype development as well as in the concluding

The figure Figure 14 shows some of them – a welcome screen, a screen simulating a message from a user with a supplied map showing user's location, screens with offers to add a new function, screens related to a weather forecast, a text in combination with an image and a photograph.

Participant selection. As a next step, we had to select people, whom we were going to offer participation in the development and the subsequent trial. Regarding the size of the testing group, Nielsen, based on years of experience and research (Nielsen & Landauer, 1993) recommends, that '*elaborate usability tests are a waste of resources. The best results come from testing no more than 5 users and running as many small tests as you can afford.*' (Nielsen, 2000) So, instead of involving a lot of people, we decided to keep the group rather small, but diverse to represent the variety of people from our target group. It involved either persons over 80 years old, and younger ones aged over 50, but affected by a chronic ailment which affects their cognitive capacity or skills. The diseases of the younger people in our group include multiple sclerosis, schizophrenia, and severe depression. The majority of people involved should preferably have no or very limited previous experience with smart electronic devices, but we wanted to involve also some with limited experience, so we could benefit from their comparison of our software with what they know or what they have tried in the past. Our goal was also to involve people from different backgrounds, living either in a city and a rural area, alone or sharing a household with a family member. To identify candidates, we used our social links of friends and acquaintances. When we identified a person fitting into the criteria, we told him, that we were working on a novel program which would make access to the Internet resources much easier and that we would welcome his participation on testing. Anonymized profiles of participants and information about their involvement are covered in chapter 6.

5.2.3 A FOCUS GROUP

Though we eventually involved ten people in the usability testing, three participated on the initial kick-up focus group¹⁷. From those invited to the focus group, nobody has refused. We gathered them in a room with a screen mounted on the wall. First, we introduced ourselves and briefly summarised the idea of a new program and its key features. Then we let each participant to introduce himself and to mention his previous experiences with technical devices and what he thinks, likes or hates about the modern smart devices. Then we presented the mock-up on the big screen and discussed the meaning of each page, the purpose of parts of the user interface layout. For example, we asked, "*what would you do if you wanted to see another content?*". We consulted the overall design, clarity of instructions, size of elements. Significant details about the experiences and the background of each of the participants are summarised in chapter 6 which contains profiles of all involved participants. The session was about two hours long. As the primary result from the focus group session, we gathered a list of ideas. *User interface and function ideas* were the following:

- *Bigger controls.* Participants easily identified the purpose of buttons in the mock-up, but they found the buttons and their captions too small. They summarily agreed that they would not have a problem operating them, but to make the interface more pleasant, and also with more visually impaired persons on the mind, it would be better to increase the size. Maybe shorter captions would suffice, but the font has to be easily legible without any struggles. Size of buttons might be proportional to their importance, for example, 'next' button should be quite big, whereas 'previous' or 'like' might be smaller.
- *Familiar language.* Though the participants did not find any appalling examples in the mock-up, they stressed, that the program should use simple sentences and avoid any weird words. They found a word "content" used on the mock-up quite ambiguous, meaningless or even misleading for some. It evokes something like an outline or table of contents, not the displayed item itself.
- *Forgiving.* One participant asked what would happen if he presses something else than a button. We wondered what would he prefer to happen. Participants then agreed, that in such case, nothing should happen, but, perhaps if the press attempt is repeated, the program should gently and politely suggest what to do next.

usability test was Czech. That's why are the texts in figures often in this language.

17 Because they were also involved in the follow-up usability testing together with five more persons, the personal profiles of all are in the section 6.2.1.

- *Tutorials.* Though they found the user interface simple and easy to learn, they agree on an idea that an introductory tutorial which would introduce the functions and the purpose of the program would be useful. Also, whenever a new feature is introduced, it should be preceded with simple and clear instructions, so the user won't have to seek support.
- *Statements and questions.* A discussion about the proper formulation of questions, comments and button captions arose. There was no general agreement among the participants about variants such as “*The program will ask you ...*” or “*I will ask you ...*” or “*We will ask you ...*”, or about “*Do you like pictures of nature?*” combined with 'yes'/'no' vs “*Pictures of nature*” combined with 'like'/'do not like' vs “*I like pictures of nature*”/“*I don't like pictures of nature*”.

Besides the function ideas, the participants came up with few tips about the *content* they would consider useful. Their input regarding the content was relatively limited. In general, they said they can't really imagine the potential or the possibilities of the software yet. We tried to help them think about their habits – what they usually do in the morning or during the day, where they go, what interests them, etc. It helped to establish a more creative environment.

- They praised the idea shown in the mock-up to involve useful tips regarding *health*.
- One participant mentioned that she likes experimenting with new *cooking recipes* – she, for example, watches related TV shows or even buys a printed magazine because of a small cookbook which is provided as its attachment. So, maybe she would welcome exciting recipes.
- One participant mentioned that she loves cats and always likes seeing them. So, the program might show pictures of *pets* and other pleasantly looking animals.
- One participant is interested in *sales* offered by food chains. Sometimes she visits several stores to compare prices. It makes her feel good if she knows she made a good purchase. So, the program might be able to tell for example, where they sell a well-priced butter. But she could not assess if something like that is even possible.
- One mentioned, that sometimes it happens, that in the morning she does not know what is the date today. So, perhaps, the first content displayed in the morning could be a page with the *date and time*. A weather forecast might accompany it.

At the end of the session, we let the participants try several variants of a software keyboard on a tablet. We could see clearly, that none of them works satisfyingly. Though all were eventually able to type a snippet of text, it was definitely not a pleasant experience for those were doing it for the first time. They felt ashamed, and it even put their willingness to continue in participating in risk – some stated, that maybe 'it is not really for them'. Eventually, the session in a positive discussion and all agreed to continue. But the bad impression the software keyboard made on the participants made us think to *avoid text input* altogether, at least in the set of essential functions.

5.2.4 BRAINSTORMING WITH VOLUNTEERS

As soon as we summarised the findings from the focus group, as a next creative step, we arranged a brainstorming session with another group of volunteers. This time, five people in productive age were involved. It included an information systems developer, an officer in the area of social care, a senior pre-development designer in the automotive industry, a language teacher and tutor, and an accountant from the field of construction with mechanical engineering educational background. They preferred to be involved anonymously. To save the time during the brainstorming session, we provided the participants with the initial design ideas (4.3) in the version which was available at the time, a functional link to the mock-up, and the summary from the focus group (5.2.3) in advance.

The goal was to benefit from the variety of different views and experiences. The session was about an hour long. The revealed ideas follow. Because the session opened up a lot of topics, we present them in a concise form. Some of the listed ideas were not a direct result of the brainstorming, but appeared in close relation to the brainstorming session, for example, when we were summarising the brainstorming results.

User interface ideas:

- If a user presses an inactive part of the interface, there should be clear feedback from the system about the attempt – e.g. a text “press the button” appears, highlight goes on the action pane, content pane fades.
- Buttons might be enhanced with icons. But we would have to consult relevant research or do our own to decide how exactly to do it not to make things worse.
- Because the textual input is troublesome, as revealed by the focus group, we might consider voice input. E.g. a voice message to comment a content provided by a relative. The voice input might also be combined with speech recognition.
- Proper placement of buttons – distinguish between system actions and content actions. System actions should be those which are displayed for all or almost all content types and should be placed in a pane separated from the content. Content actions should be placed within the content pane.
- There might be status information, such as the current date and time, displayed somewhere.

Function ideas:

- Privacy concerns for and of users whose location and other personal data would be gathered and processed.
- How will the system be able to connect with the family, perhaps via an authorising SMS?
- If there is no more content available, the program might recycle the materials shown in the past.
- Consider various strategies on how to decide which content to provide. The user might be either asked whether he is interested in, e.g. health-related materials prior offering relevant items, or just try to serve a sample and then decide based on his 'like'/'dislike' feedback.
- From the knowledge about content preferences, the program might assess not only which content to offer next but also adjust functions and interface. For such an algorithm, we would need relevant data as some correlation between skills, behaviour patterns, and interests. Either it may come from an outer source, or we may try to generate our own. A large user base would be needed.
- Keep it simple. For example, the 'previous' action from the mock-up is not essential, should be offered instead to the more advanced users.
- As soon as the system learns about the interests of users (and, perhaps, also about their position), it might start offering interaction focused on the shared interests.
- Some functions might depend on the availability of location data of either the user or his relatives. The dependence of various function on the availability of the location data should be further analysed. Examples of features depending on location are weather forecast, location-related tweets or pictures, maps, nearby point of interest.
- It would be practical to have screen-sharing support or another way to access and manage a device running the viewer remotely. It could be used by either a family member or a dedicated technical assistant.
- Make an input from family members and friends easy. For example, if a relative likes a content and wishes to share it with the user, he chooses a relevant “share to” action on his smartphone.

Content ideas:

- Short textual content, such as tweets from the city hall where the user is living.
- Provide a bit of fun – games, crosswords, sudoku. Should be evaluated.

- Name-day¹⁸, a page with a simple message “today it is a day of <a name>” + provide some details about the name origin or some famous persons bearing the name.
- If we have access to the data about names and birthdays of people from user's circle, we might notify him, probably a day ahead.
- “Kalendarium¹⁹” notable events from the past which happened at the same calendar date, but on a different year. As a source of data, it might use, for example, Wikipedia or 'Slavné dny' series at stream.cz.
- Spiritually uplifting type of content, such as the Bible.
- Novel or a poem, either in textual form or as an audiobook.
- Quotes of famous people, maybe in connection with the “kalendárium” idea. Sayings, fragments of culturally relevant ancestral wisdom.
- Family photo album. It could be connected, e.g. to a cloud photo sharing service.
- A multi-page content. It might refer to the phenomenon of PPV presentations shared among the elderly via email mentioned in 4.2. Regarding the implications for the user interface and how the navigation is implemented, for example, if a user clicks 'like' on the introductory page of a multi-page content, the pages of the whole multi-page set would be displayed one-by-one on his subsequent 'next' clicks.

5.2.5 A GAME SESSION

To evaluate, at least quickly, whether the idea of involving games, which appeared during the brainstorming, might be viable, we invited one of our participants, 82 years old Ludmila who never played any computer game, to try various touchscreen-based games on a tablet. Though she needed a substantive amount of instruction from us and more time to practice, she was able to handle interface of several games, and at the latter part of the session, she was doing quite well in few of them. In the end, she concluded that she enjoyed the experience, and she could imagine spending a couple of minutes a day playing a game. Observing her, we also noticed the potential of games in training users how to manage the touchscreen user interface, especially some of the strokes beyond the simple touch, in a pleasant way.

Our finding is in harmony with a study performed by Heart & Kalderon (2013), who conclude, that there is indeed a fraction of seniors who play computer games, such as chess or solitaire. So, seniors may like computer games. However, as the authors conclude, probably the most frequent use of computers among seniors is e-mailing and writing documents. A concept of now-popular *gamification* pioneered, e.g. by Huang & Soman (2013), might be evaluated in the context of the intended software. Presenting selected functions of the application as a game might help users to overcome some of the barriers of adoption (related to the idea of the appropriation, refer to 3.3.1), such as lack of self-confidence, lack of interest, shyness, and hesitations. The early results look promising, so we will likely evaluate them more as a part of subsequent research in the future.

5.3 GENERAL DEVELOPMENT AND ARCHITECTURAL CHOICES

With what we call a *functional prototype* we went even further beyond what a prototype in Warfel's (2009) definition does and which purposes it serves. We wanted to test not only the user interface but also the functional blocks and the overall architecture so that we could make more robust conclusions about the real potentiality of the proposed software. This section provides an introduction to the development part of the applied research stage covered by the thesis. We will briefly name fundamental software design principles and techniques we have used, introduce the overall architecture of the system as a whole, and explain, on which technologies we have decided to found the system and why. Further details about the systems

18 Each day of the year in the Czech calendar has a name (or several names) assigned and there is a tradition to celebrate bearers of a particular name in the day set by the calendar. The celebration is called 'jmeniny' or 'svátek' in the Czech language.

19 In reference to once a relatively popular program broadcasted by the Czech public TV.

architecture, its functions and how have they been implemented are in the appendices 11, 12, and 13. We also provide reasons for various decisions we have to take during the development. The detailed description of the prototype and the development process, though put into appendices, are one of the important contributions of the thesis. They show, how the proposed inclusive social software might be developed, present innovative and creative solutions for various technical problems and allow follow-up research. The text presents not just the state of the system used for the experiments, but also various potential future improvements.

5.3.1 OPEN TECHNOLOGIES

The system we are proposing should not depend on any proprietary technology, if possible. It should stick to the standards and proven design practices. Making the system dependent on closed technologies, we might undermine its application potential. If we wished to make an exhaustive list of all systems, tools, and technologies involved, we would definitely miss something. So, instead we just summarise those which we perceive as particularly important, some others are discussed in the respective sections of the following chapters.

We have developed most of the system using *Eclipse* environment with *PyDev* extension for Python language support and *Mercurial* add-on for version management, running on a *Debian GNU/Linux* desktop. For testing and debugging of the client part of the system we used mainly *Chrome* browser and its developer tools, but because we wish to make the client part platform and browser independent, we also tested in *Firefox* using its development tools. Desktop versions of both browsers were used for testing a content rendered by themselves, but also for testing a content rendered by the mobile version of the same browser on a sample of a target client tablet. A MySQL database provides persistence to the system, but it has been implemented in a database-agnostic manner, so a shift to a different database system won't require significant changes in the source codes. For deployment, we used web server *Apache*. A decision regarding the dependence on available technologies which have influenced the architecture of the whole system more than any else was the choice of an application framework.

5.3.1.1 THE APPLICATION FRAMEWORK

We decided to build most of the project on top of *Web2py*, Python-based web framework created by a community of developers lead by Di Pierro (2014) from DePaul University. We implemented several information systems based on the system so far which have been deployed in production use during past several years, which puts us in a good position to assess the functions, parameters and quality of the framework in the context of the intended prototype of the proposed system. In the following paragraphs, we present selected Web2py features and key attributes.

It is *platform agnostic*. It runs on Windows, Mac, Unix/Linux, Google App Engine, Amazon EC2, and almost any web hosting via Python 2.7/3.5/3.6/pypy. It may be deployed behind Apache, Nginx, Lighttpd, Cherokee and virtually any other web server via CGI, FastCGI, WSGI, mod_proxy, or mod_python. It can further embed third-party WSGI apps and middleware. As a storage provider, it supports SQLite, PostgreSQL, MySQL, MSSQL, FireBird, Sybase, Oracle, IBM DB2, Informix, Ingres, MongoDB, and Google App Engine. The framework further *speaks multiple protocols* which include HTML/XML, RSS/ATOM, RTF, PDF, JSON, AJAX, XML-RPC, CSV, REST, WIKI, Flash/AMF, and Linked Data (RDF).

As a framework which started as a university teaching tool to help IT students gain *good software engineering practices*, such as Model-View-Controller design or Server-side form validation, it helps to produce a code which is readable, scalable, and maintainable. On the other hand, it *does not force developers to overkill*, as some other platforms tend to. For example, it does not use an object-relational bridge, which would force developers to apply object-oriented design in all cases, but just an easy-to-use data abstraction layer. Each developer may decide whether, when and how to map his objects into the underlying database. It has been designed with *security* on the mind, so it prevents the most common types of vulnerabilities including Cross Site Scripting, Injection Flaws, and Malicious File Execution.

To *jump-start development*, it includes an SSL-enabled and streaming-capable web server, a file-based relational database, a web-based integrated development environment, web-based management interface and scaffolding application. The *batteries included*, such as internationalization support, multiple authentication

methods, role-based access control, an error logging and ticketing system, various caching methods for scalability, the jQuery library for AJAX and effects, streamline and simplify the development; so it is possible to concentrate the efforts on the core functionality of the system which is being developed.

Before deciding for Web2py, we considered several other options including popular frameworks such as node.js, Django, or Ruby on Rails. Some of the frameworks also provide great functions and vibrant communities of developers. Among the reasons which let us decide in favour of Web2py is the *python language*. E.g. according to Garey and Lang (2008), Python is an excellent choice for high productivity, high-performance application development because of its ease-of-use syntax and high quality comprehensive standard libraries. We may testify on this; Python allows development using rapid prototyping techniques in short development cycles.

According to its web page, Web2py is less verbose than Java-based frameworks and its syntax is cleaner than PHP-based frameworks, which makes applications simpler to develop, and easier to read and maintain. Actually, Web2py is *inspired by* several good-quality frameworks, including Ruby on Rails and Django. As we experienced in the past, maintaining a system which is based on an ever-changing framework may be difficult, increase downtime and maintenance costs, etc. In the light of these experiences, the fact that Web2py is always *backwards compatible* since its inception in 2007, which is unique among the competition, contributed to our decision.

5.3.2 KEY PRINCIPLES AND THE ARCHITECTURE OVERVIEW

We wanted to design the system as extensible, modular, but working in a well-orchestrated manner. To do so, we applied common good design principles, such as object-oriented design, and separation of MVC layers. We were also careful when it came to the dependence on any external libraries, which might limit the application potential of the resulting system or affect its performance. For example, if we needed just a one or few functions from a big library, we usually preferred to implement our own lightweight library instead. To fulfil the primary functional purpose of the system, we had to reuse or integrate various available services. But doing so, we always put reasonable layers of separation between the service and the core of our system to make future changes as painless as possible.

Figure 15 provides an overview of the architecture of the system as a whole. It is evident from the picture that the most significant part of the system is its *back end*. There the vast majority of functions and logic are implemented. The back end breaks into several components. Individual content providers are responsible for pulling content from various online sources. They also transform the data into a form, which can be further processed by the system core. The system core may call various supplementary services to provide functions such as automatic translation or semantic recognition. It also stores the data in the relational database. Towards the clients, the back end offers its services via an API. The API talks in XML and besides else serves the contents prepared by individual content providers.

The *default front end* is also implemented as a server. It communicates with the back end via the back-end API and is responsible for presenting the content to the user. It also facilitates the communication between the user and the back end. The last part of the system is running directly in client's browser.

The architecture has been designed as *multi-tiered* to make the system extensible, scalable and more manageable. Because of the complex architecture and the level of extendability, we call neither the software proposal, nor the developed prototype an application²⁰, but rather a *software* or a *system*. The term *software platform* would also be appropriate.

20 Though we do not call the whole system an application, the word application may be used in specific contexts. For example, both back end and front end are Web2py applications, which refers to a program which is developed to be executed in the Web2py running environment. Also, the part of the front end code which is developed to be executed in a browser is correctly referred to as a progressive web application. It contrasts with an idea of a front end developed as a native application for a mobile operating system, such as Android or iOS. Though the term 'application' is in these contexts suitable for parts of the system, in particular when referring to the system as a whole, we refrain from using it.

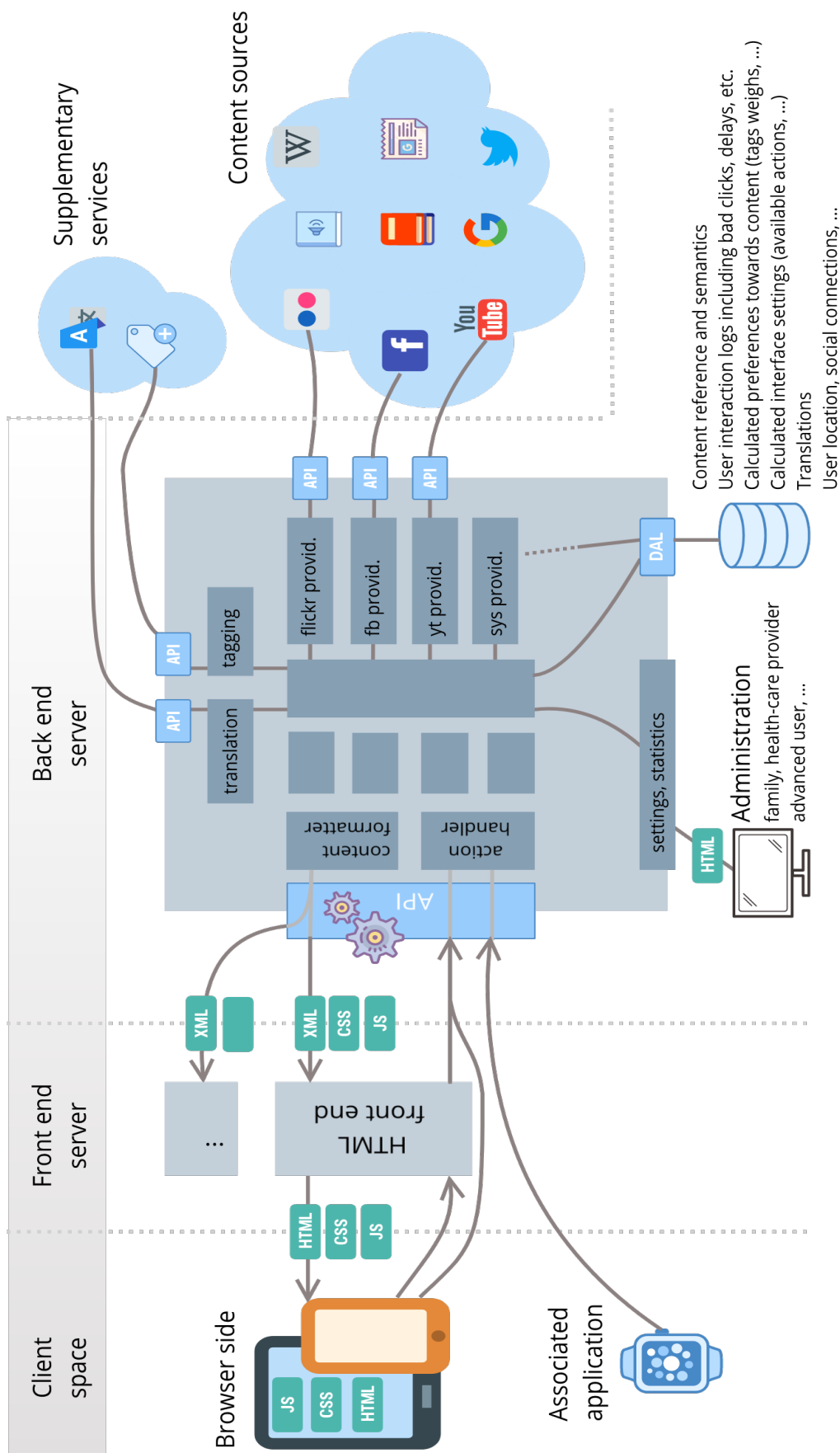


Figure 15: Overall architecture of the proposed system

6 IN-DEPTH USABILITY TESTING WITH THE PROTOTYPE

The purpose of involvement of volunteer participants was to *improve the quality of our proposal* of new software which would harmonise with the needs of the elderly and to *evaluate the prototype* which has been developed according to the proposal²¹. We also wanted to *experimentally apply the methods* from the in-depth human-centric design toolbox suggested in 3.3.3. Besides this we were also interested in evaluating some of our previous findings regarding the *consumers' behaviour and needs of the elderly*, thus contribute back to the basic research. Specifically, we were interested whether the trial would help to confirm the assumption, that seniors should not be treated as a homogeneous group by engineers and product designers. Involvement of volunteer users started in the pre-development with the focus group (5.2.3) and the game session (5.2.5). Finally, we applied the in-depth usability testing method to gather feedback about the developed prototype which is covered in this chapter. During the test, we wanted to let users reflect on functions, user interface, served content and also the whole concept demonstrated by the prototype. As suggested by the in-depth usability testing method, we focused primarily on *qualitative research* based on *moderated interviews and observation*. As an additional input, we used the hard *data automatically gathered by the system* during the trial from user's interactions.

6.1 THE TEST PREPARATION AND STRUCTURE

Participants. In accordance with the former delimitation of the target group (refer to 4.1), only individuals older than 50 years who retired from any full-time job, were facing age-related physical and/or cognitive decline, but have not yet reached the “real old age” (Rubin, 2007), identified by a sharp decline in both mental and physical abilities (Degnen, 2007) were chosen. Following Nielsen's recommendations (2000), the sample size was kept small, which allowed to use fully evaluate the potential of the in-depth human-centric usability testing method, treating each participant as a unique individual. Selection of participants chronologically fell into the pre-development stage, so it has been explained in section 5.2.2. From the invited people one refused our offer and one, though willing to participate, eventually was not able to because of lack of support for the idea from her relatives who live in a shared household. Details about the two are at the end of section 6.2.

6.1.1 RESEARCH QUESTIONS

Three research questions were formulated:

Question 1: Can even seniors with limited or almost missing previous experience with any digital technology start using inclusive social software, supporting them with only a minimal level of assistance?

(The question evaluates, whether the recommendations regarding the simplicity and adaptability of user interface make a product easy-to-use, as expected.)

Question 2: Is the inclusive social software concept as prototypically implemented subjectively beneficial for seniors?

(The purpose of the question is to assess the potential of the newly introduced concept of inclusive social software.)

Question 3: Which implications for further development of an inclusive social software (and, perhaps, for senior-friendly software in general) can be derived by in-depth human-centric usability testing and how such testing may further understanding of seniors' needs and limitations?

(The question leads to an evaluation of in-depth human-centric usability testing method itself. In addition, a better understanding of seniors leading to recommendations regarding senior-friendly product design and development are expected, based on the analysis of users' learning curve, the intensity of their interactions in time, their problem-solving strategies, etc.)

21 The relevant analysis and development are covered by chapters 4 to 13.

The research may lead to the formulation of follow-up hypotheses concerning a specific subgroup of the elderly or the elderly in general.

Falsifiability. To allow other researchers evaluate the results of the trial (Popper, 1959) we provided a substantive amount of information regarding the prototype development (appendices 11, and 12), its deployment and preparation of client testing devices (appendix 13), and the trial organisation (the following sections below).

6.1.2 STRUCTURE OF ENTRY MEET-UPS WITH PARTICIPANTS

We designed the entry meet-up to take approximately 45 minutes²². We did not force any limit because we wanted to keep the friendly atmosphere. The outline of steps is below.

1. *Informal dialogue.* Ask polite and friendly questions, establish a relationship, get a broad insight into the person's needs, interests and limitations. (about 15 minutes)
2. *Semi-structured interview.* Gather the demographic and socio-demographic data. Ask about health, family, experiences with digital technology. Ask for self-assessment of skills towards the technology. Ask the participant likes or dislikes about technology. It is possible to ask for example, about Google, Facebook, Twitter, and Instagram. It should be done in a way which won't make the participant feel intimidated. If he has heard them, follow-up questions may be asked, such as '*What do you think about them?*', '*How do you feel about them?*' Information about his habits towards media should be gathered too. Relevant questions such as: '*Do you watch TV?*', '*Do you read news or newspapers?*', '*Do you listen to the radio?*'. And deeper questions such as '*Why?*', '*What do you like or dislike about ...?*' or '*How do you feel about ...?*' (about 15 minutes)
3. *Prototype introduction.* Tell quickly about the purpose of the application and demonstrate on a separate device. Ask for immediate impressions and assessment. (about 3 minutes)
4. *Instructions.* Hand the participant his testing device²³. It may also be useful to accompany the device with a sheet of paper or a small notebook where the participant may make any notes about his experience. Instruct how to charge the tablet, how to turn the display on and off, how to turn the tablet if its battery gets drained. (about 4 minutes)
5. Let the participant try the software. Answer any questions. (about 5 minutes)
6. Instruct where to reach for assistance, if needed. Arrange for the concluding meet-up. Thank for the willingness to participate. (about 3 minutes).

During the session it is possible to make notes, but not in an excessive manner which would erode the friendly atmosphere. Make a short report about the meet-up. Focus mainly on the necessary input data (refer to the section below) and any other interesting findings and observations which might help to understand the participant's personality and his circumstances. The length of the report may differ, based on the amount of relevant information gathered from each participant.

6.1.3 DATA FROM SEMI-STRUCTURED INTERVIEWS

We focused on gathering the following data from the trial:

Participants' profiles. We acquired essential *socio-demographic variables* about participants, such as age, marital status, and gender. All participants were Czech residents. We were also interested in their *health*, and the situation in their *family*. For example, if they were living in a shared household with someone, we wished to know whether they were in good terms with their relatives, if they have *friends* outside the family and if so, how many and how close the friendships are. Regarding *habits*, wished to know for example, if they are used to watching TV, listening to a radio, reading books and which genres interest them. Also, in which degree are they interested in news and how broad their *horizon of interests* is.

²² In most cases, it was just about the time or with talkative participants slightly longer.

²³ Though it was not our initial plan, after one of the first experiences (6.2.1.2) we have decided to start giving the participants also a touch pen.

Participants' experience. We gathered information about the main area of their previous occupation. We also wanted to know which electronic devices they use or at least have tried. Specifically, we were interested in the categories of devices such as mobile phones, computers, tablets. Regarding mobile phones, we made a difference between devices with an operating system, smart mobile phones, mobile phones with hardware buttons (“dumb” mobile phones), mobile phones with a touchscreen.

In harmony with the in-depth usability testing, we did not fill-in structured questionnaires with participants to gather the information. Instead, we preferred the form of semi-structured interviews. Most of the inputs have been gathered during the initial entry interviews, but subsequent visits often allowed to reveal more details. If a person did not feel to disclose a particular piece of information, we did not force him in any way. The participants were told, that within days they will be asked to assess their experience with the prototype. Namely, that we were interested in the following:

Assessment of functions. We wished to know, if the user interface is perceived as clear, intuitive, not putting an unnecessary cognitive load on users. It may relate to the overall layout, control elements, captions, font sizes, colours, etc. Especially we were interested if the user interface will make any of our participants stuck in a particular situation, not able to move forward or to perform the intended action. In the final assessment meeting with each of the participants, we asked explicitly about their likes and dislikes towards the contents.

Assessment of content. We equipped the prototype with content providers able to serve users with videos, images and audiobooks. Besides this, the Main System Provider was designed to guide users and gradually open new functions. We wished to get feedback also about this concept.

Feelings. As an essential in-depth human-centric design principle, we were interested in users feelings at times when they were using the prototype and after. So, a survey provider was there to collect basic feedback about their momentary feelings once a day. And mainly, we asked relevant questions in the final assessment meeting with each of them.

Suggestions. We were also very much willing to listen to any further tips and ideas regarding the prototype.

6.1.4 SOFTWARE-PARTICIPANT INTERACTION DATA AND FROM SUPPORT CASES

Automatically collected data. Between the entry meet-up and assessment meet-up with each of the participants, data has been collected automatically by the system. It includes:

- The history of contents served to the participant (the content queue).
- Every touch on the screen, either correct leading to action understood by the system or wrong when the user touches an inactive part of the interface with no control element, together with screen coordinates.
- His 'like' and 'despise' toward content objects.
- Daily self-assessment of the immediate feeling (via the Survey Provider 11.2.12). The question was “How are you feeling now?” and it was asked once in the morning and once in the afternoon each day.
- All media events²⁴, together with the position in the playback.

All the data above also has an exact timestamp assigned. We did not record the history of changes in the user's like and dislike values for individual tags²⁵ because we did not have any plan to use this data. So, these values were simply updated any time user clicked 'like' or 'dislike'. Furthermore, the database contains all the data necessary to reconstruct the history, if needed.

Quick implementation. Anytime we received feedback from participants which indicated that we should make a change to the system's functions, we made such an update immediately if possible. This short development cycle was part of our iterative approach to the development (5.3.2).

24 Such as volume-up, volume-down, pausing, resuming. Also finishing the playback is considered as an action.

25 User's like, and dislike values are calculated and stored for tags to represent his preferences. Refer to 11.7 for more details.

Support cases. We were ready to provide any support needed. It involved even repeated visits at some participants and one support call. Each support event has been recorded. It was important to record the support cases also because the support is one of the external forces which may affect the appropriation process, as explained in the relevant chapter (3).

6.1.5 ASSESSMENT MEET-UPS WITH PARTICIPANTS

We designed the concluding assessment meet up to take approximately 30 minutes²⁶. The outline of steps is below.

1. *Informal dialogue.* Mainly to establish friendly and cooperative atmosphere. (about 8 minutes)
2. *Semi-structured interview.* Ask the following questions, but avoid to sound too formal. The interview shall be blended with an open discussion about the participant's experience and impressions. Try not to interrupt participant if he is not answering directly, talking about something else, or if he is asking his own questions. Use easy-to-understand terms, avoid technical jargon. (about 20 minutes)
 - *What did you like about the functions?*
 - *What did you dislike about the functions?*
 - *What did you like about the contents?*
 - *What did you dislike about the contents?*
 - *How did the sessions with the program affect your mood? How were you feeling when you were using the program or after?*
 - *Do you have any suggestions or ideas about the program, such as what should be improved, added, or removed?*
3. At the end ask the participant if he would like to keep the testing device for an undefined time and continue using the program or if he would like to participate in a subsequent trial if there is any. Finally, thank and say goodbye – at least for now. (about 2 minutes)

6.2 THE COURSE OF THE TEST AND THE RESULTING DATA

We present the data about and from participants in the following sections. The participants were involved not all at the same time, but gradually in the same order as we present them. Because the trial deals with sensitive personal data, we do not use participants' full names. Each participant is listed by his first name²⁷ and his real age.

6.2.1 ACTIVE PARTICIPANTS

We invited 12 persons to participate, for practical reasons all of them living in a 15 km range from Chrudim city in the Czech Republic, from where the trial was organized. To reach the participants, existing social links of researchers were used (neighbours, acquaintances, friends of relatives, etc.). Eventually, 10 persons aged from 53 to 93 participated actively. In two cases (6.2.1.5 and 6.2.1.6) the participants were sharing a household and using the program together. As the first information about each participant, we provide a brief profile. Details about meet-ups and support cases follow. And we conclude with the assessment meet-up and summary of interaction data collected during the trial in the structure functions, content, feelings, suggestions. Two invited persons were eventually either not willing or not able to actively participate. The reasons are explained together with their profiles in the following section 6.2.2.

²⁶ In real, the meet-ups were from about 30 minutes to about 1 hour long.

²⁷ To adequately protect participants privacy even some first names have been changed.

6.2.1.1 Iva, 57

Health. She is on the full disability pension with multiple sclerosis which mainly limits her mobility to a degree she can't walk for more than a few hundred meters and falls often, causes fatigue, frequent head pains, worsened vision. She is also treated for moderate depression and osteoporosis.

Life and the family. She lives in a city, in a family house with her two adult sons. We could observe, that they all have mutually strong bonds and that they treat each other with respect.²⁸

Experience. In the past, she worked as an accountant and used a computer at work, where she gained average computer literacy skills, mainly related to the office and secretarial work. Now and more than for three years she no longer uses a computer. But has her own tablet which she likes and regularly uses to access digital content. She likes reading books on the tablet – though it is a bit heavy and not so easy to be held for a longer time, she appreciates the backlight which allows her to read at night without a light turned on. She also likes that she may adjust the font size. It makes it more comfortable than a printed book. She is also used to watching videos, reading news almost daily. As a relaxation she solves Sudoku. She likes breaking her own records in solving the hardest variants. Sudoku helps her to detach her mind from her problems temporarily. She neither watches TV nor listens to the radio.

She was one of the persons who also participated in the kick-off focus group (5.2.3).

The entry visit. Upon seeing the prototype, Iva commended the interface and also the whole idea. Since the beginning, she had no struggle operating it²⁹. She said, for herself, what matters more is the quality and relevance of the content than the user interface. She also prefers a more interactive way of using the Internet. But she will try using the program time-to-time.

Functions

- In general, she finds the interface pleasant and very easy to operate.
- For a newly served content, the program always sets the volume to the maximum level. She would prefer if the program could remember the last volume level and set it automatically for any future content.
- It happened to her sometimes that, probably as a result of multiple sclerosis, her finger inadvertently fell on the display, causing an action being triggered. Because she often hovered her finger over 'next' button, it usually led to the loading of the following content in the queue. She would appreciate having means to go back to reverse the inadvertent action.

Content

- Regarding types of content she likes videos the most – actually, after a few days she disabled the picture content, so only videos were served after that.
- During the time she gradually trained the program with her likes and dislikes, so it has learned her preferences about content. So, now it serves the kind of material she likes – documentaries, soothing videos about nature, artistic videos, or pleasant relaxing music.
- Though in general, she liked the content, once it happened that a documentary about how coffins are manufactured in the US and how mummification is still applied in the modern age was served. She found the topic awkward and also not suitable for aged users.

Feelings

- Sometimes she has a problem with sleeping. In such cases, she sticks to reading or solving sudoku. But she also liked the program, because she could entertain herself effortlessly, just pressing the 'next' button. Eventually, she liked it more than what she expected.

28 Maybe even to the point, that the sons do not hurry to found their own families. But it would be a topic for different research.

29 It is not a surprise because she is the most experienced user among the participants. That's also the reason why we scheduled her as a first person in the usability testing, so she could help to reveal any potential glitches which might stumble other, less experienced participants.

- Also, she commended the program in connection with moments when she is feeling exhausted or emotionally down. In the past, on such occasions, she was just sitting and staring out of a window or plainly not doing anything. Now when she gets into this mood, she tends to grab her tablet and launch our program. Because she is feeling cognitively depleted in these moments, the simple interaction involving only the 'next' button suits her, and she likes that it does not include making any decisions.
- But at other times, when she feels better, she returns to consuming online content more interactively.

Suggestions

- She recommends a morning welcome invitation with the date and time with a weather forecast. It should be formulated in a natural language rather than in the conventional structured format of a weather forecast.
- If a user goes through a long series of contents, there might be a screen with a question related to his well-being, such as *'Do you remember to drink properly?'*, *'Would you like to stretch your body a bit?'*, *'What about a short exercise with your hands?'*, or *'If your eyes are sore, don't forget to blink.'*
- If a user navigates to the next content, he might have an option whether to resume the playback of the current content later. It should be resumed on a future occasion if he clicked 'like' and it should not be resumed if he clicked 'despise'. About the playable content which user did not rate she is not sure how to decide, variants should be evaluated.
- She recommends a function which would allow recalling particular content, for example, to show it to someone. Maybe, if a person clicks 'like', another button might appear with a label 'again', which would add the liked item to a list of favourites.

Other comments

- She has noticed on herself that the 'next' button may support impatience and even become a source of addiction. She related the following hypothetical situation. A user is listening to a music video which he likes, but he is not paying real attention because his mind is already figuratively wandering around the following content in line. So he clicks the button, interrupting the playback in the middle.

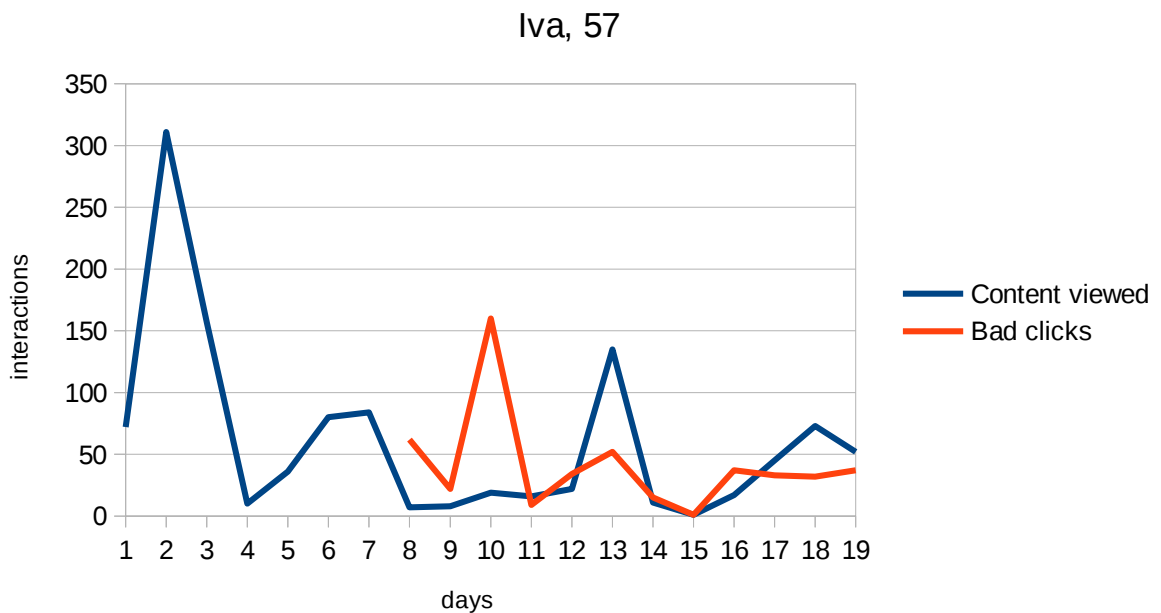


Figure 16: Interaction frequencies of Iva, 57

Usage statistics. We involved Iva at the very beginning of the usability test. She was also the most active user among our participants. Figure 16 shows that her activity varied from a few items consumed per day to several hundred. Her bad clicks are not listed from the beginning. Sadly, there was an error in the program which prevented them from being recorded. According to her, mostly she used the program at night time when she was not able to sleep and also at times when she was in a bad mood, which provides a partial explanation for the rapid spikes and dramatic decreases of activity. Also, maybe, if we could observe her in a long run, the appropriation stage when both positive and negative forces determining her activity would stabilise, we could see more balanced results.

6.2.1.2 VĚRA, 82

Health. About three years ago she experienced a severe brain stroke. Though she has recovered quite well, it has left her depressed and less mobile. A few months ago she suddenly fainted. After waking up, she found out that she lost control over her limbs and even her ability to speak. After the incident, she spent two weeks in a hospital. The conclusion about her case was that her severe depression disrupted her daily routines, so she almost stopped drinking and eating, which disrupted her metabolism. After her hospitalization, her capabilities have returned almost to the normal level. As a follow-up treatment, she spent several more weeks at a psychiatric hospital. Her main current diagnosis is a periodic depressive disorder. She also suffers from neurological problems and a variety of other age-related impairments.

Life and the family. She lives with her single son. He provides some essential practical care, but almost no emotional and social support. When he returns from work, he locks himself in his room. We asked her what does he do when she knocks on his door. She replied that he plainly tells her not to disturb. He does neither relate anything to her nor asks her anything. So, she spends most of her days just staring out of a window in her room and observing the life outside. Though she is living in a city, her neighbourhood is quiet, so all what she usually sees are kids on their way to school, a postman, few neighbours and a few cars passing by. At least she has lunch regularly delivered. The lunch delivery is usually the most significant event of her day. Though we found that her life lacks any excitement, she does not complain. She is quite satisfied with her life and feels pity for other people, such as homeless or living in war-torn countries.

Experience. She worked as a dressmaker. After talking with her for almost an hour, we found her surprisingly intelligent and with a fairly good memory. But regarding technology, she has virtually no skills. She never used any smart gadgets, not even a simple mobile phone. She also neither watches TV nor listens to the radio.

The entry visit. At first, she was relatively enthusiastic about the tablet and the program in it. She was willing to give it a try. When we were presenting it, she also liked the content, especially neat pictures of animals and landscapes. We felt that she likes pictures better than videos. She scanned the pictures closely for many seconds and commented on the contents after. In particular, she loved quality pictures of animals, such as birds. But as soon as we handed her her tablet, we could see, that the program has problems with interpretation of her touches. She was pressing the screen too long, or too short, sometimes she did a swipe instead. We quickly found out, that at this point the user interface, tested only by Iva so far with no complaints, was not ready for Věra yet. Also, when the system offered her the 'like' button, it confused her even more. We could observe that she is getting anxious and no longer enjoying the session. Even though her touches were gradually better, after a few minutes, she suggested that she would instead give up and offered to return the tablet. We assured her that the problem is not on her side and promised to try to solve the issues.

The second visit. We returned the same day and to help her to operate the tablet, we have brought a touch pen. It improved her ability to operate the program significantly. But the problems with interpretation of her touches did not disappear entirely. So, we have left her the device so she could be trying it on her own and returned to solve the problem with different types of strokes (refer to 12.1 for the technical solution). But she just kept the tablet in the box until our next visit.

The third visit. We came over a week after. The user interface has been upgraded in the meantime to support different touch variants, to suppress text selection, any context menus and other unwanted browser functions. We let her try the functions again both with the help of the touch pen and with fingers only. Using fingers, the experience was still affected by her long nails. We counted on it, so we were ready to provide manicure this time. With short nails, she was able to operate the upgraded user interface with ease, and she

found it even more comfortable than using the touch pen. After about five minutes she turned her attention from the interface back to the content being shown. We observed that she was more confident now enjoying the experience for the first time. She went through several tens of pictures and few videos, so the program offered her 'like' button again. This time she accepted it. But we felt that these two buttons are just enough for her. More control items would only confuse and discourage her. So we decided to disable the Main System Provider which is responsible for offering new functions. At the end of the session, she concluded that it is not much difficult to use the program. But even though, again she expressed her lack of self-confidence. The feedback this time was significantly more favourable. But we still felt that she will need more guidance and tender support to start using the tablet on her own. She did not use the tablet until our next visit several days later.

The fourth visit. She said, her knee was aching recently, and she did not feel to do anything. Then we spent with her about 30 minutes, holding the tablet, she was pressing the 'next' button relatively easily, though a little bit worse than the last time – maybe because she was currently not feeling well overall. Soon she started commenting some of the pictures and also she watched several videos until the end of the playback. If we asked for example “*Would you like to be there? (at a concert)*”, she replied, “*Yes, I would like to be there to listen, but not to play.*” “*Why wouldn't you like to be there to play?*” “*I wouldn't be able to.*” At the end of the session, we concluded that she had no longer any problems with the software buttons. Only on one occasion, it happened, that she inadvertently zoomed in a bit – it shows that we will have to investigate a bit more, which user interaction events to intercept and absorb. She also liked the content and in general the whole session.

During the visit, we also made an effort to reveal why she did not use the program if she liked it. Based on her answers and our observation, the first cause is psychological. Though in many areas she retained her mental powers, for example, she has a quite good memory, she badly lacks self-confidence. It impedes her willingness to make decisions, even on trivial matters. In her world lacking any excitement, even taking the tablet out of the box and turning the display on feels like a big deal. The second cause is related to her tactile impairment. Though she does not have a big problem with the touchscreen, a hardware button on the edge of the tablet for switching the screen or the whole device on and off is too small for her. She was able to palpate it and to press it correctly when instructed. But we observed that she does not feel confident about it. The detail picture of the button is displayed in Figure 17.



Figure 17: Detail of the power on/off button of the testing tablet

The third problem relates to the fact, that in her home setting there was no comfortable place, where she could easily place the tablet and use only one hand to operate it. Neither holding the tablet with her left hand nor having it put on her lap, seems like a sufficiently comfortable option for her. And her fourth problem is social. She likes using the program as a tool for socialising – commenting the contents, sharing her feelings about the content, etc. But because when she is alone, and even when her son is at home she does not have anyone to share the experience with, she is not motivated enough to consume the content on her own. The famous statement 'happiness only real when shared', attributed to Christopher McCandless³⁰, seems to be

³⁰ Some dispute the authorship of this exact statement. But what is almost certain, that McCandless underlined the last part of the

true in Věra's case. Perhaps, these four combined caused that she has remained almost passive during the trial even though she liked both the contents and the user interface.

The fifth visit. Věra was enthusiastic to see us again. Again she had not difficulties touching the software buttons, but she liked our guidance throughout the session. For example, we often asked her '*would you like to go to the next page?*', she smiled in response and touched the 'next' button. Her comments about the contents were very lively and in many cases, the content evoked free associations. For example, there was a video with a piece of concert accompanied by dance. She commented, that it is a waltz and that she also used to dance when she was younger, but she did not dance with boys, but with her older sister. And it was not just waltz, but also polka, and even tango. But it just the past, she said. A photo of a mushroom led her to remember, that she used to enjoy mushrooming when she was young, back in the forests around the village of her childhood. She commented a scene with a sunset that she remembers several beautiful sunsets she has experienced during her life. But she added, that she likes sunrise better, because it indicates that the day is starting, whereas sunset brings dark night. The whole session was delightful for her. Even, when her lunch was delivered, she did not care. We spent about an hour with her, a she was willing to continue even longer.

During the session, we could observe, that the program may help to bring topics to talk about. When we came and asked how was Věra doing, she just shrugged her shoulders with no reply. Then we could, perhaps, ask about what did she observe in the street today and what will be the lunch today. And the topic ideas would be exhausted. But the content served by the program, though it was in no way directly related to her life, made her reminisce and share the memories. It may not only positively influence the momentary mood, but also build, strengthen, or re-establish social connections.

Functions

- Though eventually, she was able to deal with software buttons, we have found out, that labels on relatively small video control buttons should be typed in a bigger font. Maybe we could pick a shorter word which would fit in even with a bigger font. We could also make the pause/resume button more visually distinctive. For example, a 'stop' traffic sign might be better.
- Also, the indicator of voice level in the form of a green line is not clear to her. Unlike others who are familiar with the symbolism for example, from TV, it was not a clear concept for Věra. Something more intuitive should be considered, for example, an ear icon which would be growing to indicate the volume increase.

Content

- She liked the content. We felt that pictures were even better for her than videos because she could take her time to think about what she is seeing and about associations. Some videos were quite fast for her. But she liked classical music.
- We have revealed, that Věra should be shielded from any content with a negative message. For example, she would not bear the typical news – about crimes, corruption, violence, frauds, etc. There was a moment when she did not recognize a singer, so she asked who is she. We told her the name and that she, though quite young, has died already. Immediately, it had a visible negative impact on Věra's mood. *Feelings*
- At first, when she experienced problems with the first version of the interface which was not able to properly interpret her touches she felt anxious and almost as giving up.
- But after we fixed the interface, gradually she started liking it. On our last visit, she apparently enjoyed the experience. It had a soothing, refreshing and energising impact on her.

statement in a print of the novel Doctor Zhivago: “*And so it turned out that only a life similar to the life of those around us, merging with it without a ripple, is genuine life, and that an unshared happiness is not happiness.*” authored by (Pasternak, 1957).

Suggestions

- The hardware buttons pose a problem for her. It would be better if there were prominent and easy-to-find hardware buttons or no hardware buttons at all. Also holding the tablet is not comfortable for her, she would need a stand or mount.

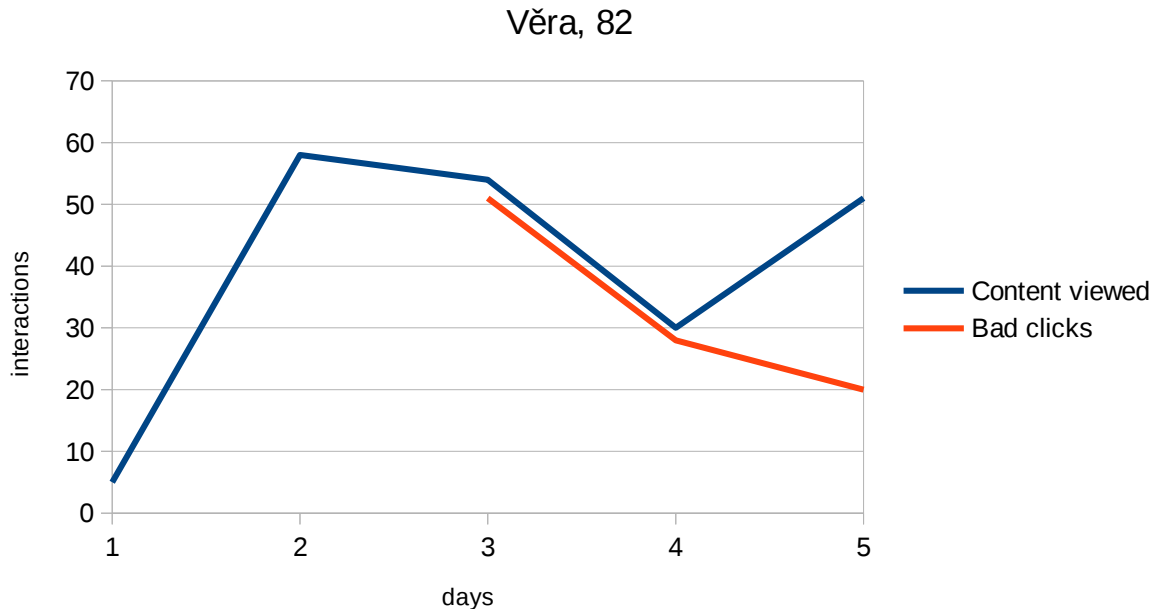


Figure 18: Interaction frequencies of Věra, 82

Usage statistics. Also for Věra, 82 we did not record bad clicks from the first sessions because of a problem in the data collecting algorithm. As shown in Figure 19, the interaction frequencies do not provide much valuable insight, because during the sessions we were present and the amount of content consumed during the session was determined not only by Věra but also by ourselves. The better good/bad interactions ratio during the last session harmonises with our perception of how she was able to handle the application after the user interface upgrades which have been done based on her feedback.

6.2.1.3 ANNA, 81

Health. She, despite the age, is doing relatively okay physically with no severe health problems besides high blood pressure and mild diabetes. Her condition allows her to live actively – for example, she reads books, and during the season she is busy in her garden.

Life and the family. She is living alone in a two-generation house in a rural area. Her daughter occupies the other unit. Besides the daughter, she has two more children, several grandchildren. She keeps in touch also with other relatives who visit her quite often.

Experience. Anna worked as a cook. She has very limited experience with smart technical devices. She uses a dumb mobile phone with hardware buttons and she can both call and text. She also watches TV and listens to the radio. She was never interested in computers or any advanced technical gadgets. She even said that technical devices were irksome³¹ to her.

The demonstration visit. Before seriously considering the participation, she asked us to come over and explain it a bit more in detail. During the visit, we understood, that she has fear from technical devices and also that she is a bit reluctant to leave her comfort zone, and not willing to exert effort to learn something new. At first, she was almost sure that she 'would not be able' to use a tablet and wanted to refuse. But after a short demonstration, she concluded that it is easy and that she would be, perhaps, able. We found out that she also underestimates her potential. We could see, that she has no problem with functions such as 'next', or 'like'. Without any instructions and previous experience, just based on button captions, she recognised how

31 She used the Czech word 'protivné' which could be translated as 'nasty', 'odious', or 'obnoxious'.

to lower the volume and control the playback of video content. After about ten minutes of playing with the program, she mentioned that she would want to have more control over the contents. Namely, that she would like to have a button to choose a type of material, for example, only pictures or only videos. Her bright and relevant idea, pronounced after such short testing, impressed us. So, before revisiting her, we have implemented the suggested function.

The entry visit. On our second meeting, we came to hand her a testing tablet. Because her daughter had an Internet connection with Wi-Fi which also reaches Anna's flat, we planned to connect the tablet to this Wi-Fi. Soon we realised that there is probably an incompatibility between the Wi-Fi access point and the testing tablet, which is causing instability in connection. The tablet was going on and off repeatedly. So, we had an opportunity to test the interaction with the application under such unfavourable conditions. We could observe, that this kind of connection problems significantly affected the experience. On some requests the content was loaded with no issues, other times it was entirely served by the service worker from the browser cache. But in some cases, the main HTML page was loaded from the server, but the linked picture did not load successfully, so service worker had to serve a fallback image. Though it was not as bad as if there was no service worker action, for example, the fact that there was a title belonging to real content, but a fallback image displayed, confused her. Sometimes she clicked to load new content, but the poor connection caused a significant delay of several seconds, which made her doubt if she did something wrong. The technical problems allowed her to focus sufficiently neither on the user interface of the program nor on the content. Undoubtedly it was not a smooth experience for her. But for us, the session was useful because we could observe, how technical problems affect the mental forces which may decide whether a product gets appropriated, or rejected. Věra understood the cause and agreed to give it another chance.

The third visit. Next time we have brought a SIM card with us so we could use a different Internet connection. Again, we experienced particular connection issues because the 3G signal at her place was not too stable. But the problems were not as severe as the last time. Mostly the responses from the program were quick, and Anna did not have any apparent problem with interaction with the user interface. After a few minutes she concluded, that indeed it is easy. She revealed more details about the interface – for example, when she was adjusting the playback volume, she commented that there is an indicator of the audio level in the form of a green line. In the middle of the session, a postman rang her doorbell. She correctly pressed the relevant button to pause the playback and resumed it later when she was back. At one point, the quality of the Internet connection fluctuated more, so the program disconnected. She noticed that something went wrong because the system control buttons disappeared and 'next' was the only button left (the program went into the offline mode). But, she remembered the meaning of the connection status indicator in the top right corner of the screen, noticed the change of its colour, and correctly identified the cause of the problem. The fact that she understood the cause made her feel relieved. Almost at the end of the session, she asked how much the testing tablet costs. She said that maybe if she gets used to it, she could buy the tablet when the trial ends.

The fourth visit. She said she liked the time spent on the tablet. But there are also many other things which are keeping her busy, such as cooking, house chores, gardening, meeting with relatives, or visiting doctors. And she also likes TV and crosswords. According to her, that is why she did not use the program intensely. But she believes that the idea has potential, especially for seniors who are not too active as she is.

Functions

- She would appreciate if she could put a selected content in a list of favourites and return to it later.

Content

- She did not like foreign songs much; she prefers if she understands the lyrics. Better if there were more Czech songs, for example, folk or brass.

Feelings

- She feels antipathy towards any technology. The trial was the first time somebody made her use a similar device, though her relatives made an effort in the past several times. For example, it irritates her if her granddaughter, once physically active, spends hours on her mobile phone, which is not good for her health.

- But, despite the antipathy, she felt relaxed, because it was effortless to handle the program, and also quite excited about the content.

Suggestions

- Nothing else.

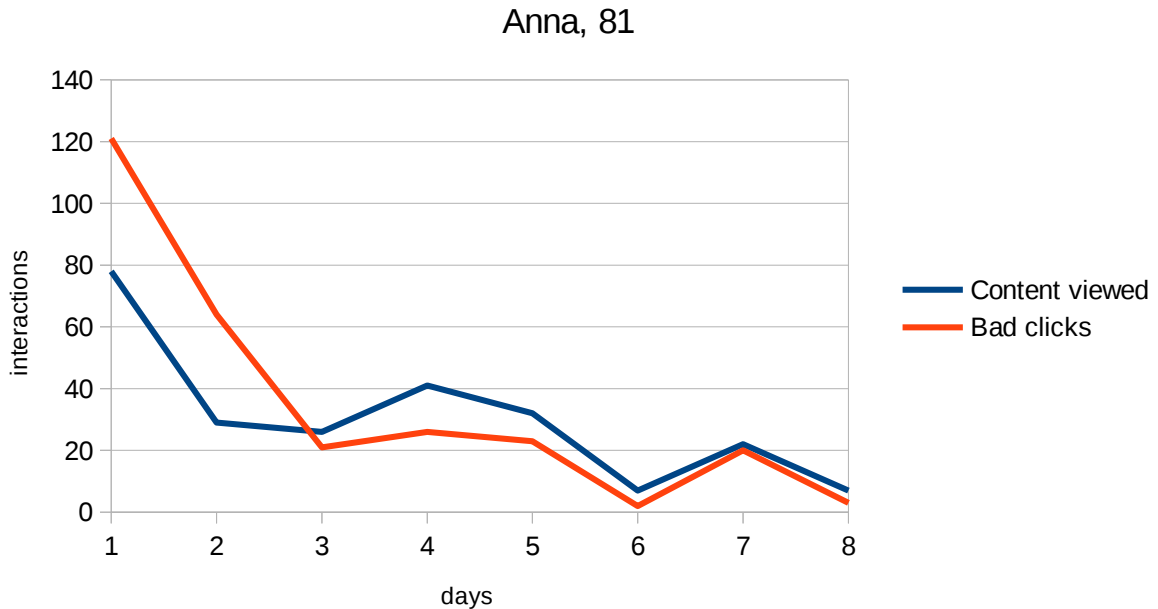


Figure 19: Interaction frequencies of Anna, 81

Usage statistics. In Figure 19, we can see a downward trend in Anna's activity. It is likely related to the way how the forces like enthusiasm were driving her action at the beginning, but slowly diminished as the appropriation was in the progress and other forces took the main control. The lower activity also matches with warmer weather. She told us at the concluding meeting that she expects to use the program less in the coming days because she will be spending even more time in the garden.

6.2.1.4 VĚRA, 93

Health. She was doing relatively okay. Complained only about back pain and the fact that her age limits her mobility. She can walk a few hundred meters, and it exhausts her. Despite her age, we could see a vital spark in her eyes.

Life and the family. Věra is living alone in a flat in a city. Despite her age, she keeps her flat tidy and relatively modern-looking. Her relatives are living relatively far. But she did not complain, actually she likes being independent. Her relatives are in regular touch with her. We found her family functional. She also has a vibrant social network of other friends. Věra enjoys her life.

Experience. Věra went through different positions which included both white collar and manual work. She never used a computer. She owns and can operate a dumb mobile phone with hardware buttons. But just a few months ago her granddaughter has given her a tablet. The granddaughter also arranged for her an Internet connection via a cellular network. Now she uses the tablet mainly to follow her children on Facebook, read eBooks and to play YouTube videos. But still, quite often she gets confused or stuck with the interface or behaviour of some of her applications. For example, she is trying to load something on Facebook or YouTube, but she is unable to find it, or eventually, she ends up somewhere else. But, as we noticed, she does not get upset if it happens – and if there is something else what interests her, she just enjoys. Perseverance and positive approach help her not to give up. She was one of the persons who also participated in the kick-off focus group (5.2.3).

The entry visit. She showed us her tablet and how does she use it. We commend her, and she proudly related, that when her granddaughter has given her the tablet, just after watching the granddaughter for few minutes,

Věra grabbed the tablet and, to the granddaughter's surprise, started operating it on her own. We asked her to try to compare the simplicity of the user interface of our program. After just a few pages, she concluded that the user interface is totally simple. According to her everyone must be able to handle it. She was quite enthusiastic about the simplicity and said, that it would be great for those seniors living in nursing homes who 'do nothing but stare from a window' – it reminded us of the other Věra (6.2.1.2). Soon after she started commenting on the content being shown, telling us about her likes and dislikes. Such as that she likes classical music, either orchestral, violin or piano play. She is also passionate about the music of the twenties and thirties, step, and even some contemporary US music. She also likes reading. Regarding other media, she sometimes watches TV or listens to the radio, but generally, she does not enjoy it much. As her favourite, she mentioned a TV series called *Esmeralda*, but she felt a bit ashamed of liking it. Advertisements inserted in broadcasted content irritate her, so she prefers public stations to commercial. Regarding the type of content, she likes knowledge competitions. But she does not like the pace of modern programs because she feels they are too fast to be pleasant or easy to follow – people are talking fast, scenes are changing rapidly, etc. So, she likes online content better. While she was playing with our program, we have noticed, that she likes the idea of rating content. It gives her certain feeling of importance – that her vote counts. She commended the survey page with the question '*How are you feeling today?*' and tried to assess her feelings genuinely to answer truthfully. She also almost immediately had several useful tips for improvement. We were amazed by her smart comments and observations. The suggestions are listed in the assessment part.

The second visit. Just two days after the initial session she called, asking for help with the application. We have arrived and noticed, that the lack of Internet connection caused the problem. Actually, in her case, we set up the testing tablet to connect to a portable hotspot which we enabled on her old tablet. And it happened that the portable hotspot turned off, which caused she was no longer able to connect to the testing tablet. While we were solving the problem with the connection, she shared her impressions about our prototype. She said that she spent almost the whole morning playing with the tablet. She appreciated the new function which allows her to choose the type of content³². Regarding content, she liked the videos and commented, that the program was able to deliver both music she knows already and some material which was completely new. In general, she enjoyed the content and said it was fun. She also suggested deferred playback as a new function (see the assessment part below). She related, that when she noticed that something went wrong because all buttons but 'next' have disappeared and the program was no longer able to serve any more videos, she tried to explore in an attempt to solve the problem. Though she was not able to reconnect, she revealed that on the testing tablet there are other applications as well and also various settings. Though it was interesting for her to find out, she also admits that it confused her and that she would need more time to understand all the functions – as she did with her old tablet.

The third visit. We received one more call with a complaint that there is something wrong with the program. Later at the spot, we revealed that the cause is the same as the last time. So, even though at this stage it was not our plan to test the program on other devices than on the dedicated testing tablets, after considering other options, we have decided to simply install the application on her old tablet. The process was simple – we just adjusted the autoplay flag in the Chrome browser, navigated to the relevant page, agreed on adding the application on her homepage. The last step was to start the application from the homepage and fill-up her credentials. She told us again that the program itself is very simple³³. We used the opportunity to talk more about her perception of the Internet and feelings when using it. She said, though it sometimes frustrates her if something goes wrong, such as if her Skype stopped working and she did not know why or even when our application stopped working as expected because the tablet lost its Internet connection, in general, she appreciates that she can benefit from the content available online. It feels fresher than TV or radio, and she also likes that she may interact more, applying her preferences. Less than a year ago when she was for the first time confronted with the interface of her tablet, she did her best to understand the instructions given her by her granddaughter because she did not wish to appear incompetent, to lose face, and to put any burden on the granddaughter. It harmonises with conclusions from our research about the deep needs of the elderly (4.1.3). Regarding her comparison of the old tablet and the new one, she concluded that the larger 10,1” display is pleasant and that the new tablet is really quick. But she also likes her old 7” tablet because it is

32 It has been implemented in the meanwhile to satisfy a suggestion from Anna.

33 She literally used an expressive Czech colloquial statement: “*Je to fakt jednoduchý, jako pro blby*”.

more portable and handy, so it is easier to carry. She also likes the function of her old tablet which automatically turns the screen on and off when she flips the tablet cover.

Functions

- She found the functions and the interface very easy, especially in comparison with other applications she uses.

Content

- She enjoyed most contents, such as classical music and audiobooks. Pictures were not so exciting according to her.

Feelings

- Playing with a tablet is her favourite relaxation. And it also applies to our program.

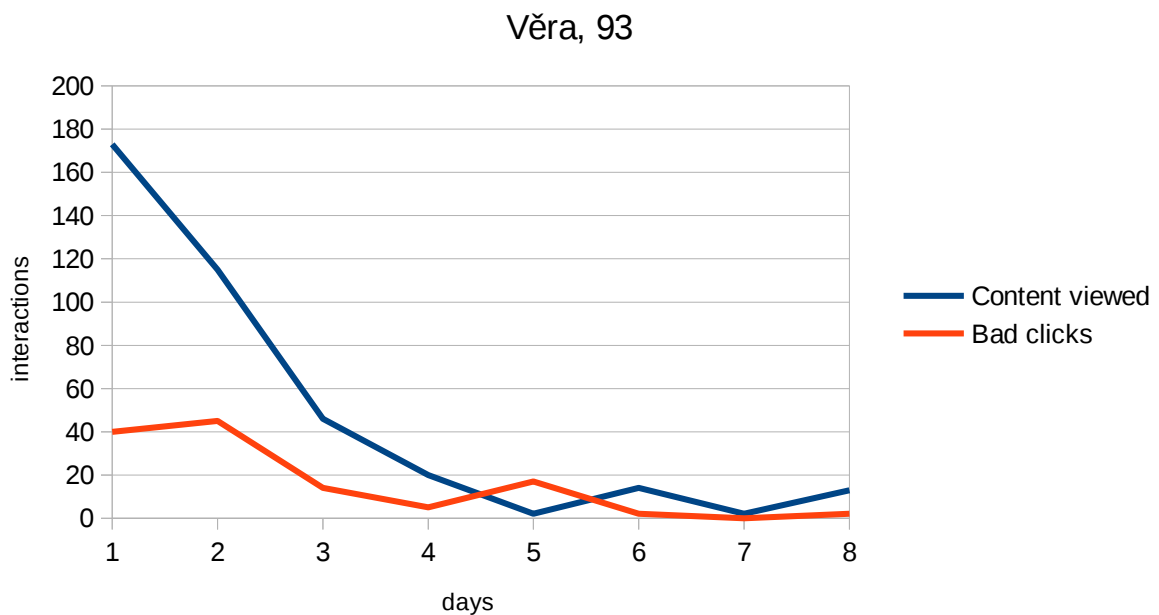


Figure 20: Interaction frequencies of Věra, 93

Suggestions

- At the first meet-up, she immediately had several meaningful suggestions. For example, she has noticed that there was no visible battery level indicator, unlike on her other tablet. She would like to have such an indicator.
- She would also like to have a status bar with the current time.
- Regarding content, she would definitely like if there is a way to connect family albums. Specifically, she said, that on the content selection page she would like to have an option for “family”. On the question of what does she mean with family albums, she explained that she is not referring to just fresh pictures, but the whole history of family pictures. She would like to have options to either browse the pictures randomly or by date.
- Besides the family albums, she would like to be greeted every morning with a fresh weather forecast – she is demonstrating by the weather widget application she has on her old tablet.
- After browsing with ease through several tens of content items and asking the questions from system and survey content providers she further comments that she would prefer to have more control over the content being shown, such as to choose which specific kind of videos should the system be serving or navigating to a specific chapter of an audiobook.

- She thinks it would be practical if it is possible to skip to a next content, but have the currently shown video served again and start playing from the place where it ended the last time. For example, she likes a documentary offered by the system, but she would prefer to watch it at a different time if she is more in the mood for music.

Usage statistics. Also for Věra, 93 the statistics in Figure 21 show a clear downward trend, which might be attributed to the progress of the appropriation process. Also, when we transferred the program to her old tablet, it was less calling for her attention than before when she had it on a dedicated device. When the program was in a company of the other programs she was used to, it had to compete for her time. Because the content she likes most is coming from her family and our program does not support these sources of data yet, it likely caused a significant distraction.

6.2.1.5 VĚRA, 78 AND VĚRA, 53

Mother and daughter Věra and Věra are living in a shared household in a house in a rural area.

Health. Věra Sr. has a wide variety of age-related problems, such as a memory loss, high blood pressure, cardiac arrhythmia, rheumatoid arthritis, but none of them in a very progressed stage. Věra Jr. was diagnosed with schizophrenia in her childhood, and since then she has been under medication. Her schizophrenia involves mood disorder symptoms and paranoid beliefs and delusions. She does not suffer from disorganised thinking and behaviour and has never experienced catatonia. Because of her diagnosis, since her early age, she has been on the full disability pension.

Life and the family. They both are living a relatively active life, though it mainly revolves only around their homestead. They are in charge of their livestock which includes a small herd of sheep, chicken, geese, and a pig. They are also active in their kitchen garden and their house. All the activities are keeping them busy, however the focus is limiting their horizon to their very neighbourhood; especially Věra Sr. is not showing much interest in anything beyond.

Experience. Věra Jr. because of her condition never had any job. Věra Sr. was employed her entire active life in the agriculture. They both have very limited experience with smart devices. They are struggling even to use a dumb cell phone; during the first meet-up, they asked a favour – if we could help them to change a number of one of their contacts on their phone.

The entry visit. They almost refused the idea to participate in our trial, feeling that they would not be able to operate the tablet. But after seeing the user interface, Věra Jr found it easy and pleasant and Věra Sr, though not commenting, was looking patiently with signs of interest. So, they agreed to be involved. As a means of Internet connection, we had to use the cellular. There was a G3 network available in the area, so the program was loading the contents fast enough for a smooth experience. When we instructed them how to charge the tablet, Věra Jr. found it easy and similar to their mobile phone which uses the same micro USB connector.

The feedback call. The next day Věra Jr. called. According to her voice, she was slightly agitated or distraught. But she did not complain about the program, but rather on her mother: “*My mother clicked 'despise' but I liked the video, so now I am mad at her because I am worried that the video and also videos of a similar type are lost for good, that we won't be able to access them again.*” She also stated that the mother is not at home now, because she went to see a doctor. But that they are planning to 'broadcast'³⁴ in the evening again.

The second visit. A week after they told us, that they both truly liked the contents and found the program easy to operate. Especially in the evening, they set time aside for a session with the program, and they even argued who would be using it first, which sounded a bit funny. But since the third day, the tablet started complaining that its battery level is low. For a reason they could not name, the problem with the battery discouraged them. So, instead of just charging the device they returned the tablet in the box and waited for us. We were able to observe, how even a minor technical problem may break the appropriation of even an enthusiastically acclaimed product, causing its refusal. Věra Jr. concluded that the program was a good idea. She thought it might be especially valuable for seniors living in elderly care homes whose lives are boring due to the lack of any engaging activity.

34 She said in Czech “*večer budeme zase vysílat*”.

Functions

- They both liked the program functions and found its interface easy. Specifically, they commended, that the controls are well-visible and legible.

Content

- They liked the content overall. They did not like videos with exercise sessions; those felt boring.

Feelings

- They both enjoyed using the program. Especially Věra Jr. felt joyful and energised and 'was smiling' after watching videos about cute animals and fairy tales³⁵.
- They did not like when the tablet started complaining about its battery level. It made them feel anxious and in result they even quarrelled over the tablet. Věra Jr. suggested that it just has to be charged, but Věra Sr. persuaded to put the tablet back in the box. The reason she provided was '*so we wouldn't break it*'.
- When they were sharing the tablet, it was not much comfortable to hold it in a comfortable position which would provide a good view for both of them.
- Their participation raised their interest in the online content. They concluded, that '*it was a pity that we did not have Internet*'.

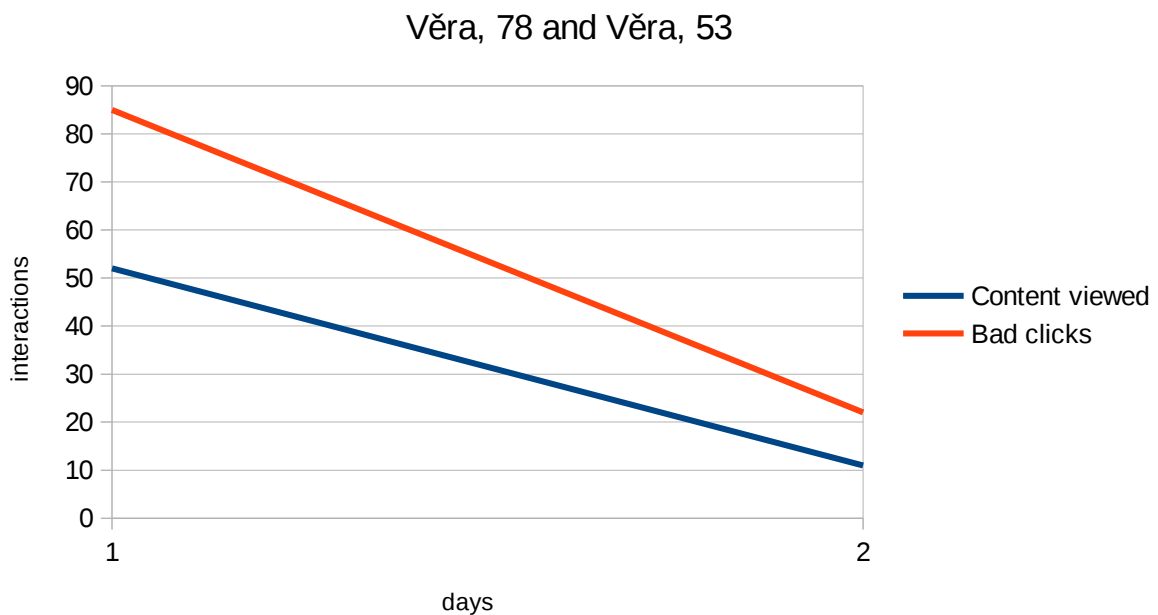


Figure 21: Interaction frequencies of Věra, 78 and Věra, 53

Suggestions

- Věra jr. suggested a stand for the tablet, so it won't be necessary to hold the tablet for a long time, because, according to her, it might quickly fall and get broken. Also, after a while of holding the tablet arms get tired and it may even lead to cramps.
- The 'battery incident' made us think of proper indication of the battery level. There should be an indication in a status bar. It is a usual feature of portable electronic devices and we were planning to implement it even before getting the feedback from Věras. But their experience made think that it might not be enough to prevent what has happened. As a better solution, we could, for example,

35 In their stream so-called 'Večerničky', short animated films, with a long tradition in the Czech Republic, were included.

extend the Main System Content Provider, so it would, in the case of a low-battery level, serve a system page asking the user politely to put the device on a charger. Of course, a charging stand or/and wireless charging station would mean a significant improvement too.

Usage statistics. Věras interactions were affected by the incident with charging and the subsequent quarrel over the device. So, we can't deduct much information from the statistics in Figure 21.

6.2.1.6 JOSEF, 78 AND KVĚTA, 75

Health. Josef has an athletic figure and enjoys fairly good health. He exercises regularly and he even engages in running at least once a week, though of course, his performance is not as in his youth. Květa's health is significantly worse. Her failing kidneys require her to undergo dialysis in a hospital several times a week. Both have a bright mind with no apparent signs of cognitive decline.

Life and the family. Josef and Květa are living in a two-generation house in the city. Their daughter and a little granddaughter occupy the other flat. Josef has a variety of interests. For example, he watches documentaries on TV and reads magazines about nature and space. He is also busy around the house, he does the shopping for their household and sometimes even cooking. He is also the one who regularly sends Květa to the hospital and fetches her after the dialysis. Health condition limits Květa, but she also lives an active life. For example, she helps her daughter to raise the granddaughter and to look after her. They also have a second daughter whose son, now in his early teens, visits the grandparents often. They use the chances to contribute to his emotional and intellectual growth. For example, they incited in him an interest about the space, so the grandson enjoys reading the same scientifically popularising magazine as his grandfather does and he also attends an after-school course/hobby group of amateur astronomy. But they agreed, that recently they were struggling to keep him on lately. They feel that they have less in common than in the past. When he comes, often he just spends the time with his sight buried in his mobile phone, which irritates the grandparents. But they admit, that they also have to respect the changes in the society, which show up on their grandson. According to them the changes among youngsters involve diminishing interest in sports, physical activity, reading any voluminous content, but increasing interest in shallow content on digital media.

Experience. Josef has gained professional experience as a heavy-current electrician for the national railroad company. About 15 years ago he was persuaded to use a computer at work. But the exposure lasted just a few months. After retiring from the job he never used a computer anymore. He has a smart mobile phone but uses it only for calling. He is not a confident user of digital technology. About two years ago his wife purchased a tablet; she uses it regularly mainly for reading and for watching well-chosen videos.

The entry visit. We were more interested in feedback from Josef, because of his lack of previous experience. So, though Květa was also around, we addressed mainly Josef during the visit. He at first did not wish to participate. He said that he felt dumb if it comes to modern electronic devices. But after a quick demonstration, he was immediately able to operate the program and he no longer needed any further instruction. He felt a bit awkward about the personified formulation of messages used by the Main System Provider in the welcome and instructional screens. He also soon started commenting on the content being displayed. After a few minutes of using the program, he felt that there is not really much to test because everything is clear and straightforward. So he asked more about the exact purpose of the trial and the related research. He was also interested what else the program can do besides showing pictures and playing video.

The second visit. We were quite interested in getting to know, what caused that Josef did not use the tablet more. He explained that there were other things which were keeping him busy, such as care for the household, shopping, cleaning, some maintenance, etc. He also admitted, that as his means of relaxation he likes reading his magazine about space and nature and he finds it more pleasant than using the tablet. The main reasons were probably two. First, the material substance – even if he finds the contents attractive, it is still more pleasant for him to hold a printed magazine. The tablet requires gentle treatment, is slightly heavier and has buttons and the active display which responds to his touches, which distracts him. The second reason was the content. His specific interest in relatively narrow and the contents provided by the program did not match his interests closely enough. He was also aware of his participation in research, which affected his behaviour. As soon as he tried all functions of the program, he felt that the goal of the research has been fulfilled and that there is no longer any point in continuing.

Functions

- Regarding the user interface, he found it very easy, especially compared to his previous short and not really fruitful attempts to use a computer.

Content

- He found the content quite interesting. But it did not match his specific areas of interest enough for him to use the program more intensely.

Feelings

- He liked the experience, but he could not name any related particular feelings.

Suggestions

- According to him, the program should be able to provide a wider variety of contents and functions to be more interesting. He thinks that for other people who are less active the program might be very beneficial.

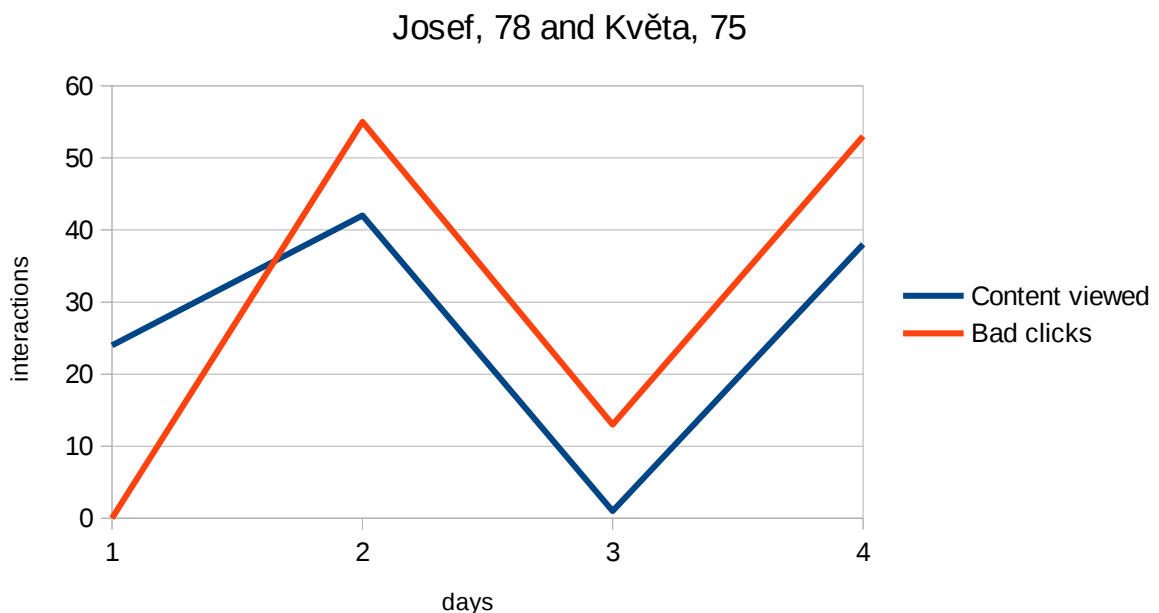


Figure 22: Interaction frequencies of Josef, 78 and Květa, 75

Usage statistics. Josef's usage of our program was not much intense, because of all his other duties and activities and lower motivation. The frequencies are captured in Figure 22.

6.2.1.7 LUDMILA, 82

Health. Ludmila suffers from a variety of age-related health problems such as high blood pressure and osteoporosis. She also has sensory issues – her fingers are insensitive sometimes, and she is farsighted. But her strong personality does not allow her to complain. She is still very active both physically and mentally.

Life and the family. Though she was raised in a farmer family, after growing up she has moved to a city. Now she is living alone in a beautifully decorated two-storey house. Though she is alone, she does not feel abandoned. Ludmila has two children living in proximity, both with their own families. She also has several siblings who all are living in nearby villages. Some of the siblings and their families are still active in agriculture. Ludmila keeps in touch with them. During seasonal campaigns, such as a potato collection time, despite her age she volunteers on her relatives' fields. She also walks across the whole city or rides on her bicycle almost every day. Ludmila prefers it to public transport because if she moves on her own she feels more independent and she is even able to get to her destinations more quickly. Her regular activities involve cooking and baking – what she prepares she then usually distributes to the relatives and friends. It is also her

passion to knit clothes for salvaged dolls which have been thrown away by their owners. She feels like saving them and giving them new lives. She appreciates that she does not need almost any support from anyone, but rather that she instead can often be a source of help. She also works on family chronicles which involves the genealogy of the whole broad family, which she types on a mechanical typewriter. Her activities make her feel proud and valuable.³⁶

Experience. She worked as an officer and a regional politician³⁷. She uses a dumb mobile phone. A few years back she tried to learn how to access the Internet using a computer. But as what we understood from her grandson because she is proud and does not wish to show any incompetence, it caused that she was not patient enough when he was teaching her. According to her, she struggled with the mouse and also with windows, menus, and other parts of the user interface. Now, for almost a year she owns a tablet. It feels much easier. She can play videos, read the news and other content. She also receives links to videos, PPV presentations and other materials via email from an aged relative (refer to the introductory paragraph in 4.2). Sometimes she gets stuck with her tablet and needs support, which irritates her.

She was one of the persons who also participated in the kick-off focus group (5.2.3).

The entry visit. We installed the program on her tablet. The introduction and demonstration of our program took only a few minutes. Instead, she used the time of our visit to tell us more about herself, to show us her house and some of her creations, such as the collection of dolls. As what we found from the automatically stored interaction records, she used the system quite intensely the very first evening. But the intensity of usage dropped in the following days.

Support call. We wanted to know if she had any problem with the program. When we asked her, she explained: “*I liked it, and I watched all until the broadcasting ended.*” She could not clearly explain what did she mean by the statement that the broadcasting had ended. We assured her that the supply of contents is virtually infinite. It surprised her. She said, perhaps, she will continue.

The second visit. The assessment visit was also quite short. Ludmila said she liked the program, both its contents and the functions. We felt that she was genuine, but also that she would not admit even if it was the opposite.

Functions

- A 'back' button would be great because sometimes it happened that she moved to a next content accidentally, or only wanted to return to the previous item.
- For her, the font on video controls was too small. She had to wear eyeglasses. Maybe a shorter word as a label would help. The smaller size of her tablet partially caused it.
- She experienced once that a voice of a singer started coming from her shoulder bag. She quickly found out that she accidentally started the playback. Maybe protection to prevent such incidents would be practical.
- It also happened twice, that her pet bird³⁸ stepped on the tablet and stopped the playback or even turned the display off. But we do not have any idea what to do to prevent this.

Content

- She liked almost all the content. Regarding videos, she liked the music videos, documentaries, artistic videos and even exercise demonstrations – she found them practical.
- She also commended the audiobook with its big font used for the text display.

Feelings

- She said that the program was good for the times when she was resting on the bed in the evening or during the night. She felt relaxed, entertained, and educated.

36 It harmonise well with our previous findings (4.1.3, 4.1.4).

37 During the communism in the Czech Republic, she worked for a non-communist political party. But the party had to respect the leading role of the communist party and participate in the governance in a coalition named National front.

38 A parakeet.

- Slight source of tension was for her the fact that she was aware of being part of a trial.

Suggestions

- She would welcome more educational documents, especially about Czech history.
- She suggests redesigning video controls.

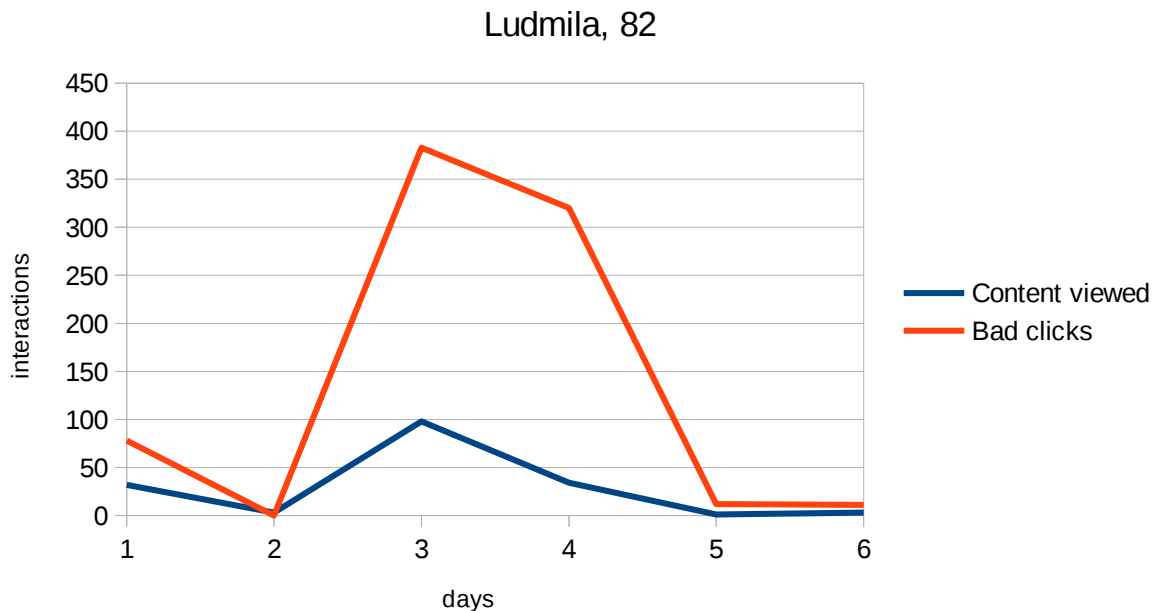


Figure 23: Interaction frequencies of Ludmila, 82

Usage statistics. In Ludmila's case, the statistics (Figure 23) reveal something about her psychology. As described above, she did not let us demonstrate the prototype properly because she gave us only a few minutes. But from her later call we understood that she missed a big deal of the whole concept of the program when she told us, that she had finished all the content. Here wrong clicks show, that she rather than asking, tried to figure everything out on her own. The data also suggest that she was probably not patient with the interface, clicking rapidly in explorative attempts. Though she commended the program, because of her many activities and distractions, it is not clear, if the program would find a stable place in her life.

6.2.1.8 ANNA, 73

Health. Anna is going through various age-related health problems which involves rheumatoid arthritis and unspecified heart problems. But she did not complain.

Life and the family. She lives with her boyfriend in a flat in a city. Besides her apartment in a small town, she spends significant amounts of time in her boyfriend's apartment in Prague or a cottage in the countryside. Her boyfriend is 78 years old former construction engineer specialised in bridge construction. He uses part of his time to study – for example, he attends a course of the Spanish language. He is an active Internet user, likes to be informed about what's going on around the globe, especially in areas of his interest, such as Latin America and prefers online sources of information he chooses over the traditional mainstream media. To access the Internet, he uses a laptop. When a technical problem occurs, he is sometimes clueless, but in general, he is a moderately experienced user. The self-assessment of his skills matches the information provided by Anna and our observations. She also has a son and a sister, but they do not see each other often. She also likes reading books or going for walks to nature with an organised group of senior tourists. We found Anna very friendly, outspoken and talkative.

Experience. Anna is a former senior sales manager. She worked in an international sales department of a state-own manufacturer. Anna is a basic computer user. For example, she knows how to write and print a document. But she has limited direct experience with online content. Just two weeks ago she got a new

smartphone, but still not familiar with the interface, struggling even to access contacts or use the essential call functions. She did not connect her smartphone to the Internet yet even though her boyfriend has an Internet with a local Wi-Fi installed in their flat. Anna does access Vladimír's laptop only seldom. Though she also likes to be informed and she would, perhaps, appreciate particular online content, she feels that Internet content is quite complicated, which keeps her away most of the time. And because Vladimír's areas of interest regarding the online content are different to hers, they are not used to working with Internet resources together. They both like classical music and like attending concerts together, though, sometimes, their assessment of specific content differ.

The entry visit. She shared the reasons why she perceives online content complicated and why she feels intimidated to use the Internet more. In her case, it is not mainly a matter of user interface. She can handle even a mouse. But the extensively hyperlinked content makes her feel lost. For example, once she wanted to try to look for good quality stockings. So, she turned the computer on, launched a browser, typed the query, and clicked one of the results. It transferred her to an e-shop. While looking through the stockings offers, a picture of a hat interested her. So she clicked it, and it directed her to a different page. She liked the hats, but an elegant leather shoulder bag captured her interest, so she clicked again. When her eyes were already sore, she found out, that she just had spent an hour browsing, but did not accomplish anything useful. She just turned the computer off and felt disappointed. When we were talking to her, we noticed, that she tends to think and speak similarly – associations easily lead her mind from a topic to a topic.

She has one more problem with the Internet. Maybe also because her boyfriend is interested in politics and sometimes even in conspiracy theories, and relates his worries and opinions to her, she feels insecure about the Internet. She also notices and takes seriously any news about security incidents and breaches of trust on the Internet, such as the recent news about the Facebook scandal with the misuse of personal data (Byers, 2018). All those intelligent technologies make her feel being watched by a big brother. Yes, she knows (Orwell, 1949). She is also worried about the beginning of the era of intelligent robots and ubiquitous electronic technologies. Whenever she uses the Internet she feels a bit anxious about the consequences of her actions, for example, if the information she provides won't be misused. That's also one of the reasons why she did not set up the Internet on her mobile phone yet. We found the awareness of safety and security issues related to the usage of the Internet, which is healthy and vital, hypertrophied slightly in her case. When we told her that the program we are asking her to test is safe, that currently works as a mere reader and that she can't break anything with her actions, it made her feel more relaxed.

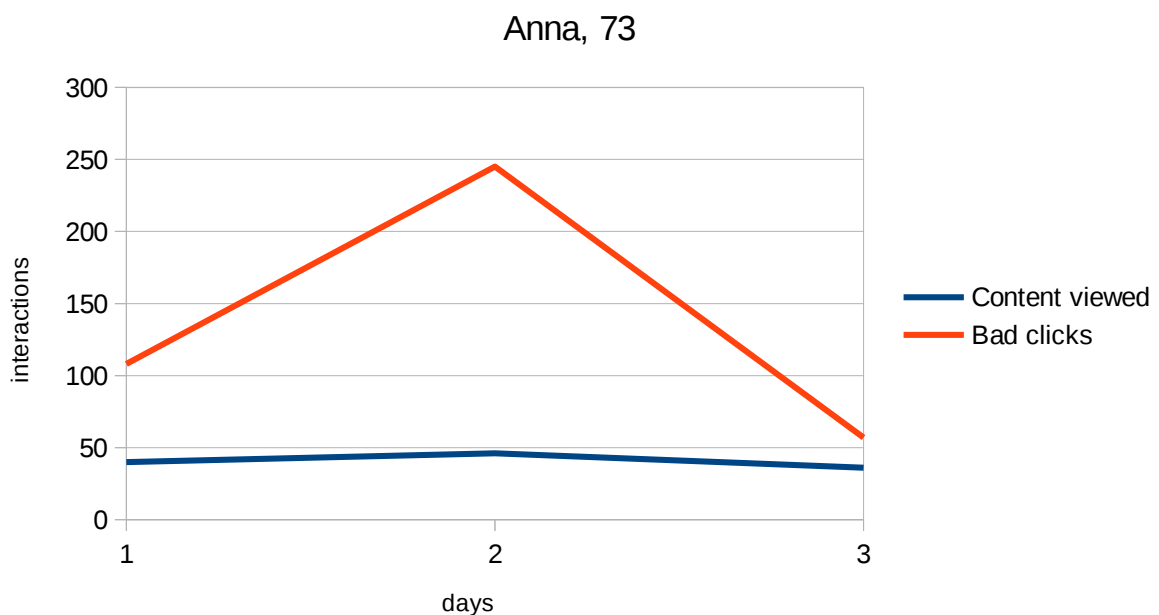


Figure 24: Interaction frequencies of Anna, 73

Support call. She called and complained that the program is no longer showing any new contents. We quickly found out that the tablet has disconnected from her Wi-Fi. So, we navigated her by phone, where to turn the Wi-Fi on again. It was relatively difficult, and it took at least 15 minutes.

Functions

- It happened to her that her Wi-Fi got disconnected which made her struggle.

Content

- She liked almost all contents – namely the music videos, fairy tales, videos which involved animals, beautiful pictures of landscapes and nature.
- Anna also appreciated the audiobook content, but she said she prefers if she reads on her own, because she may choose her own pace and is more focused.

Feelings

- She felt relaxed and entertained.
- Only it displeased her when she experienced the problem with Internet connection. At first, she did not recognise what's wrong, what made it worse.

Suggestions

- It would be nice to have means directly in the program to turn the Wi-Fi on if it gets disconnected.
- Maybe the program could indicate the problem with the connection more clearly than just in the status bar – for example, showing notification in the main content pane.
- Remote access to the tablet for maintenance would be practical.

Usage statistics. The data we gathered about Anna's interactions show stable engagement during the testing days (Figure 24), but because she was involved almost at the end of the trial, we could not observe her activity for a more extended period to reveal possible patterns.

6.2.2 PARTICIPANTS NOT ACTIVELY INVOLVED

6.2.2.1 MIROSLAV, 83

Health. Miroslav has various unspecified health problems. The symptoms include worse hearing, joint pains, back pain, and a sleep disorder.

Life and the family. Miroslav is living alone in a village. Most of the time he spends in his kitchen garden, watching TV, or doing some household chores. Though his daughter calls him every day and visits him weekly, Miroslav feels lonely and abandoned. We found out that Miroslav has a negative attitude, he tends to criticise everything around. He also lacks concentration. His interests are limited mostly to practical topics about farming and gardening.

Experience. Miroslav formerly worked in agriculture and also as a truck driver. He uses a dumb phone, watches TV, listens to the radio.

Call with the daughter. We talked to his daughter to ask regarding Internet connection in Miroslav's place. She expressed her doubts. According to her assessment of him, nothing similar to what we have created might catch his attention and interest. She related that he does not even focus when the family is presenting him pictures from a holiday, how much less what we were planning to introduce to him.

The entry visit. We had to use a cellular connection, and only 2G EDGE network was available in the area. It caused that the application was loading the content slowly. It was bearable, but the user experience suffered. We found him very talkative. Since the beginning, he was relating various stories from his past, his feelings, complaints, etc. Also, since the beginning, he was not much willing to participate. “*You know, I am dumb,*” he said. When we let him try, he had no difficulties touching the software buttons, nor pressing the tiny switch on-off button on the side of the device. But his lack of concentration on the content was apparent. Often, loose associations lead his attention astray. For example, one of the content items loaded during the

session was a folk song on which he commented “*Oh this is Šuláková, I know the singer, but she has died recently. I used to listen to her when I was living in, ...*” and he completely lost any remaining attention to the video being played and continued talking about his various experiences. There was not even one case when he would be paying attention to any item for more than just a few seconds. We assume that our presence might have been a distracting factor. After about 30 minutes he started complaining that he started feeling a sharp pain in his chest. “*Oh see – I am really a scrap. And this (referring to the tablet) is just making me feel worse. My chest is in pain. I really can't participate in this. Take it away.*” We did not push our attempts forward any longer. Instead, we called the daughter and asked her what shall we do if he is complaining of chest pain. We were worried that it might be a cardiac arrest or some other serious condition. The daughter told us, that this is his standard behaviour and that most likely there is no need to worry. We just stayed with him and listened to his stories. After a while, he said that the pain has gone.

6.2.2.2 Květa, 85

Health. Květa has rheumatoid arthritis and severe heart problems which significantly limit her mobility. After a few tens of steps, she starts catching her breath and has to rest. But mentally and emotionally she is in good condition.

Life and the family. Květa is living in a village together with one of her daughters. But, as we found during our visit attempts, the relationship with the daughter is far from perfect.

Experience. Květa worked in agriculture. She has never used any smart electronic devices. She only uses a dumb mobile phone.

The entry visit. When we came to present the application, the daughter appeared instead. She was quite in a bad mood, not feeling well physically and she mentioned, that they quarrelled today with her mother and that she has to calm herself down by a physical work in the garden. We understood that it was not a good time to pursue our goal to involve Anna in the trial. We made one more visit at their place, but it was also not successful. Květa was not feeling very good this time, and the daughter was again not supportive. So, we were not able to involve her. Květa left on us an impression as a wise and intelligent lady. The attempts have taught us a lesson about the importance of the immediate social environment of a senior.

6.3 SYNTHESIS OF THE FINDINGS

The trial has been conducted as in-depth usability testing, which is one of the methods from the in-depth human-centric design toolbox (3.3.3). During the trial, we combined semi-structured interviews, informal dialogues and user interaction data collected by the system. We found the methods relatively easy, but also time-consuming at the same time, because a significant amount of time has to be dedicated to each of the participants. Answers to the formulated research questions based on the synthesis of the collected data follow. Because of the sample size and because the selection of participants can't be considered unbiased, any possible generalization of the results requires caution.

6.3.1 USABILITY OF INCLUSIVE SOCIAL SOFTWARE

Question 1: Can even seniors with limited or almost missing previous experience with any digital technology start using inclusive social software, supporting them with only a minimal level of assistance?

The result. A big majority of participants in our trial found the prototype easy-to-use. Major usability-related complaints aimed the hardware rather than the program. Usability was also affected by Internet connection issues. Some participants suggested extensions to the program functions, which further support the conclusion, that the implemented features did not feel too complicated. Table 3 provides an overview.

The participant	Usability Complaints	Other Function Requests	Usability Praises	The Conclusion
Iva, 57	missing back function the program does not remember sound level settings	morning welcome reminders deferred playback	the concept makes the program easy-to-use the interface is intuitive pressing just 'next' feels extra	easy

		sometimes she wants more control over contents	easy	
Věra, 82	problems with touchscreen ³⁹ problems with hardware buttons she was indecisive at times about proceeding to a next item extra functions beyond 'next' and 'like' were too much small video controls labels an unclear indicator of voice level the absence of a mount or a proper place or space setting for sessions	-	eventually was able to operate the 'next' and 'like' buttons with no apparent problems and was able to focus her attention on the contents rather than functions or interface	undecided
Anna, 81	the experience was affected by issues with Internet connection	would like to have a bit more control over contents deferred playback	found it very easy and intuitive	easy
Věra, 93	felt a bit lost when the program went into offline mode upon Internet connection problems	deferred playback battery level indicator connect a family album morning welcome weather forecast would like to have more control over contents	found it very easy and intuitive likes the function which allows selecting a type of material	easy
Věra, 78 and Věra, 53	struggled with charging and complained that there was not a sufficient indication of the battery level did not have a proper stand or mount for the tablet	-	found the program intuitive and easy-to-use prominent, legible and clear controls	easy
Josef, 78 and Květa, 75	does not like the material substance of a tablet in comparison with a printed magazine, it is not pleasant for holding	would need more control over contents	found the program intuitive and very easy-to-use	easy
Ludmila, 82	had a problem to understand the concept of infinite content supply and at a certain point, she thought that the supply of contents had been depleted small video controls labels would like to have a screen lock for travelling with the tablet	back function more educational content more content about history	found the program easy-to-use commended the audiobook function, especially the big font used for the text display.	easy
Anna, 73	the indication of the Internet connection state was not clear enough for her, so she did not understand that she is offline	a button which would turn the Wi-Fi directly from the program interface, so there won't be any need to access settings a better indication of connection state remote access to technical help	besides the problem with the Internet connection, everything else was clear and easy-to-use	easy

39 Upgrades during the trial mostly solved these problems.

Miroslav, 83	said that he is dumb and that any such electronic device is just too complicated for him – but the barrier was rather emotional	-	understood the controls and the whole interface quickly and had no apparent problem	difficult
Květa, 85	-	-	-	not tested

Table 3: Perceived ease-of-use

6.3.2 BENEFICIALITY OF INCLUSIVE SOCIAL SOFTWARE

Question 2: Is the inclusive social software concept as prototypically implemented subjectively beneficial for seniors?

The result. A big majority of participants found the prototype beneficial. There were some complaints about a non-relevant or unpleasant, or boring content. Some participants also concluded that other activities kept them busy, so they did not use the program much. But mostly, they found the content interesting and relevant, and sessions with the program made them feel relaxed or energised. Table 4 provides an overview.

The participant	Perceived Benefits	Complaints	The Conclusion
Iva, 57	relevant content mostly helped if feeling exhausted or emotionally down helped when could not sleep	sometimes an unpleasant content being served might lead to addiction	beneficial
Věra, 82	helped her to reminiscence helped to reveal topics to talk about made her feel both soothed and energised	made her feel anxious when facing problems with usability (mainly at the beginning)	beneficial
Anna, 81	raised her interest in technical devices made her feel relaxed	gardening, TV, reading printed books, and crosswords remain as her main means of relaxation	beneficial
Věra, 93	likes the idea of rating contents and gradual adaptation to her preferences likes being surveyed about her feelings videos and audiobooks were relevant and interesting	she would prefer having contents from her family included found exercise videos boring	beneficial
Věra, 78 and Věra, 53	widened their horizon of interests found sessions really enjoyable Věra Jr. felt energised and joyful after watching they even regretted that do not have a permanent Internet connection	made them quarrel about who will be using the tablet and which content to keep playing and which to skip	beneficial
Josef, 78 and Květa, 75	he liked the overall idea several videos interested him	the content was not sufficiently relevant he prefers other ways of relaxation, such as reading a printed magazine, or a physical activity	undecided
Ludmila, 82	liked most of the contents – music videos, documentaries, artistic videos and even exercise demonstrations – she found them educational and practical felt good, relaxed, entertained, and educated the program is good for the times when she is resting on the bed in the evening or at night.	lives an active life with many activities including helping relatives and others, which keeps her busy, so she does not have much time remaining for any entertainment she knows how to access Internet content directly, so an easy-to-use program does not bring a significant additional benefit	beneficial
Anna, 73	liked nearly all content	worried about privacy	beneficial

	even after a few days she was still able to recall what did she watch or saw and what did she like about it	prefers reading books on her own than listening to an audiobook	
Miroslav, 83	-	he did not see any clear benefit	not beneficial
Květa, 85	based on our preliminary explanation, she found the concept interesting and potentially beneficial for her	not possible to involve her because of unsupportive family	not tested

Table 4: Perceived benefits

6.3.3 OBSERVED SENIORS' CHARACTERISTICS AND RELATED SOFTWARE DESIGN IMPLICATIONS

Question 3: Which implications for further development of an inclusive social software (and, perhaps, for senior-friendly software in general) can be derived by in-depth human-centric usability testing and how such testing may further understanding of seniors' needs and limitations?

Intentionally we have selected participants with different backgrounds, health conditions, family situations and experiences. Interviews, observations and user interactions with the program have shown, that the subcategories the participants represented were reflected in differences in their feelings, needs, their perception of the program, its contents and functions and the way they handled it. But on the other hand, the previously identified clusters of deep needs were relevant to all participants, even those whom we were not able to involve in the trial. Also, there were common patterns in the interaction data gathered by the system.

Potential impacts of inclusive social software. Klímová et al. (2016) synthesise works of Formosa (2013) and Rain & Svarcova (2010) into methodological principles which might help older people to overcome the barriers which do not allow them to use the Internet. They include motivation, general identification with terminology, basic principles, practical use of the particular Internet service, and regular use of the acquired computer skills. Our trial has shown, that the barriers might be eliminated not just gradually, but even dramatically by appropriate products. By the means of appropriate technology, seniors might be able to renegotiate their role in the society, become more respected source of experience and mentorship for younger generation, refresh their family role, exploit their potential as a workforce, etc., effectively reducing the generation gap as one of the dimensions of society fragmentation and instability and with impacts on well-being or health. To understand the exact impact, more research is needed.

Additional observations. Besides the aforementioned findings regarding usability, suggested functions, perceived benefits, and complaints as well as characteristics of seniors presented in answers on the first two research questions, the following additional observations were made; some might be formulated as questions or hypotheses for follow-up research:

- Iva, 57 has mentioned that the 'next' button may support impatience and might even lead to an addiction.
- Věra, 82 has helped us to understand, that the model of the Main System Provider has to acquire more intelligence to be able to recognise skills of the user and choose proper time to offer new functions accordingly. It will require research to find appropriate algorithms.
- Věra, 82 also helped us to reveal, that more investigation will be needed to identify and prevent any potential for unwanted interactions. Though we adjusted the program behaviour in this regard during the trial, we still have to deal for example, with interactions which may lead to unwanted zooming.
- Věra, 82 helped us to identify a new usage scenario where a caregiver or a family member uses a tablet at a session with the aged user. It helps the senior to reminiscence on his memories. They both may reveal new topics to talk about.

- Anna, 81 helped us to see, how an effortless experience may help a senior to overcome his negative feelings. This effect and similar effects might be further examined with the help of our model of appropriation.
- Věra, 93 and Ludmila, 82 have demonstrated, that age does not necessarily matter. Věra, 93 surprised us with her explorative nature, healthy self-confidence and broad scope of interests. Ludmila, 82 with her many others-oriented activities and a busy schedule.
- Věra, 53 has shown, how the proposed system might be beneficial for users suffering from major psychiatric disorders. A follow-up trial aimed at this category of users might be organised.
- Josef, 78 helped us to reveal the limitations of tablets in comparison with printed materials. It highlights the importance of flexible displays⁴⁰ and other hardware advancements.
- In the cases of Květa, 85 and Věra, 93 we could see, how the family may influence the chances of seniors to benefit from the technology, both negatively, and positively.
- Miroslav, 83 has taught us, that regardless of any efforts, there might be impenetrable mental barriers.
- Several participants indicated that we should reconsider the video controls – the size, shape, colour, labels, and also the related sound level indicator. Research could help to come to an optimal solution.
- We observed, how participants were adopting different strategies to deal with problems which arose during the testing. For example, Internet connection issues caused that the content was loading slowly, some started touching controls with a high frequency or with increased pressure (Věra, 82, Anna, 73). If something went wrong when we were not present, some participants called for our technical support (eg., Věra, 78 and Věra, 53), others started exploring the tablet functions in an attempt to find out what is going wrong and used the call as a last-resort option (Věra, 93).
- Some users started losing their confidence, thinking that they must have done something wrong and applied various strategies to deal with the issue.
- Several participants had problems with the hardware. It included issues with charging, with small hardware buttons on the edge of the tablets. These issues will have to be examined and addressed appropriately.
- Sometimes there was no suitable and comfortable place to use the tablet in the participant's home setting. Neither holding the tablet with a left hand nor having it placed on the lap was adequate for some. In their case, a requirement for a pleasurable experience is to have a proper mount or stand, where they could easily place the tablet and use only one hand to operate it.

6.3.4 DISCUSSION AND POSSIBLE FURTHER RESEARCH

Though we specifically instructed participant to be realistic and objective in their answers and assessments and not try to please us or make an impression, still the results might be affected by the way the trial was conducted – in a friendly, positive and assistive atmosphere. A more strict arrangement of the experiment would possibly lead to less positive results. Also, the selection of participants was not random and not chosen to form a statistically relevant sample of the target group. The introductory interview, as well as any further contact between participants and researchers, might have influenced the result. That's why the trial course is described in detail, involving every such interaction, so other researchers may analyse the data from their own perspectives and possibly argue. To make more firm conclusions, more data would be needed – either we would need to observe the participants in a more extended run, or involve more. A possible approach for the subsequent analysis would be to set dimensions, such as experience, health, and family situation, then rate each participant based on the information we have gathered on a numeric scale and identify if they form specific clusters. Then analyse if there are similarities in needs, feelings,

40 An example of a flexible display is a PaperPhone (Lahey, Girouard, Burleson, & Vertegaal, 2011)

perceptions of the program, and interaction patterns within these clusters. The following two hypotheses are set for further research:

1. *Inclusive social software can open up the access to digital services to the digitally-illiterate users, including seniors.*
2. *The concept of inclusive social software is technically and economically viable, including the necessary hardware.*

Further analysis. The data gathered during the finished trial may undergo further analysis. For example, we could try to examine user's likes and dislikes as well as the resulting like and dislike weights assigned to tags or total counts of different types of contents served from various content providers to identify common interests in the group. But also for this goal, it would be appropriate to gather more data first.

Prior- and after-trial self-assessment. The trial made us also think about a follow-up, where we would let users rate themselves prior and after in variables such as self-perceived skills regarding electronic devices, feelings toward the devices, or even the comfort sources revealed by our explorative research and used by the derived models⁴¹. Comparing the values recorded prior to and after the trial, we could assess the impact on their lives. Of course, the danger of various biases would have to be taken into the account.

Better in-trial self-assessment. The self-assessment survey which we involved in the trial had only one question which has been asked once in the morning and once in the afternoon. We found out that this way the survey did not give us precious feedback about the participant's perception of the program and the impact on his mood and feelings. It would be better to add a check-out function, which would allow a user to end a session deliberately. Upon checking out the program might ask the self-assessment question again. Then, we could easily compare the values recorded prior to and after each session and thus evaluate the impact of each session. We could even use these data to examine which type of content gives the best results, what is the optimal length of the session, or on which daytime the program can improve participants' mood most.

More rigorous participant selection. For the purpose of the trial, we simply kept inviting various persons who met the selection criteria until the desired amount of participants was reached. Existing social links (neighbours, acquaintances, friends of relatives, etc.) were used, which might be a source of an unwanted bias. A follow-up trial might work with a more specifically defined target group. Random participant selection or other methods might be used to avoid or limit the bias. Snowball sampling or similar selection methods may be considered too. Social stratification may be used to define the target group for the trial more precisely. The relation between socio-demographic characteristics (e.g. age, digital literacy either self-assessed or measured, health conditions and impairments, presence of other persons in the households, etc.) and perception of functions and content, overall assessment, and suggestions might be examined more thoroughly.

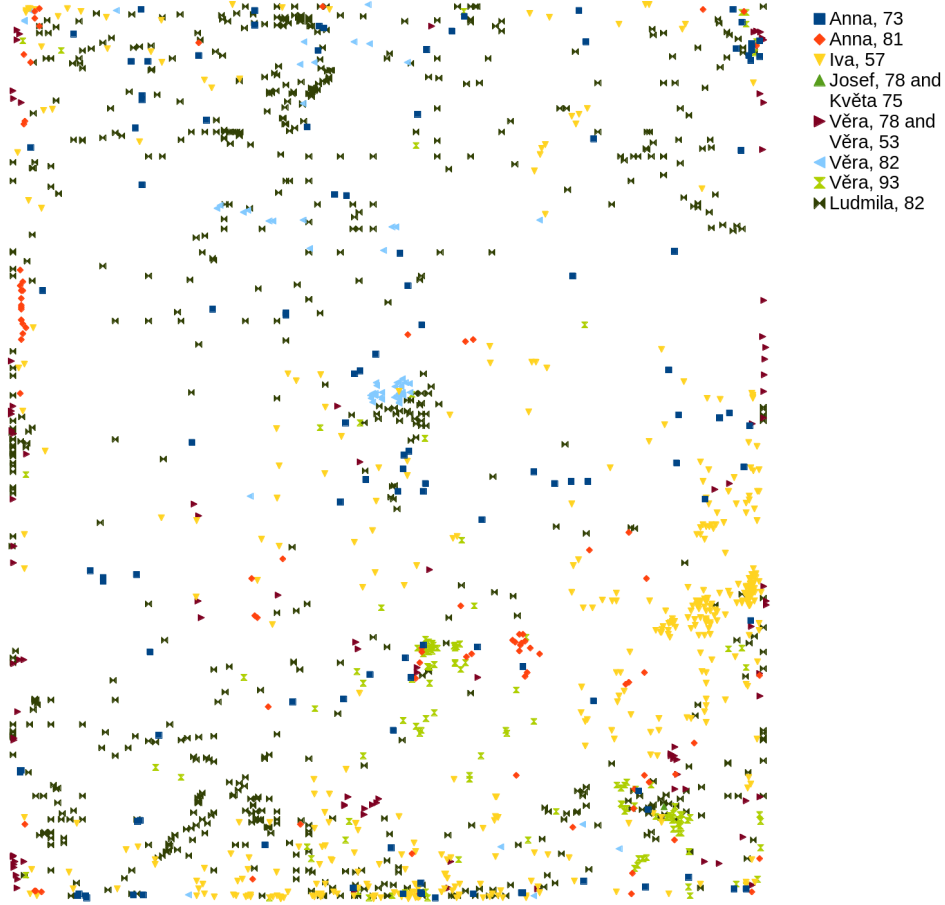
Analysis of bad interactions. The data gathered about users' bad interactions, i.e. touches on parts of the screen with no active control elements, may provide a foundation for further analysis. The two X-Y scatter charts (Figure 25) represent the whole tablet display area. Each point represents X-Y coordinates. The charts provide an overview in which areas of touchscreen the bad clicks occurred in both horizontal and vertical position.

In total, we recorded 781 wrong clicks in the horizontal position and 1689 bad clicks in the vertical position. Because some participants used devices with different screen resolutions, we had to transform the collected data to the same scale first. The data displayed in the charts illustrate the interaction of individual users. We can identify both *differences* and certain *common patterns*. Probably the most obvious is the high frequency of bad clicks around screen edges in the horizontal tablet position. It is most likely related to the way how users hold the tablet. Because the inactive frame was not wide enough, holding the tablet has lead to inadvertent touches. Majority of bad clicks in the central part of the display is likely related to explorative attempts of some users, e.g. Anna, 73 for the horizontal orientation and Ludmila, 82 for the vertical. A visible cluster of bad clicks of Iva, 57 close to the right side of the tablet in the vertical orientation may be related to her multiple sclerosis. She complained (6.2.1.1) that sometimes it happened that she has lost the

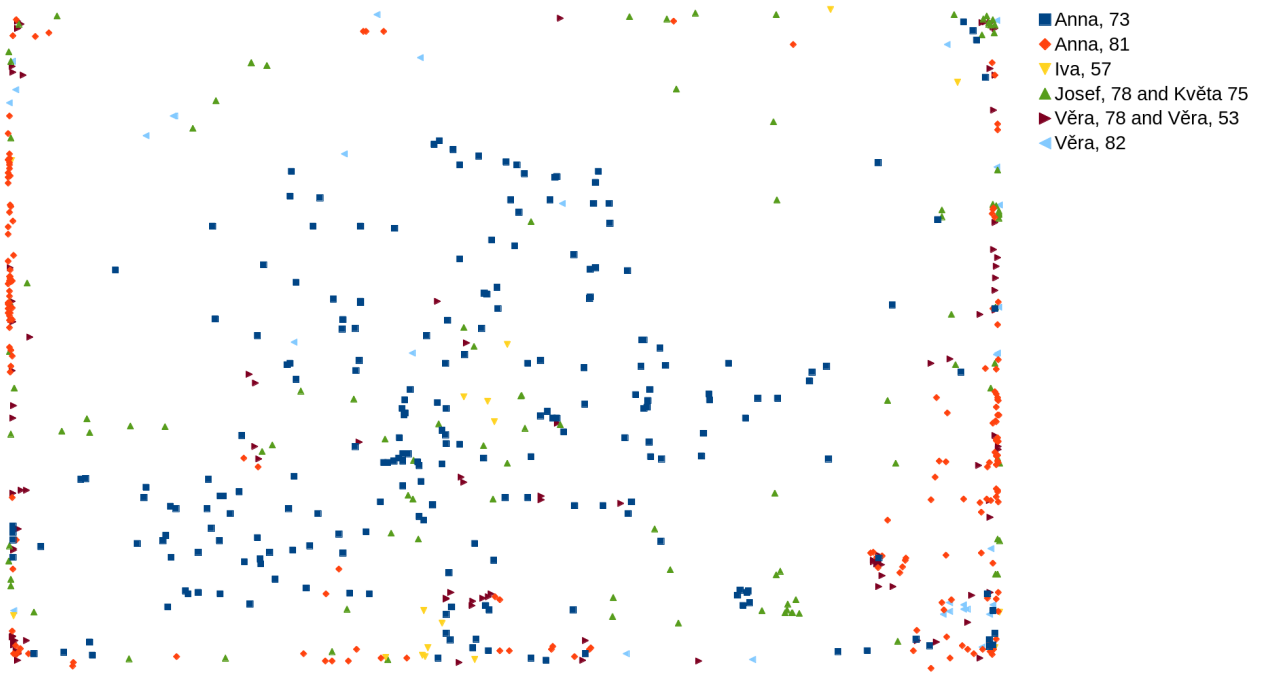
41 Social touch, autonomy with anticipated support, feeling of being competent, and helpfulness and self-worth.

control of her finger, which caused an inadvertent touch in the 'next' button. So, probably, she has learned how to hold her finger in proximity to the 'next' button, but not directly above the button, so the system won't interpret inadvertent touches as requests to load the next content. We can also see differences in the preferred orientation of tablets – some participants preferred horizontal, some vertical and some used their tablet in both orientations without any clear preference. Cluster of touches of Věra, 82 in the centre of the vertical orientation probably relates to the problems we had with the Google Chrome video autoplay policy, which caused that in some cases video playback did not start as we expected and user had to click on a play button generated by Google in the centre of the embedded element. The element was relatively small, so some users experienced problems touching it. In response, we updated the prototype program and also adjusted the Chrome autoplay policy on the testing tablets (11.2.8, 6.2.1.2). Věra, 82 was affected most by these problems, because she was one of the first participants involved in the trial.

An analysis of wrong clicks might help to adjust positions, sizes and other properties of control elements used by our prototype. If conducted more extensively, it could even lead to general suggestions regarding graphic user interfaces for touchscreen-based devices. We consider this as another *research opportunity* for the future. Bad clicks might be compared with correctly interpreted interactions. Eye movements monitoring might provide an additional insight. Relations between socio-demographic characteristics and interaction patterns might be examined.



Bad click coordinates - vertical tablet position



Bad click coordinates - horizontal tablet position

Figure 25: Bad click coordinates in both vertical and horizontal tablet position

7 RESULTS AND POTENTIAL

7.1 MAIN DELIVERABLES

The dissonance between available products and the needs of the elderly was thoroughly analysed and based on the findings, a concept of inclusive social software was proposed, its prototype implemented and successfully tested. Three results stand out as the main deliverables; Figure 26 illustrates how knowledge from various fields of science had to be combined on the course of the research.

1. On the conceptual level, dimensions of knowledge management were identified and *responsible knowledge management* was proposed, accompanied by the hypothesis, that its effect on economy objectives, in the long run, may be bigger than the impact of the traditional knowledge management.
2. On the practical level, *in-depth human-centric research and design* principles with a practical toolbox containing relevant methods, evaluated and ready to be applied in the knowledge management research and practice, as a contribution to the often lacking diffusion of knowledge management theory into practice,
3. On the application level, the proposal of *inclusive social software* together with its *well-designed and evaluated prototype* shows how appropriate software might allow seniors benefit from advancements of digital and knowledge society; in parallel, it serves as a use case of a practical application of in-depth human-centric methods.

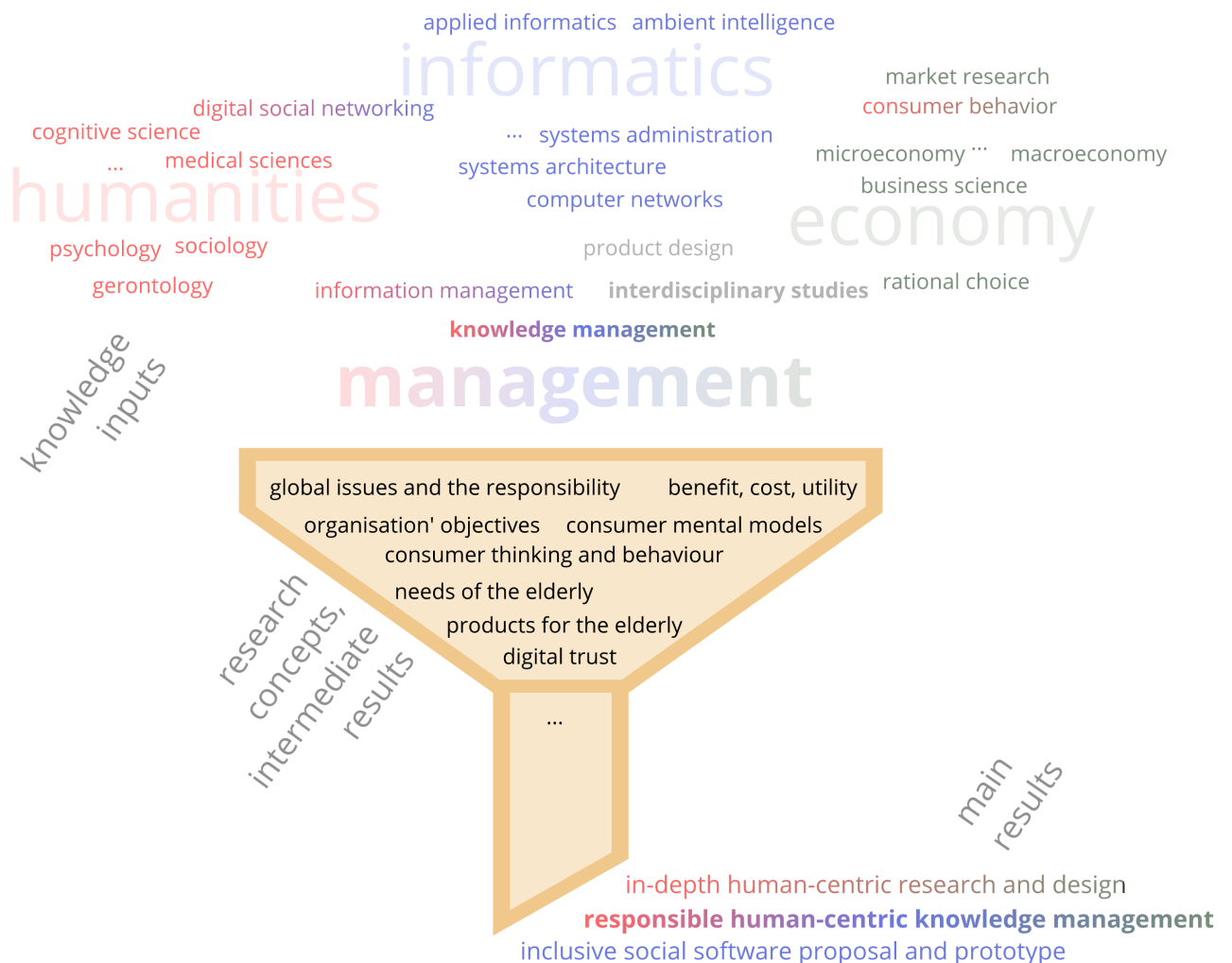


Figure 26: Multidisciplinary nature of the thesis and the main deliverables

7.2 RESULTS IN SPECIFIC RESEARCH AREAS

7.2.1 INSIGHT INTO CONSUMER'S THINKING

The goal of the first research area was to propose an extension to the human-centric design which would more tightly respect consumers' needs, feelings, and reasoning. The goal has been reached. The in-depth human-centric design, a novel research and engineering approach has been introduced on the foundation of other available theories and human-centric design approaches. The novelty of the proposal lies in its emphasis on subtle psychological determinants and forces behind consumer reasoning about products. It emphasizes what we call deep needs of users rather than the product. In addition to the conceptual proposal, a toolbox with recommended methods has been defined.

Which theoretical foundations could be used to describe consumer's reasoning about a product? Both behaviours-centric and emotions-driven approaches put humans in the centre of attention in the process of product design. The rational choice theory and cognitive science each provide relevant insight, each from a different perspective. The rational choice theory is more formal and normative which makes it more suitable for situations with conscious decisioning. Cognitive science is more descriptive and helps to reveal and understand how we indeed think and behave, including many of the inconsistencies, biases, flaws in our reasoning.

Which specific applicable concepts can be identified in the underlying theory? Product evaluation has its internal structure – it may be split into conceptually different consequential phases, consisting of smaller or shorter steps. Relevant concepts from rational choice theory involve rational comparing cost and utility or benefits (both expected and experienced) and comparing the cost/utility ratio of competing options. Relevant concepts based on the cognitive science theory involve steps of evaluation, anchors or reference points, gradual adaptation, two parallel chains of reasoning, and simplicity in reasoning reflected in the applicability of linear models.

Which distinct product evaluation stages might be identified? At first, a product has to pass the acceptance stage – attract attention and motivate to try or purchase it. This stage is typically relatively short and involves more rationality. Then, in order to become an integral part of the user's life, the product has shown its benefits soon and provide sufficient flow of perceived benefits to beat gradually induced boredom and other negative forces. This appropriation stage may last for days. Successful products have to pass both stages, and all individual steps within the stages. A failure anywhere on the way drives the product away from the scope of user's interest, which effectively means its refusal. In the beginning, rational reasoning together with shallow and temporary emotions, such as visual appeal, curiosity or euphoria drive the process. But later, in the appropriation stage, the product has to be pulled forward by reinforces, resonating with user's deep needs. Both evaluation stages have been examined more in detail beyond the thesis in respective research papers.

Which implications for product design might be derived from the deeper knowledge about consumer's thinking? A product has to be perceived beneficial, reachable, and the best choice out of the available competing options to become accepted by a consumer. And to become an integral part of the consumer's life, it has to succeed in the process of appropriation, where initial short-term emotions, such as enthusiasm, grow gradually into a habit. Initial enthusiasm may be influenced, e.g. by the way how the product is being introduced. The optimal level of enthusiasm may be surprisingly lower than what we expected. Products have to respect the diversity of feelings, needs and skills of the target group.

Which methods may researchers, designers, engineers or knowledge managers use to understand consumers better? In-depth human-centric design toolbox recommends, for example, in-depth explorative research, in-depth modelling, collecting ideas, in-depth user testing, and in-depth usability testing. Beyond the thesis, we outlined models of mental processes, which, being used together in a chain, cover the reasoning from the initial decision to the final appropriation.

7.2.2 INCLUSIVE SOCIAL SOFTWARE PROPOSED

Three goals were set. (1) To deepen the understanding about needs of the elderly in relation to the information technology which might contribute to the better satisfaction of the needs. (2) To propose a kind

of software which would harmonize with the needs. (3) To practically evaluate relevant in-depth human-centric design methods proposed earlier. The goals have been reached. First, we performed explorative research on deep needs of seniors. As a result, we have revealed four interrelated clusters of deep needs of the elderly. Then, market research has been performed in order to examine how well available products fulfil the needs and their strengths and weaknesses. The synthesis of the findings led to the proposal of inclusive social software, a kind of software with the potential to harmonize with the revealed needs of the elderly. In the context of the analysis of requirements on the software to meet the needs of seniors, we discussed terms often used interchangeably, such as social media, social networking site, social network, social networking software, etc. The systems, though called 'social', sometimes even put people apart and widen the trenches of misunderstanding. So, in the reflection of the in-depth human-centric design principles, we suggested a term inclusive social software for the type of software, which rather than merely providing communication means, helps users to rediscover topics to talk about and to understand each other again. Then we identified areas in which software should accommodate to seniors and their cognition.

What are the essential needs of the elderly which information technology might help to satisfy? Among youngsters' deep needs, power, identity, and fragmentation were identified by other researchers. We used this research as a reference. For the group of the elderly, our research concluded in four interrelated clusters of deep needs: 1. social touch, 2. autonomy with anticipated support, 3. feeling of being competent, 4. feeling of helpfulness and self-worth. The knowledge about seniors' needs and feelings may help to come up with beneficial products. For each of the clusters, we provided relevant guidelines for designers.

How are the available products and services in line with the revealed needs of the elderly? According to available statistical figures, seniors are increasingly interested in digital content and increasingly involved in digital socialising. But, on the other hand, they are still sidetracked in comparison with the younger generation. We examined available social networking sites, mobile applications, and smart electronic devices claiming to be tailored to seniors' needs and briefly assessed, how closely they match the true needs of senior users. General purpose social systems promote rather shallow relations. User interfaces of many systems are too complicated, do not harmonise with thinking patterns of seniors, or do not respect their limitations. Systems designed for the elderly may, on the other hand, underestimate mental or social skills of users and stigmatise. Systems which would allow the elderly to live in a home setting more independently, feel more capable, and keep in contact with their close would be likely highly welcome. As a part of the market research, we paid special attention to two service providers and systems integrators, whose products and solutions seem to be most promising. Market research revealed significant dissonances in what seniors need and what many products, even those intended for them, indeed offer. Though a lot of work has been done, there is still a great market opportunity for innovation.

Which qualities should a software possess to satisfy the needs of the elderly users and respect the variety of their cognitive, sensory and motor impairments? The software should provide a simple, reliable, adaptive, self-explanatory, consistent, accessible, unobtrusively assistive and guided user interface. Its functions should respect the appropriate mental models of senior users regarding media consumption, metaphors, and interaction patterns. Not only user interface should be adaptive, but also the overall architecture should be extensible to adapt to the variety of interests, skills, and needs of individual users from the target group. Various online services potentially beneficial to the elderly exist, but they are not accessible for many of them because of complicated and not fully consistent user interfaces, based on non-familiar metaphors, and because of other reasons. They may be integrated behind a consistent novice-friendly facade. With deployment on the mind, the system should also be designed as easily scalable. Social-oriented products should leverage existing relationships instead of supplanting them or building new ones. Supportive technologies tend to increase a negative feeling of dependence; seniors should feel that they are in control of the technology. On the other hand, easy-to-use pervasive communication devices could increase positively perceived emotional and anticipated support. To support the important feeling of competence, a disruptive approach might help to reduce barriers seniors often face when they try to benefit from technology-rich services. Software functions should reflect appropriate media consumption strategies. Even seniors in physical or cognitive decline should be treated as active participants in society rather than needy and dependent. Innovative products might help seniors rediscover their role and remain a vital part of the community.

7.2.3 INCLUSIVE SOCIAL SOFTWARE PROTOTYPE DEVELOPED

Two goals were set. (1) To experimentally develop an inclusive social software in harmony with the proposal. (2) To evaluate relevant in-depth human-centric design methods. Both goals have been reached. During the experimental development, not just in-depth human-centric principles and methods, but also general good design and development principles were systematically and consistently applied. Though still in its prototype stage⁴², it might eventually reach production. Not just the prototype application itself, but various creative ideas and innovative technical solutions may be considered as an output of this stage.

Which functions and services might an inclusive social software provide? It might serve as a highly-personalized universal gateway to virtually any kind of digital content and services, including digital media consumption, practical services (shopping, finance, health, etc.), communication and collaboration, or even content creation. But, in contrast to the widespread trend of adding functions, the program should offer as little functions as possible to its new users; then it should grow with the user, gradually learn and reflect user's preferences, requirements, as well as his limitations. Instead of being accompanied by external user documentation, it should guide the user directly, gently and with respect. In result, new users, even those not acquainted with information technology at all, should be able to start using the program almost immediately and gradually learn, exploring and unlocking its functions. It may require to involve traits, components and algorithms of a knowledge application, such as a knowledge base, information repository, agent technologies, etc. Function areas considered during the prototype development involve e.g. an appropriate content granularity, adaptive relevance of content to the user, navigation and feedback, content creation, intra-system and cross-system interactions, safety and security.

Which principles should be considered when developing a user interface for the elderly users? A user interface is undoubtedly one of pivotal parts of any software aiming the elderly. Making user interface senior-friendly does not merely mean bigger buttons. It may require a radical redesign, to respect users' problem-solving strategies, their experiences, patience, etc. Common and omnipresent concepts such as menus, navigation bars, sliders, etc. might not be suitable. Various problems may also arise with the hardware aspects of user interfaces (response and interpretation of strokes on a touchscreen, size of hardware buttons, connectors, the positioning of the client device, etc.). Heterogeneity of the target group requires to involve more participants in user interface testing. In summary, a senior-friendly user interface should be simple, reliable, adaptive, static, self-explanatory, unobtrusively assistive, consistent, accessible, generous, and guided. Various modalities may be considered.

How various methods from the in-depth human-centric design toolbox can be applied and combined in a software design project? The experimental prototype development has shown, how a software development project may be firmly based on revealed deep needs of its target group. Further, in harmony with the in-depth human-centric design principles, we intensely applied creative methods and involved real users since the pre-development stage. It involved e.g. collecting ideas, wireframing, a focus group, a brainstorming session, a game session.

Which technologies to choose for an inclusive social software? The vision of inclusive social software is more likely to be fulfilled if it is implemented not as a proprietary product, but in an open way, as a platform inviting researchers, developers, content providers, systems integrators, to participate and jointly let an ecosystem grow. From this perspective, well-documented and respected open-source technologies should be preferred to proprietary, including the dependencies.

How to design the overall architecture of an inclusive social software? The extensible, multilayered architecture was strongly recommended. It will make it easier to combine both code and content – e.g. develop or adopt new content providers, content formatters, translation services, content classifiers, etc. The architecture of the prototype was carefully designed. It involved, for example, dividing the program into meaningful components with well-thought-of dependencies between them, defining communication interfaces between components and their collaboration, layers of code abstraction including but not limited to model-view-controller, identifying key objects throughout the system, implementing scalable and database-agnostic persistence, and layered self-recovery and error handling. Its architecture allows involving

42 Being in the prototype stage of development, we did not apply e.g. unit testing and similar methods to not affect the pace of the development.

a virtually unlimited variety of digital content sources; the contents may be systematically transformed (e.g. translated, classified, or automatically enhanced with additional data) and presented in a simplified way, which adapts to users' preferences. The user interface of the software grows with the user's capabilities, starting with a radically reduced set of functions, adding more gradually as the user learns more. Because the software is divided into a back end and front-end part, it is also possible to develop alternative viewers which may i.e. support users with more specific needs or preferences. We developed a default HTML-based front end. Its parts are intended to be executed in a browser as a progressive web application. Because it uses modern technologies, such as service workers, it provides basic offline functionality and look and feel almost like a native application.

How to deploy an inclusive social software? Scalable and flexible architecture regarding deployment was strongly recommended. The program should be ready to run in various environments, from a small-scale single-server scenario to a load-balanced multi-server or cloud scenarios, both able to support dozens of users. During the prototype development, deployment was considered significant and it led to various useful results. For example, shell scripts have been developed to automate the creation and deployment of web applications running in Web2py framework⁴³. Other deployment-related areas involved setting-up support for SSL communication and specific configuration of Apache web server. Deployment may involve not just the server-side. To perform the in-depth usability test of the prototype, suitable client devices had to be selected, purchased and prepared for the trial.

7.2.4 LESSONS FROM THE IN-DEPTH USABILITY TESTING

Two goals were set. (1) To let users who suffer certain cognitive, sensory, or motor evaluate the prototype in regards to the perceived benefits and ease-of-use. (2) Further evaluate the relevant in-depth methods, namely the in-depth usability testing method. In harmony with the in-depth human-centric design principles, users were involved since the beginning of the development, starting with a focus group. The involvement of participants gradually increased during the in-depth usability testing. Eventually, the testing involved 10 participants aged 53⁴⁴ to 93 with an average of 75; two others were not able to participate or refused. An in-depth usability test was conducted, including semi-structured interviews and observation in combination with the data about users' interactions gathered by the system. No statistical methods for data analysis were used.

Is the developed prototype perceived as beneficial and easy-to-use by the involved participants, thus has the concept of inclusive social software potential to become beneficial for the elderly? The prototype was almost unanimously perceived as beneficial and easy-to-use by our participants.

Which functions and content are the most important and/or interesting for the participants? Participants made positive claims about the benefits. For example, using the program helped a participant if he was feeling exhausted or emotionally down, when he could not sleep, to reminiscence, to reveal topics to talk about, to feel both soothed and energised, relaxed, raised interest in technical devices, widened the horizon of interests. Participants liked the idea of rating contents and gradual adaptation of the program and found the content relevant and interesting. Some liked to be surveyed about their feelings. Some recalled the content even after a few days. Some, who never used the Internet before, regretted that do not have a permanent Internet connection and that the trial has a limited duration. In general, participants liked all categories of content provided (music and videos, pictures, audiobooks) and participation made them feel relaxed, entertained, and educated. Regarding the feedback we gathered for the prototype development, some of the findings and suggestions have been already implemented during the trial. But the rest is still awaiting its implementation in the future.

Which challenges the participants encountered during the trial and which strategies did they use to deal with them? Though not severe enough to discourage the participants or ruin their overall impression, certain usability-related problems emerged during the trial. They involve problems with the hardware. Relatively

43 Web2py is a Python-based web application framework which we used, together with other open technologies, as a backbone for our system.

44 The age of 57 might seem too low to fit in the category of the elderly. But, we opted for a wide definition, which highlights not the age itself, but the health and self-perception.

common were problems with the touchscreen response, and interpretation of strokes; some caused by tactile, cognitive or motor impairments, some probably by a low electro-conductivity of dry skin. We also came across problems with tiny hardware buttons and charging connectors. One participant did not like the material substance of a tablet in comparison with a printed magazine. Regarding the software, though the program used relatively big partially-adaptable software buttons, some participants still complained that they were too small. For one participant any extra functions beyond simple 'next' and 'like' were too much, caused that he become indecisive; others, on the other hand, required more functions and controls. One had a problem to understand the concept of infinite content supply and at a certain point thought that the supply of contents had been depleted. Though the program was able to operate in offline mode, connectivity issues led to confusion at times. The surrounding environment also played a big role - some participants did not have a comfortable chair or table to use the device; absence of mount or stand was also a problem for some. One of the two who refused to participate said that he is dumb and that any such electronic device is just too complicated for him; more likely it was rather an underestimation and wrong self-assessment. In the summary, more problems were related to the hardware, underlying operating system and the environment, than to the developed prototype. It shows, that developing a program suiting the needs of the elderly might not be enough if other dimensions, such the deployment on the client side, hardware issues, and physical environment, are not taken into account.

What else can we learn about seniors from their interaction with the software and from their impressions? With the help of in-depth human-centric design methods, we may further extend the knowledge about senior's problems, perception, needs, aspirations, etc. For example, further analysis of interaction attempts which were not understood by the system ("bad clicks") might become fruitful to reveal more about problem-solving strategies and about the cognitive adaptation when a user is learning how to operate a product.

How homogeneous or heterogeneous group do they form in regards to their needs, values, opinions, abilities, or habits? The trial supports the assumption, that there are significant differences between skills, needs, and habits of seniors, so they should not be treated as a homogeneous group. On the other hand, some common patterns also appeared, though, we would need more data to examine them thoroughly.

Do the proposed in-depth human-centric design methods prove their practical value for the processes of product design and development? The experimental application of in-depth human-centric research methods deepened our insight into the needs of the elderly and new ways how information technology might help. It involved both expected and surprising findings. Followed by the experimental application of in-depth human-centric design methods, our research eventually resulted in a promising software prototype.

How the research, from its explorative stage to the usability trial, demonstrate the potential of knowledge management to deal with the current society-wide problems and challenges? The trial with the prototype as a particular deliverable of our research demonstrated how knowledge management may not only lead to products with commercial potential; but, if applied in a responsible manner⁴⁵, it may lead to results beneficial for the society as a whole, for example reversing its growing fragmentation and isolation.

7.3 FURTHER RESEARCH POTENTIAL

The content of chapter 3 summarizes findings published at conferences and in scientific journals⁴⁶. Most of the research is still awaiting further publication. The detailed description of the in-depth usability test setting and procedure (chapter 6) as well as detailed technical description of the developed prototype (appendices 11, 12, 13) allow other researchers to repeat our steps and falsify or validate our findings (Popper, 1959). In addition, we have already identified exciting areas for follow-up research. They are briefly presented below.

7.3.1 THE POTENTIAL IN THE AREA OF UNDERSTANDING CONSUMERS

Subsequent research, either conducted by the thesis author or by other researchers, might build upon the results achieved so far in the area of consumer's feelings and behaviour. The following paragraphs provide a

45 Refer to the section 1.2.2.

46 Mostly they are listed among publications in 10.2.

brief outline of the potential research paths. It involves extensions and refinements to mental models of product evaluation (Zejda, 2011c, 2012), which were mentioned only briefly in the thesis.

The in-depth human-centric design. The in-depth human-centric design concept may be further examined and extended in various ways. Heterogeneity of target user groups makes the design and engineering more complicated. Explorative methods may be used to reveal the deep needs of various target groups of consumers, either falling in broad definitions, such as youngsters, or more specific, such as people with a certain impairment. Then, with deep needs of different groups of people identified, relations between the groups may be examined. Methods from the in-depth human-centric design toolbox may be evaluated more thoroughly in experimental applications. More relevant tools matching the in-depth human-centric design principles may be suggested and examined. So, the in-depth human-centric design may further contribute to both the basic and applied research, and experimental development.

Formalisation and evaluation of acceptance models. The acceptance models have been defined based on the general principles of the economy, but their parameters have not yet been set. To formalise and evaluate them, it will be necessary to perform experiments with real users. The experiment should be divided into two stages – formalisation and validation. For example, at the beginning of the first stage, each participant would be asked to assign weights to the comfort sources defined by the model⁴⁷. Then, a prototype of a relevant product would be quickly presented to him and he would be asked if he would accept the product or not. Then, he would be asked to estimate, how the product might influence his comfort sources, the answer on a numeric scale would be recorded. Similarly, he would be asked how much resources⁴⁸ is he expecting to invest to adopt the product. The data collected – variable estimates and the real acceptance outcomes – would be used to choose specific model functions⁴⁹ and their parameters. Then, the same data would be gathered from more participants. But this time, the model would be used to estimate the acceptance result based on the input variables and the results would be compared with the real outcome. Proper measures should be taken to minimise response bias⁵⁰ which might distort the results.

Formalisation and evaluation of appropriation models. Also, appropriation models should be formalised and evaluated. In the first stage of the experiment, each participant would be provided with a sample of a product and asked to rate model entry values⁵¹. Then regularly, preferably with a daily frequency, participants would be asked to rate the relevant processing variables defined by the model⁵². DREAM data collection methods (The Pennsylvania State University, 2015) could be applied to collect the subjective assessment. It could be combined with automatically recorded frequencies and characteristics of the participant's interaction with the product. As soon as the user reaches one of the final stages defined by the model⁵³, the data collected during the trial would be used to adjust the model parameters. As soon as the model combines data gathered from a sufficient sample of consumers, the trial may go into a second stage. In this stage, the model now with parameters calculated based on data from real users, would be used to *forecast* results of appropriation and its duration, based on initial data provided by new participants. Again, data from them would be collected. And as soon as they reach a final stage of the appropriation process, the real outcome of the process would be compared with the model forecast.

Further model refinements. Though the models have been founded in relevant theory, all have been constructed with intrinsic simplifying conditions. The conditions, on one hand, have allowed keeping the models simple and easy to understand, but on the other hand, they limit the coverage of the models and may even lead to misleading conclusions if applied carelessly. So, the models should be further extended and stratified for the variety of target groups, and types of products and specific situations. As an example of a simplifying presumption, even in the refined model of acceptance the exert function is still binary, so an aspect of life is either reachable or not, thus a partial adoption is not supported by the model.

47 As revealed in our explorative research, for the broadly defined group of seniors the comfort sources are social touch, autonomy with anticipated support, feeling of being competent, and feeling of helpfulness and self-worth.

48 For the group of seniors, we identified time, effort, and support as key resources.

49 As an example, an analogue of Cobb-Douglas production function, well-known in the economy, might be a good exert function for the model. But still, the experiment is needed to find representative coefficients.

50 The suggested experiment might be vulnerable for example, to question order bias.

51 In the current version of the appropriation model, the initial variables are initial enthusiasm and initial qualms.

52 Currently, the variables are a disappointment, bore, mastering, perceived utility, and level of appropriation.

53 Either appropriation or rejection.

Model implications. Further implications of the models might be identified. It involves, for example, examination of parallels between the rational-choice-theory-based model of acceptance with the underlying economic theory.

7.3.2 SCIENTIFIC POTENTIAL OF INCLUSIVE SOCIAL SOFTWARE

The research which resulted in the formulation of a new kind of software and to development of a functional prototype also bears a scientific potential. The prototype we have developed thanks to its versatility may help in solving some of the research areas mentioned in the previous sections. For example, it could be used for longitudinal research to evaluate models of appropriation. Selected particular areas for further research are briefly outlined in the following paragraphs.

In-depth usability testing. Involving a sufficient number of users, we might perform quantitative research in addition to the qualitative. In such research, factor analysis might be used to identify the structure of participants' deep needs, interests, abilities, and limitations. Their interest factors might be used as an input for cluster analysis to specify groups of seniors with similar deep needs, interests, abilities, and limitations. Each group could be examined by their socio-demographic characteristics. And, to find differences in their deep needs, interests, abilities, and limitations between the groups, factor analysis may be conducted again. We may also consider different usability testing methods, such as pair testing⁵⁴. With the help of the prototype, we could also compare the engagement of participants from different regions⁵⁵. Because the prototype is not limited to just one type of client device, we might use it to further compare the suitability of tablet, smartphone and computer devices for senior users.

Critical assessment of graphical user interfaces. We would like to use the prototype to evaluate various user interface guidelines, such as Material design (Google, n.d.-d), or Flat design (Apple, n.d.) from the in-depth human-centric design point-of-view. Actually, in our preliminary assessment of these guidelines, we have identified many flaws if it comes to aged and impaired users, but a thorough examination would be needed. A potential approach is hinted in the section which presents the data about wrong interactions of our participants during the in-depth usability trial. We could also use our prototype as a reference for usability testing of mainstream services, such as YouTube, Facebook, or Instagram with senior users. Usability testing might be performed – for example, we would present screenshots of the applications and ask participants to guess the purpose of each of them. Then give them simple tasks, record eye movement, measure reactions, and let them speak their minds aloud (“loud thinking”) to reveal thought processes. To add the in-depth human-centric design dimension, we should investigate more about impressions, feelings and satisfaction.

User interface modalities. The in-depth human-centric usability test concluded, besides else, that the used hardware was a weak point, some participants struggled operating the touchscreen or the tiny hardware buttons or connectors. Various available devices might be tested. Alternatively, novel hardware prototypes might be developed for the purpose. Position, size, feedback of buttons could be tested. Less common user interface modalities might be considered too. Suitable hardware in combination with suitable software would likely open the digital world to an even bigger group of users.

The role of the setting. We observed, that the ergonomics of the environment plays a significant role. Comfortable chair, suitable table, stable and adjustable mount or stand for the electronic device, light conditions, quality of the Internet connection, other people sharing the household influence the patience and endurance, the perception of software, etc. It is definitely an area worthy of further research.

Automated surveys. With a pool of regular users, the proposed system would provide a great tool to perform various statistical surveys. The relevant content providers, which allows to define survey questions and push them in the stream of content, has been already developed. So, the prototype may serve as a natural tool for application of 'dynamic real-time ecological ambulatory methodologies' aimed at collecting data about ongoing behaviour, experiences, physiology, and environmental factors in people's natural settings (The Pennsylvania State University, 2015).

54 A method when one participant is reading instructions and the other participant is fulfilling them. The approach is pioneered, e.g. by Pavlicek and his team (Rymešová, Benešová, Hradecký, Pavlíček, & Bock, 2013).

55 Namely, we are interested in involving more participants from the Czech Republic, USA, and the Philippines.

Creative science. In section 7.4, we have identified plenty of usage scenarios for the prototype, respectively for the type of software which the prototype represents. A creative exploration of these scenarios, by the principles of creative science, pioneered, e.g. by Callaghan (2013), might lead to valuable results. Work has been started already to evaluate the potential of the prototype for virtual travelling.

Automated usability testing. We might record patterns of user behaviours from either usability testing sessions, or from a productive usage. The user interaction sequences may be used to define vectors of behaviour. These vectors, if gathered in sufficient amounts, might be used to train a neural network. The trained network could be potentially able to either predict user behaviour on a user interface, intelligently validate user interface designs, provide feedback to designers, and rate their user-friendliness and other parameters. We might consider using for example, of apparatus of system dynamics (Forrester, 1971), techniques of analytic hierarchy process, abbreviated as AHP (Saaty & Peniwati, 2013), or its more specific variant analytic network process known as ANP (Saaty, 1996) to describe behaviour. It would be a challenging task, but with a potential to dramatically reduce the cost of usability testing.

The trial has shown other potentially fruitful areas for follow-up research, for example, a danger of seniors' addiction to digital media and its prevention, gradually-adapting intelligent user interfaces for seniors, the potential of digital content to revive old memories and to bridge social gaps, digital content as a supplementary therapy for major psychiatric disorders, automatic collection of data for an analysis of problem-solving strategies adopted by users, or impact of hardware, home, and social setting on senior's access to the digital content.

7.4 POSSIBLE APPLICATION SCENARIOS

Seniors with no doubt constitute a commercially important and especially in developed countries growing market segment. And if we include secondary segments, such as seniors' their family members and seniors-oriented service providers, we could easily assume, that we are dealing with a segment which potentially includes almost the whole world.

Kazimi explains which major potential benefits tablets and access to digital content give seniors. If we generalise his statements, the resulting areas are 1. social media, 2. access to information, 3. practical purposes including commerce, 4. entertainment, 5. health and well-being (Samsung, 2015). In addition to them, according to the in-depth human-centric design principles, we have identified a category of creative and fulfilling engagement.

In the following sections, we outline the ways how the proposed system might serve to cover the areas. In the last part, we discuss the potential of alternative user interface modalities. For most of the functions and scenarios discussed below the prototype would have to be extended. It would typically involve development of new content providers or new supplementary services. But none of the scenarios would require a significant change in the overall system architecture, which has been designed to allow a very flexible usage.

7.4.1 SOCIAL MEDIA FOR SENIORS

Intelligent tracking of family members. Whereas the elderly most likely don't wish to feel monitored⁵⁶, some might like to follow the lives of their children and other relatives or close friends. So, the system might collect geolocation data from travelling family members' gadgets and present them to the senior user. The mere location data might be automatically *enhanced* on the back end with additional information pulled from external sources, such as a map, location-related pictures⁵⁷, or location-relevant weather. Other relevant sources might include family members' Facebook posts, Tweets, etc. This enhancement approach would help to solve the common difference in the preference of frequency of communication between seniors and their active children. Family members may be too busy or distracted with other activities. It makes the frequency of their contact with seniors lower, which may be perceived inadequate by seniors. They, in effect, may be feeling lonely or abandoned. Appropriate algorithms might be used to increase the

56 Revealed in our explorative research summarised in 4.1.

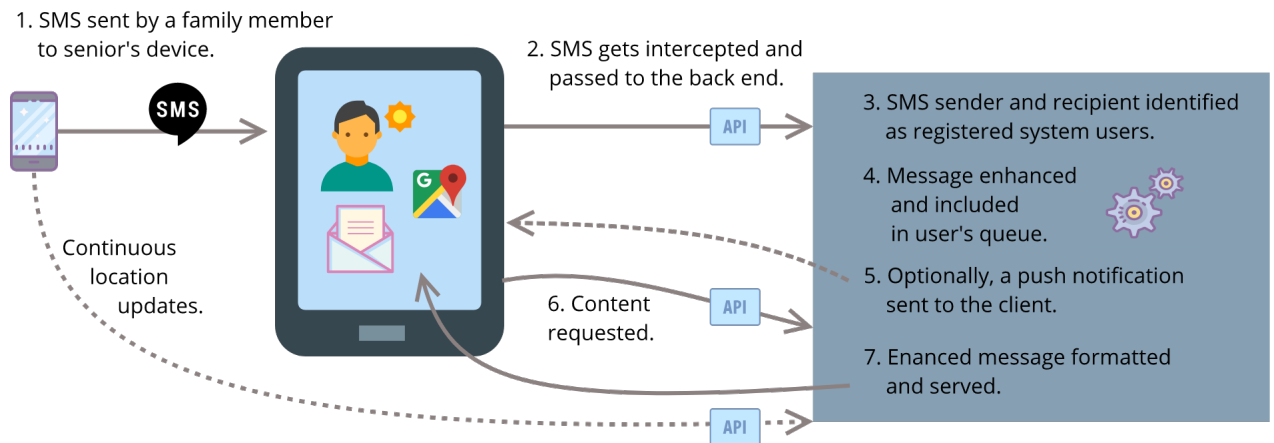
57 We may utilise geo-search services of content sources such as Flickr, or Wikipedia.

connectedness. For example, if the system reveals that a family member did not interact with the senior in any way during the whole day, it may politely notify. But even a message artificially created by the system with enhanced location data may make seniors feel more connected. Triggering of such automatic message may be geo-fenced. For example, the message would be sent only if there is a big distance between the family member and the senior, or when the family member's location has changed significantly during the day. The suggested semi-automatic approach might be perceived as advantageous by family members because it could improve the feeling of connectedness *effortlessly*.

*Virtual travelling.*⁵⁸ The idea is an extension of the concept of intelligent tracking described above. It refers to a scenario when a family is travelling to a remote place, typically for a vacation. Their aged parents may be intensely interested in their whereabouts, so they would like to follow the steps of their family in their tablets. In addition to the examples of sources of content which could be involved mentioned in the previous paragraph, also pictures taken by family members, uploaded to a cloud picture-sharing service, and analysed by image-recognition technology could be used. Seniors, be automatically informed about the places the family members visited, relevant weather, maps, distances, descriptions of the places with highlights, could feel as if travelling with them. It also perfectly fits our definition of inclusive social software (4.3) in the in-depth human-centric design sense as a program, which not just allow communication, but helps parties to understand each other better and to have shared topics to talk about. Seniors could be not only feeling more involved but even able to share with their family members what they have revealed about the places they were virtually present during the day. So, based on the information from their senior family members, the family members could even get ideas which other nearby places of interest are worthy of their attention. Thus, seniors could be actively participating in a shared experience even if their impairments are not allowing them to be present physically. Such usage would promote vital interaction and strengthen family bonds.

A rich simple and consistent communication tool.

A) SMS sent by a family member to senior's device



B) SMS sent by a family member to service provider' switchboard

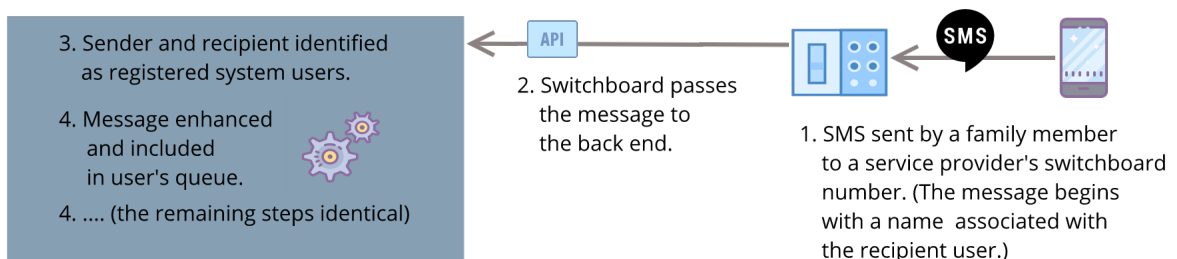


Figure 27: Examples of alternative routes of message processing, all leading to a consistent user experience

58 A paper about this scenario is being prepared for submission in a tourism-oriented journal.

To follow the in-depth human-centric design principles, inclusive social software should allow users not merely to share information, but also emotions and feelings and to promote or re-establish vital bonds. So, we would like to see, for example, an aged grandmother who takes a picture of a freshly baked pie and attaches a voice message with an invitation for her family members to come over. Communication channels in our system might include calling, video calling, recording and sending voice messages.

We also like the idea of fully replacing the textual input with a voice in combination with speech-recognition, used for example, by GreatCall, which is mentioned in 4.2.3. We should also come up with support for taking and sending pictures and videos. The program should also be able to receive various kinds of messages, either textual (SMS, email), or pictures or audio. Again, we might apply the content-enhancement idea, so for example, before sending, the user would be asked whether he wishes to have a geolocation-related data added. Such enhancement would be done automatically by the back end. Figure 27 illustrates the idea of providing a consistent messaging experience to senior, regardless of the communication channel chosen by the family member.

The first illustrated scenario requires the family member to have a little monitoring application installed either on his mobile phone or another mobile gadget, which keeps back end updated about the location changes. The updates may be sent periodically, or only upon a relevant event, such as sending a message. The messaging process itself is triggered by the family member who sends an SMS to senior's number. The message gets intercepted by a small native application which consumes it and passes it to the back end. The back end system determines if the sender is allowed to communicate with the recipient. If not, the sender may be notified. Then the system determines the sender's location. If it is known, the message may be enhanced and included with high priority in recipient's queue. Optionally, if the client's viewer accepts push notifications, he may be proactively informed. Upon a content request, for example, if the user pushes the 'next' button, the enhanced message gets formatted and displayed. The second scenario is suitable, i.e. for the cases when a senior does not have his mobile phone number. Then, the family member may send his SMS to a service provider's switchboard number, which works as a proxy. As soon as the message is received by the back end and involved user accounts are identified, the remaining steps are identical. Analogously, messages sent by e-mail or via a chat, messenger, or a social media would all go through a similar process to be presented in a similar way to the recipient.

Call me button. We like the idea of a 'call me back' button implemented by Claris Companion (refer to 4.2.4.1). It allows the senior to notify a family member so he may respond at a convenient time. The function respects the needs of both seniors and their family members. It is likely that many of them would prefer asynchronous communication with their parents during the daytime to avoid distractions from work.

Content-centric communication. The system might allow users to attach a comment to a content item, perhaps in a form of voice, maybe in combination with easy-to-understand emoticons offered from a limited set. The comments might be shared with other users, allowing content-directed communication and building networks around shared interests.

7.4.2 SENIORS' ACCESS TO INFORMATION

Awareness. Power of traditional mainstream media, such as the TV in forming opinions is probably even stronger in the case of the senior population. Such power may be used for both good, e.g. to educate people and to raise their awareness in important issues, and for evil, such as if politicians spread fears among the population to gain popularity and make a stronger grip on power. The misuse may have different forms, from straight lies to just giving enormous attention to a chosen marginal problem to distract attention. The system might eventually disrupt the monopoly power of traditional mainstream media for some target groups and provide an alternative channel with a diverse palette of news, opinions, and other sources of awareness. It might help seniors to apply critical thinking and be less vulnerable to manipulation. The news content feed might be implemented for example, as a configurable and adaptive RSS reader. An inspirational example of an initiative trying to spread valuable and important ideas is TED, an organisation which posts lectures for free distribution (TED Conferences, 2018). The lectures span over a wide range of topics from nature and science to arts and culture. Their effort is to make the talks engaging, interesting, and educational. A lot of TED Talks are available with translation into many languages. Our system might also

provide location-relevant news and other information. For example, it might be attached to a Twitter account of a local municipality hall.

Teaching tool. Seniors are willing to learn. The proposed software might help to fulfil some of these aspirations. The already implemented mechanism of serving content from a user-tailored queue is well-suited for memory expanding and rehearsal systems, such as popular Memrise (Memrise, n.d.) or open source Anki (Elmes, 2018), and may perfectly assist, for example, to improve vocabulary in a foreign language. But it provides virtually infinite opportunities for teaching and education. The Anki web reads: “Anyone who needs to remember things in their daily life can benefit from Anki. Since it is content-agnostic and supports images, audio, videos and scientific markup, the possibilities are endless.” and its slogan is “remember anything, remember anywhere, remember efficiently” (Elmes, 2018). The same may apply to our system. We might even develop a content provider able to read Anki flashcard decks, which are available in abundance or adopt Anki's advanced algorithm for spaced repetition. Flashcard-based learning systems and their algorithms have also been assessed by researchers (Godwin-Jones, 2010). We should turn to their conclusions before proceeding to implementation. As Benáčová & Valenta (2009) present in their study, until 2009 at least 16,000 older people from all over the Czech Republic have already participated in one of 400 different educational programs specially designed for seniors. Our system might also become an integral part or extension of some of such life-long learning programs.

7.4.3 PRACTICAL PURPOSES INCLUDING COMMERCE

Better engagement with care-providers. The proposed system might be used similarly as, for example, Breezie is used (4.2.4.2). An elderly-care institution may distribute tablets with the viewer program among its clients and use the system to inform them about events and engage them more in the community. For example, they could use the system to invite clients to a session in a shared room, to let them choose a lunch, or order services such as cleaning or shopping and gather feedback afterwards. The institution staff could use the web management interface to set-up the content feed and monitor the feedbacks. In addition to the web interface, the system might provide an API to access the management functions, so it would be possible to integrate it with other information systems.

Advertising and shopping. A content provider might either advertise products or even sell them directly from the system's interface. Online shopping might be made extremely easy, for example, a page would offer a product, the user would click 'buy' and on the following page, he would just confirm. To increase safety, an additional authentication mechanism could be implemented. For example, using a physical ID card with RFID or a QR code which the user would have to put to proximity to the tablet. An example of a similar method, though used for a different purpose is Jive (4.2.3). This scenario provides a business opportunity. But we would have to pay extra attention to the ethical aspects to not waste the users' benefit. In this context, current mainstream social media establish a warning example of a powerful technology, which quite often does not serve the best needs of its users, but rather the needs of the providers and their customers. Besides e-commerce and advertising, we may also think of market-oriented surveys about services, products, packaging, etc. which also has its commercial potential.

7.4.4 SENIORS' ENTERTAINMENT

Gamification. Even seniors may be interested in games. We even tried to present games on a tablet to one of our participants with a positive response (5.2.5). So, the system might come up with support for games, such as puzzles, crosswords, or memory games. A good example of a set of games suitable for the elderly provides, e.g. CleverMind (4.2.2). As a next step, multi-user games might be considered. We would probably prefer collaborative⁵⁹ games rather than competitive. But the concept of gamification goes further. We might even *gamify* the system itself. To increase users' engagement, they might collect certain 'points' for their interaction with the system, aspire to reach 'levels', be awarded 'badges', etc. The concept of gamification is covered a bit more in 5.2.5.

Chat buddy. We might think of a virtual assistant which would be used throughout the program. It would help users to identify themselves with the product and, perhaps, to build an emotional attachment. Instead of

59 Games which require a participation of two or more users on solving the game's objective.

a young female character (e.g. MS Cortana, Amazon Alexa, Apple Siri), we could consider a pet-like animal, something like 'Zuzi, the Cat' or 'Puppy Zee'. The nature and appearance of the virtual assistant might be tailored to the user profile (preferred content, tags, behaviour patterns, skills, etc.). More research would be needed. The idea of a virtual assistant is relevant to the issue raised during the focus group (5.2.3) about the proper formulation of questions and statements.

Absorb the traditional mainstream media. The system might also work as a digital gateway to the traditional mainstream media. It might pump data from archives of television stations, radios, etc. In many cases, negotiations would be necessary with holders of the author rights, because the content is usually not available for free circulation. Integration of various other sources of digital video and audio content is possible. For example, from the resources available in the Czech environment we considered the service Stream.cz (Seznam.cz, n.d.). But, though embeddable, there is no documentation about media controls which makes it more complicated than for example, embedding of YouTube content.

7.4.5 HEALTH AND WELL-BEING OF SENIORS

Therapeutic usage. With the help of relevant experts, a content provider aimed to improve memory or cognitive skills after accidents, to deal with dementia, or with psychological disorders may be developed. Specific products from this category are available, such as CleverMind (4.2.2).

Prevention of digital addiction. Our trial indicated, that even with limited content the service might become addictive, at least for some users (6.2.1.1). Because benefit for users is the priority of our research, addiction prevention measures should be considered. E.g. if a user starts spending extensive amounts of time-consuming the content, the dispatcher might suggest or even force a break – simply telling the user and not loading any more content until the break ends.

Reminders. We may implement reminders. They would be set and monitored by care-providers, family members, or others with relevant privileges via the management interface. It would be better to present them to the user not in an impersonal manner, but as if the person who has set the reminder is asking (“*Mark is asking you kindly if you took the pink pill.*” and possible answer options “*Yes, I did*”, “*I am taking it now.*”, or “*I am not taking it now*”). We like how the function is implemented by Claris Companion (4.2.4.1). Besides medication reminders, our system might also recommend, e.g. physical exercise, supplemented with practical guidance, e.g. in the form of a video demonstration. It would require proper configuration of user's needs in this regard because these are likely unified and also not easily inferable from the data routinely collected by the system. Coordination with care-provider or at least with a family would be vital to set a physical exercise program tailored to the needs of a particular user.

Advanced monitoring. The system records content-related activity, e.g. how many pages have been shown, when the user started in the morning, whether he was active overnight, etc. It also allows to let users answer self-assessment questions such as “how are you feeling now?”. Location monitoring is likely to be implemented. This information, if combined, might help to reveal valuable indicative trends. As an extension, to gather more important information regarding the physical well-being of the user, IoT wearables, such as wireless sensors, might be considered. Especially in combination with a wearable gadget, such as a smartwatch, the application might count how much the user walked each day. The information about the trends in user behaviour may become useful for the family, caregivers, physicians, and for the user himself. Ethical questions about proper data protection and human dignity as well as users' own feelings about such monitoring and reporting should be considered carefully.

Deeper identification with a location. Seniors may be deeply rooted in the location where they are living for many years. Other seniors may feel uprooted because circumstances have caused them to leave a place they have an emotional bond with. A project Bike around benefits from the Google street view technology and lets seniors with dementia reminisce on places they cherish. Authors of the project claim, that our strongest memories are intensely tied to a location: “*It's no coincidence that when you think about any big memory or past event, your first thought is often 'Where was I when that happened?'*” (Christine, 2017). Providing means to keep or deepen bonds with either the location where a user is living now or where he used to live in the past might contribute to his emotional well-being.

7.4.6 CREATIVE AND FULFILLING ENGAGEMENT FOR SENIORS

The family heritage. While recent family pictures, videos, and other content presented to a senior may help him to strengthen the bond with his family, an old digitised material, such as black-and-white photos, documents, etc. may help his *family members* to maintain *the other end of the bond*. Senior might be confronted with an old digitised content, which would help him not only to reminisce but via a voice recording function to comment on the content and share his comments with his family. He could, for example, describe persons in a picture, tell a related story, give a bit of related advice or share a piece of experience or knowledge. The younger generation might get more interested in their roots and feel closer to the aged members of the family. Seniors would feel part of the family, valued and needed.

A memory of nations. Almost every senior person has something interesting and valuable to tell. Value of the knowledge is not always limited to the family. For example, projects such as Memory of Nations (Post Bellum, n.d.-a) by Post Bellum (Post Bellum, n.d.-b), or collect such valuable memories to preserve them for the current and future generations. Collection of these memories is challenging, time-consuming, expensive, which causes that a lot of the valuable and irreplaceable knowledge gets lost with those holding it as their memories. The proposed system, equipped with voice recording functionality, might come to help. Seniors could record their memories at a convenient time, in small chunks, for example, according to an outline provided by a relevant content provider.

User tagging. We have already implemented the picture-viewing functionality. We could extend it in a way which would allow valuable involvement of users. Pictures could be displayed together with several tags provided by a tagging service. The tags would be displayed as buttons. The user would be asked to click the button which corresponds to the picture most (or click 'none' if there is no relevant tag offered). This way, we could gradually collect data which could be used as a training corpus for image recognition.

Collaborative voice recording. Users might participate in a collaborative recording project, where each of them would participate in the creation of voice content. For example, they would be given a portion of a text, such as a web page or a chapter from a book. And they would read it aloud. The recording would be made available to other users, including vision impaired. The collaboration might involve distribution portions of text between more users – for example, the direct speech would be read by a different user than a narrator's part. Of course, the participant would get access to the final result of the collaboratively created audio content. And, what's more important, elderly users could feel that they are helping others.

An educator. Some projects help seniors to rediscover their role in the society putting them in the role of educators. Good examples are Speaking exchange (Peppers, 2014) and The Granny Cloud (The Granny Cloud, 2017). The Speaking Exchange is a US initiative that connects retired people living in care homes with students learning English in Brazil, via Skype. The Granny Cloud is a team of volunteers that reach out to children with limited educational resources around the globe and provides them with the opportunity to experience other cultures. We might think of a similar scenario also for our proposed system.

Working senior. Despite being negatively affected by the age-related deterioration of both physical and mental capabilities, seniors may be a source of deep expertise in their respective fields of specialisation. The proposed software might serve as a multi-way channel involving professional education to allow seniors keeping track in their field, communication with the employer or a work team, delivering the results of their work, etc. Giving seniors a chance to stay fully active as employees may give them a source of income and a positive impulse for their self-esteem and fully utilize their knowledge as a valuable resource. Specifically valuable it might be in the ageing societies with their social systems being stretched to the limits in the near future, such as Japan and South Korea, but also Western Europe, USA, and other regions or countries.

7.4.7 USER INTERFACE MODALITIES

We may consider various user interface modalities for a senior-friendly system. To avoid mistakes, it is good to think about how the modalities relate to artefacts and concepts well-known to the users. Big screen may evoke either a TV or a window. It would feel natural to use it to look out and see the world. Tablet may resemble rather a postcard or a book. Use cases which understand the perception of different modalities may have a higher potential to match the way users think, as demonstrated by some research works discussed in chapter 3.

A large screen. We could imagine the content from the system being displayed on a big screen, such as an LCD TV. Action controls are implemented as a remote control and to provide means for voice recording and picture taking. The remote control may be implemented as a small electronic device with a touchscreen, or as a device with simple micro switch buttons. Both options have advantages and disadvantages. As a remote control, we might consider also smartwatch. Or, as a simpler variant of large screen usage, mere cloning of the content from a tablet on the screen, might match the preferences of some users.

Facial expression recognition technologies might be used to reveal how the user is feeling to record implicit 'like' or 'despise'. Fuzzy values could be assigned instead of the binary interpretation of 'like' or 'despise' clicks. Criteria such as the shape of the smile, changes in the facial expression during a period, length of media playback, or recorded like-dislike of members of user's circle, or previous record of user's feedback may be considered. If the application makes such an assumption, it should be indicated to the user in the interface in a clear, but unobtrusive way. The should get a chance to revert it if the system made a mistake.

Gravitation and motion sensors. Integrated sensors might be used as an additional input. Sensors are utilised, e.g. by an application Shake-in-trouble (Nazarkar, 2013) which sends an emergency SMS containing a current location if the user shakes his device three times.

Speech. Other potential modalities, mentioned already in the previous section, including speech. Speech recognition technology could be used for both *voice control*, and for conversion of *speech to text*, e.g. for user's comments about the content, his messages to others, or his testimonies and experiences as mentioned in the 'family heritage' or 'memory of nations' scenarios. The necessary technology is available in applicable quality, e.g. as an unpaid cloud service provided, e.g. by Google or Apple.

Such technologies, if correctly applied, might provide a significant contribution to the smooth experience. They may also make the system accessible to different groups of users, such as those who are unable or unwilling to provide tactile feedback and operation.

8 SUMMARY

SUMMARY

On the conceptual level, a hypothesis that responsible knowledge management, applied in the product design and development, may lead to leap innovations in products and services has been formulated. In-depth human-centric design provides a practical set of tools to reveal the needs of particular target consumer groups. Synthesis of knowledge from fields such as economics, psychology, sociology, medical science, or informatics revealed certain common clusters of needs of seniors, which might relevant information technology help to fulfil. However, today's software does not really harmonize with the needs of the elderly. As a step forward, a new concept of inclusive social software has been proposed in contrast with common types of programs, including software for social media, and elaborated from functional and architectural perspectives, with the needs of seniors on the mind. Inclusive social software would allow seniors to gain access to the digital content and services of today's knowledge society. Based on the proposal, a complex functional prototype has been developed. During the development, in-depth human-centric methods have been applied and good software design and engineering practices respected. The prototype has been evaluated in an in-depth usability trial which involved 10 participants from the target group. The trial confirmed the potential of the proposed software concept, the applicability of the proposed design approaches, and revealed more about seniors in the role of digital technology users. Finally, opportunities for subsequent research and application have been outlined.

SHRNUTÍ

Na koncepční úrovni byla formulována hypotéza, že zodpovědný management znalostí, aplikovaný v designu a vývoji výrobků, může vést k skokovým inovacím v produktech a službách. Hlubkový lidsko-centrický návrh poskytuje praktický soubor nástrojů pro odhalení potřeb konkrétních cílových skupin spotřebitelů. Syntéza poznatků z oborů ekonomie, psychologie, sociologie, lékařské vědy, či informatiky pomohla identifikovat některé z potřeb seniorů, k jejichž uspokojení by mohly přispět informační technologie. Současný software však potřebám starších lidí často neodpovídá. V kontrastu k běžným relevantním typům softwaru mezi něž patří software pro sociální média byla navržena nová koncepce inkluzivního sociálního softwaru. Ta byla následně dále rozpracována z hlediska funkcí a architektury a s ohledem na potřeby seniorů. Inkluzivní sociální software by seniorům otevřel přístup k digitálnímu obsahu a službám dnešní znalostní společnosti. Na základě návrhu byl pak vyvinut komplexní funkční prototyp. Během vývoje byly aplikovány metody hloubkového lidsko-centrického návrhu za současného důsledného respektování zásad správného návrhu a vývoje software. Prototyp byl následně vyhodnocen ve studii hloubkové použitelnosti, jíž se účastnilo 10 účastníků z cílové skupiny. Studie potvrdila potenciál navrženého softwarového konceptu, použitelnost navržených návrhových přístupů a odhalila více o seniorech v roli uživatelů digitálních technologií. Nakonec byly nastíněny příležitosti pro další výzkum a pro praktické aplikace.

9 USED TERMS

Associated application. Is typically an application which provides user-specific supplementary data or services to the back end. For example, it runs on a mobile device and collects location data from either the user or his family member.

Back end server (or just '*back end*'). The part of the proposed software and the developed prototype which provides *content*. The content is either generated on the back-end side or pulled from external sources by individual *content providers* which are system components of the back end. The contents are served as responses to the back-end services in a form which allows further transformations by the *front end*. Refer to appendix 11.

Browser-side. Refers to the code which is executed in user's browser.

A content provider (or just *a provider*). It is a component of the *back-end* part of *the proposed system* and *the prototype* which is responsible for providing a content of specific type. Several content providers have been developed for the prototype⁶⁰. By implementing content providers, the system may be extended in a manageable way.

Content pushing. It is a style of communication where the request for a given transaction is initiated by the central server in contrast to content pull (or get), where the request is initiated by the client. It is also referred to as push technology or server push by others.

Content source. In the case of a content which originates from an external service, this source service is called content source.

Content. In the context of *the proposed software* or *the prototype*, it is a piece of data served by a *content provider*, which is running in the context of the *back end*. Typically, one content item/instance/object is atomic, which means that it is intended to be presented to the user as a whole (e.g. displayed on one page in the case of a *front end* serving a graphical user interface).

Core classes (or just *core*). A central part of the *back end* architecture developed in the Python language. Other architectural components, such as content providers, supplementary services, and formatters depend on the core.

Core tables (or *core model*). The part of the *database model* defined by the *core classes*.

Data abstraction layer

Database model. In the context of the *back-end* part of *the prototype*, it refers to code in the Python language which defines the structure of database tables in a database-agnostic way. The model to facilitate persistence utilises the *data abstraction layer* of the *Web2py* web framework.

In-depth human-centric design. User-centric product design and engineering approach which stresses consumers' deep needs and feelings.

Deep needs. The most central needs of individual consumers or a specific category of consumers which determine their happiness and well-being.

In-depth usability testing. A variant of usability testing defined by the in-depth human-centric design which stresses consumers' needs and feelings.

Digital social network. The term does not refer to social media, but to a network or a web of social connections between users of social media.

Digital social relationship. Used to differentiate the social relation which exists in the digital world, but is not necessary reflected from or to the real world. We use also

Digital socialising. The process of acquiring, updating, or dropping digital social relationships.

60 The implemented content providers involve the Main System Provider, YouTube provider, Flickr provider, Audiobook provider, and Survey provider (11.2).

Early prototype stage. A piece of software has to pass several stages of development before reaching a *productive stage*. We consider that a software product is in the early prototype stage until it reaches sufficient functionality for usability testing.

Family member. Mainly in the context of the proposed software and the developed prototype we use the term for people from user's circle, mostly his close relatives.

Front end server (or just '*front end*'). The part of the *proposed software* and the developed *prototype* which parses and transforms content received from the *back end* into a form which may be presented to the user. For details about the developed HTML-based default front end refer to chapter 12.

Linear media consumption. A model of serving media content in a queue in contrast to *on-demand media consumption*. Refer to 4.3.

Mainstream social media or simply *social media*. It refers to popular general-purpose social networking sites such as Facebook, WhatsApp, or Twitter.

Mainstream traditional media. Refers to the broadcasted media intended for linear consumption, mainly TV or radio.

Model of acceptance. A kind of *model of consumers' thinking and behaviour* which describes the first stage of the evaluation process when a consumer has to decide whether to give a certain product a try.

Model of appropriation. A kind of *model of consumers' thinking and behaviour* which describes a stage of the evaluation process when a consumer is gradually integrating a product into his life.

Model of consumers' thinking and behaviour. A formal or semi-formal representation of cognitive processes behind consumers' decisions about products. It may be either a *model of acceptance* or a *model of appropriation*. Each refers to a different stage of the decision-making process.

Native application. An application developed for a specific family of operating systems, such as Android or iOS.

On-demand media consumption. A model of serving media content based on queries or other complex selection schemes which require more active participation of media consumer than *linear media consumption* model. Refer to 4.3.

Platform. We use the word platform in different meanings according to the context. It may refer to a family of operating systems, or generally to a complex software system.

Productive stage. When a software (or a product in general) is mature enough for direct utilisation. It requires that all required key functionalities have been implemented and the software has been properly tested.

Progressive web application. A software which combines features and functionalities of a *native application* and a web application. Refers to 12.3.

Senior. We use the term to refer to our main target group. Synonyms such as *the aged*, *the elderly* (for plural) are used interchangeably. Sometimes we also refer to seniors as to a *target group*. Our definition of seniors does not apply to just high age, but to common effects of growing old. Refer to 1.1.2 for details.

Shell. A user interface providing access to the operating system's services.

Smooth experience. A behaviour of a program which is perceived as pleasant and hassle-free by its users.

Inclusive social software. We introduce this term for the kind of software, which promotes vital social ties. The definition refers to the impact of a software product on the user's real social network, which is significantly different to the common perception and impact of mainstream social media. Refer to 4.3 for details.

Speech recognition. Detecting words in recorded voice in contrast to voice recognition aimed to detect the physical person behind the speech.

System architecture. It refers to the conceptual structure and behaviour of software.

System infrastructure. It refers to the way how a complex software system is deployed on devices and in running environments as well as the relevant communication channels.

The proposed software. The novel type of software which has been proposed in response to the findings of our research. We developed a *prototype* to evaluate and test the proposal. Sometimes we also use the term *system* as a synonym. We avoid using the term *application* which might be misleading because of its quite narrow meaning. Refer to 5.3.2 for an overview.

The prototype. We use this term for the developed experimental implementation of *the proposed software*. For details refer to 4.3 to 6. The sections and chapters cover the pre-development, development, architecture, deployment and usability testing of the prototype. Sometimes we use the developed prototype as a synonym.

User. If used in connection with the proposed software and with the developed prototype it refers to a person who utilises the primary functions of the system, typically a senior⁶¹. We use other terms *family member*, *caregiver*, and *administrator* to differentiate other people who might be dealing with the system in their respective roles. To avoid confusion, we do not refer to these as users.

User's circle. The term encompasses the people with strong social ties with a senior user. Mainly composed of user's *family members*.

Viewer. Refers to the part of *the prototype* which a *user* uses to access *contents*. It combines pieces of code from both *front end* and *back end*. The default implemented viewer runs on the *browser-side*.

Web2py. The Python-language-based web framework for which *the prototype* has been developed. Refer to 11.1 and 13.

⁶¹ In other parts which are not related to the proposed software, nor to the prototype the term user does not follow the given definition and has its common broad meaning as a person who utilises a product.

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10.2 AUTHOR'S PEER-REVIEWED PUBLICATIONS

1. D. Zeida, “Towards online social learning”, Ditech '09: mezinárodní studentská vědecká konference, Hradec Králové, ISBN: 978-80-7435-001-6, Gaudeamus, Hradec Králové, 2009

Abstract: Nowadays we may observe gradual transition from classical web to a state referred to as Web 2.0. Users become more active participants and more integral parts of the whole, while the distinction between consumers and producers wanes. The change is mainly social, rather than technological, so we face not only technical challenges and questions, but also challenges social. Learning and education do not stand apart, more to the contrary these processes are being influenced in a great scale. In the article I discuss the current face of affairs on the meeting of social computing and education, point out some of the new categories of requirements on educational systems and their actors and introduce several both experimental and real world attempts to cope with them.

2. D. Zeida, “Ontologies for folksonomies and for profile-based online social networks”, MendelNet PEF 2009: evropská vědecká konference posluchačů doktorského studia, Brno, ISBN: 978-80-7375-351-1, Mendelova zemědělská a lesnická univerzita, Brno, 2009

Abstract: Current web takes more and more out of Web 2.0 concepts, becomes more central to the lives of people, millions of users register in many community portals, web becomes annotated and driven by a community. The sites are doing well, but they may do even better. Many issues remain open, like how to describe a person, how to capture his interests and passions, how to help him find the relations according to his wishes. How to get to know about the requirements of users or even better, how to allow users to enrich the portal in a systematic way? With proliferation of rich social networks the importance of interconnection, integration, identity, trust and security challenges grows too. The article examines possible role of ontologies in search for answers. We particularly focus on folksonomies and on social networks based on semi-structured user profiles.

3. D. Zeida, “Trust and Trustworthiness in Online Profile-based Social Networks”, Informatika XXIII/2010, Luhačovice, ISBN: 978-80-7375-394-8, Mendelova zemědělská a lesnická univerzita, Brno, 2010

Abstract: As popularity of online social networking sites such as Facebook grows, more users are joining and further activities within the sites are becoming quite natural extension of their social life, the overall dynamics of the sites gets to higher levels. With recent incidents on the mind, importance of better trust solutions in the systems is increasingly apparent. What are possible sources of trust, how can be the trust captured into systems and how can be processed? Could

we infer a level of indirect trust between users who do not know each other yet? We also describe trustworthiness as a per-community relevant or system-wide metric of reliability of certain user. In the conclusion we point out some current challenges related to trust matters and also we recommend publications worth of reader's further attention. As popularity of online social networking sites such as Facebook grows, more users are joining and further activities within the sites are becoming quite natural extension of their social life, the overall dynamics of the sites gets to higher levels. With recent incidents on the mind, importance of better trust solutions in the systems is increasingly apparent. What are possible sources of trust, how can be the trust captured into systems and how can be processed? Could we infer a level of indirect trust between users who do not know each other yet? We also describe trustworthiness as a per-community relevant or system-wide metric of reliability of certain user. In the conclusion we point out some current challenges related to trust matters and also we recommend publications worth of reader's further attention.

4. D. Zejda, "From Subjective Trust to Objective Trustworthiness in On-line Social Networks: Overview and Challenges", *Journal of system integration*, ISSN: 1804-2724, Česká společnost pro systémovou integraci, Praha, 2010

Abstract: Nowadays dozens of people share their content in the current Web 2.0 space, talk with friends in social networking sites such as Facebook and live on the Net in many other ways. They do all this quite naturally, forgetting the healthy cautiousness sometimes. In real life we rely on trusted people. Do we know how to reflect real-world trust mechanisms into online social software? In the article we focused to bring overview on state of the art in main ideas behind a trust processing in online social networking systems. What are common sources of subjective trust, how the trust emerges and what are the sources of trust dynamics? How can be trust captured into the systems, how can be explicit trust processed to infer indirect trust, the trust between users who do not know each other? And what are the ways to infer objective metrics of trust, the reputation or trustworthiness? Finally, we point out selected challenges related to the trust in current highly dynamic social networks.

5. D. Zejda, "Online Social Networks for Elderlies - Acceptable Interfaces for People with Serious Impairments", *Intelligent environments: workshop proceedings of the 6th international conference*, Kuala Lumpur, ISBN: 978-1-60750-638-6, IOS press, Amsterdam, 2010

Abstract: Today's Web 2.0 is a place, where people express themselves, interact share their lives, socialise. Thousands of elderly people join various social networking sites or use the Net to keep in touch with their families. But, as we show in the paper, today's social software does not target their needs sufficiently. While there are usable solutions, usability itself does not imply acceptability. Acceptable interfaces should reflect user's habits, follow understandable metaphors, and above all, target their deep needs as precisely as possible. Further, the elderly can not be taken as a homogeneous group characterised by the impairments, but rather as a set of individual human beings, with specific wishes, desires, habits, and with some disabilities, of course. In the paper we formulated qualities which should social software meet to be widely perceived as beneficial and in result accepted by the elderly and by people with serious impairments.

6. D. Zejda, "Deep Design for Ambient Intelligence: Toward Acceptable Appliances for Higher Quality of Life of the Elderly", *Intelligent environments (IE-10): proceedings of the sixth international conference*, Kuala Lumpur, ISBN: 978-0-7695-4149-5, IEEE, Piscataway, 2010

Abstract: Deep design outlined in the paper is a new approach, where not only tasks, immediate emotions or habits and behaviours are considered. It aims to identify sources of emotionally rich and strong experiences and feelings to augment them subsequently by means of smart technology. Evaluation of a new technology is described as a successive process, starting with immediate decision, followed by short-term acceptance and finally long-term appropriation driven by the deep needs. The idea of deep design is being introduced in a context of ambient technologies for the elderly, because actually there are certain dissonances in what do the elderly need and what many current intelligent technologies offer. As we show in the paper, our research in sources ranging from gerontology to ambient intelligence revealed four clusters of deep needs of the elderly - social touch, autonomy with anticipated support, feeling of being competent and feeling of helpfulness and self-worth.

7. D. Zejda, "Ambient Intelligence Acceptable by the Elderly: Rational Choice Theory Model of Technology Evaluation for Deep Design", *User-centric technologies and applications*, Salamanca, ISSN: 1867-5662, ISBN: 978-3-642-19907-3, Springer, Heidelberg, 2011

Abstract: Ambient systems may support the elderly in many aspects of their lives, bringing new level of comfort, higher safety, and better health. But, as we revealed in parallel research on deep design, there are dissonances in what do the elderly wish and what the intelligent technologies indeed offer. The dissonances may lead to reluctant acceptance or even to rejection of possibly beneficial products. In this paper we borrowed concepts from economics and transformed them into generic model which captures the mental process of evaluation of new aspects of life. Proposed model is specifically aimed on ambient intelligence products, viewed from the eyes of possible elderly users, though not necessarily limited to this particular focus. The process of evaluation, leading either to acceptance or to rejection, may be described as a sequence of rational selections from available options, based on perceived benefit (utility) and cost (in terms of time, effort, support from others). Simplifying preconditions introduced in the paper reduce the model to optimisation problem of linear programming. In conclusions we discuss limitations of the model and suggest further possible refinements and evaluation.

8. D. Zejda, "Characteristics of Trust in Online Social Networks and Community of Trust as a Special Case of Online Community", Web information systems and technologies, Noordwijkerhout, ISBN: 978-989-8425-51-5, SciTePress, Funchal, 2011

Abstract: With boost of interest in Web 2.0 technologies, appropriate trust models are increasingly more important. First section the paper contains state of the art about trust characteristics, in particular multidimensionality, contextuality, scope of relevance, transitivity and asymmetry. Transitivity as a key aspect utilised in most models is described in a slightly greater detail. Discussion on scope of relevance allowed us to introduce taxonomy of trust from the scope point of view. Based on the general foundation, in the second section we introduce community of trust as a niche type of online community where users trust each other as default and where the trust loses most of its subjective flavour.

9. D. Zejda, "A Generic Model of Distrust Behaviour in Online Communities of Trust", Intelligent environments : workshop proceedings of the 7th international conference, Nottingham, UK, ISSN: 1875-4163, ISBN: 978-1-60750-794-9, IOS press, Amsterdam, 2011

Abstract: Trust is one of core dimensions of vital interactions in multi-user networking ranging from Web 2.0 to agent systems and smart environments. We describe the trust itself and its characteristics, such as multidimensionality, contextuality, asymmetry, transitivity, scope, disproportion, and dynamics first. Further a niche type of community where users trust each other as default and where the trust loses most of its subjective flavour is being presented. As a main contribution of the paper, we introduce a simple generic and extensible model of distrust for the community of trust. The model is based on activity and distrust matrices arranged into vectors in order of time of occurrence. Various derived characteristics, such as harmful/harmless or distrusting/distrusted ratios provide additional insight on the model. Tests in simulated scenarios and with real human users will follow in our future research to concretise and evaluate the model.

10. D. Zejda, "The Model of Appropriation - Contribution of Rational Choice Theory and Cognitive Science to a Better Technology", Intelligent environments: proceedings of the 7th international conference, Nottingham, UK, ISBN: 978-0-7695-4452-6, IEEE, Piscataway, 2011

Abstract: Ambient intelligence, as well as other fields of advanced applied science and technology, has a potential to improve quality of our lives. But the whole context, including psychological, and social aspects, have to be considered if we wish to make our technology resonating with user's real needs. The paper shows, how may rational choice theory and cognitive science contribute to describe and understand the mental processes which occupy user's mind during the appropriation stage of technology evaluation. As a main contribution, we present a simple model of appropriation, both verbally and in a semi-formal numerical form. Even though we are focused primarily on ambient intelligence, the model is generic enough to be applied in other fields too. The model implies, besides else, that enthusiasm induced by an early evaluation does not necessarily raise chances of success in the following appropriation stage.

11. D. Zejda, "Business Process Management and Social Web Technologies to Elevate the Non-governmental Sector", Finance, Accounting and Auditing (FAA 2012), Zlín, ISSN: 2227-460X, ISBN: 978-1-61804-124-1, World scientific and engineering academy and society, Athens, 2012

Abstract: Social capital of today's civic society diminishes, which sounds as a paradox. In the paper we briefly evaluate reasons behind these trends first to evaluate, how could information technology, process re-engineering, followed with engagement of social software help in the current crisis of civic engagement, volunteerism and social relations in general, with specific focus on non-governmental non-profit organisations. As a core of the paper we present relevant SWOT analysis based primarily on the available published research.

12. D. Zejda, "Rational Choice Theory Model of Acceptability for Deep Design with Commutable Resources", Finance, Accounting and Auditing (FAA 2012), Zlín, ISSN: 2227-460X, ISBN: 978-1-61804-124-1, World scientific and engineering academy and society, Athens, 2012

Abstract: Wide range of advanced intelligent technologies is available today, bringing various benefits, such as higher productivity, comfort, safety. But, if a technology is smart, it does not necessary mean that it will be accepted its potential users. Our research brings conclusions from various fields of science, cognitive science and rational choice theory in particular, to deal with the questions of acceptability, from both descriptive and normative angle of view. As a main contribution of this paper we present refinements of the rational choice model of acceptance published earlier. Among other changes, we introduce a new concept of life aspect sets and also we leave the simplifying presumption of incommutable resources. As an optimisation tool for the refined model we examine a variation of isoquant analysis.

13. D. Zejda, "Rational Choice Theory and Cognitive Science To Understand Evaluation and Appropriation of Technological Products by Users", Hradecké ekonomické dny 2013. Díl III. Economic development and management of regions, Hradec Králové, ISBN: 978-80-7435-251-5, Gaudeamus, Hradec Králové, 2013

Abstract: New technologies give us a potential to improve quality of lives. But, if we wish to deliver something considered as indeed useful and beneficial from the users' perspective, we have to understand the thinking patterns in users' minds first. The paper introduces relevant rational choice theory and cognitive science concepts relevant to the problem and

shows, how the theories might contribute to grasp the mental processes. Resulting simple models of evaluation and appropriation are briefly introduced in parallel.

14. D. Zejda, "Towards Acceptable Products: Grasping User's Mind by the Means of Cognitive Science and Rational Choice Theory", Symposium on Emergent Trends in Artificial Intelligence & Robotics SetInAir 2013, Košice, Topics in Intelligent Engineering and Informatics, ISSN: 2193-9411, Springer, in print

Abstract: Intelligent assistive robots, as well as other products of applied science have great potential to improve different aspects of our lives. In the past, some promising products and whole technologies failed to meet goals set for them by the scientists, inventors, manufacturers. Some of them have been set on sideline, the rest was left in oblivion. Our study of both cognitive science and rational choice theory is being motivated by the goal to help all the parties to avoid or prevent such fate for the results of their work. Psychological and social aspects of products and their properties have to be considered carefully to result in technologies resonating with user's real needs. On the following lines we present two different conceptualizations of human mind - cognitive science and rational choice theory and compare the main focus of each of them in regards to the means to capture mental processes which likely take place in a mind of the person who is appropriating a technology or a product. Two models, one based on rational choice theory, one based on cognitive science, are introduced briefly. In the concluding section we bring some implications for the process of developing, designing and presenting hi-tech products, including intelligent assistive robots.

15. D. Zejda, "Systematic approach for videoconference-based language education in the Czech context: The theory and towards a solution", IMEA, Gaudeamus, 2014

Abstract: Traditional face-to-face language courses are not practical or even feasible for many potential students due to requirements on travelling, rigid schedules, and for other reasons. Modern technologies, such as video conferencing software and hardware might help to harmonise supply and demand in language education sector. The paper presents experiences regarding applicability, the benefits and drawbacks of the video conference based on several referenced studies. They are put into a coherent context of systematic view of distant course design, conduction, and evaluation based on work of Moore and Kearsley. Different stages of the process, requirements on the technology, on tutors and students are hinted. Preliminary conclusions from our ongoing research aiming to map the situation in language education with emphasis on utilisation of modern technologies mainly in Hradec Králové region follow in the second part. Adoption of a systematic approach in creation and delivery of courses in distant or blended form among Czech language schools seems to be rare. A videoconferencing system which is being developed based on the research is introduced briefly.

16. D. Zejda, "Response of Young Elementary School Students on Native Speakers: Analysis of a Subjective Feedback from Videoconferencing Sessions with Tutors from the Philippines", 2nd International Conference on Computing, E-Learning and Emerging Technology (ICCEET 2014), Conference Proceedings Book, IISRC, Paris, 2014

Abstract: The paper briefly introduces a project which experimentally introduced videoconference-based tutoring at several elementary schools in the Czech Republic. Then it presents data collected through a questionnaire used during the project and analyses, whether involving of foreign tutors through online tutoring is less suitable for lower grades (four and five, pupils aged ten to eleven who just started learning English language) than for higher grades based on their subjective perception. The statistical methods used for the analysis are explained with reasons for the decisions. The analysis leads to a conclusion, that the low-graders accepted the sessions warmly and that the data do not show any ground for an assumption, that native speaking tutors should not be involved in early stages of language education. Finally limitations of the study are discussed.

17. D. Zejda, "Constructing Consumers' Mental Models: Towards Technology-rich Products Tuned for the Needs of the Elderly", 11th CIRCLE Conference – Book of Abstracts, 11th CIRCLE Conference, Manchester, ISBN: 978-0-9562471-9-3, Access Press UK, Lancashire, 2015

Abstract: Our interdisciplinary research has concluded in a proposal of an engineering approach, which elevates innermost feelings of potential consumers to a centre of design gravity, for all stages of design, development and subsequent marketing. On top of the findings, we have constructed a chain of models providing structured view on consumer reasoning and behaviour starting from a moment when a potential consumer is about to buy or accept a product, and then in the stages which follow. The models demonstrate, how consumers' feelings act as reinforcers during the process, eventually leading to either refusal or final appropriation. Both rational assessment and common cognitive biases causing irrationality in consumers' judgement have been involved in the models. The paper summarises our previous work, provides a quick overview of available methods and techniques aiming to understand needs of consumers, and identifies intersections with other works on consumer behaviour.

18. D. Zejda, E. Canoy, "Videoconferencing and Virtual Reality in the Context of Language Education", International Journal for Talent Development and Creativity (IJTDC), ISSN 2291-7179, Volume 3, Number 1, University of Winnipeg, Manitoba, 2015

Abstract: First, the paper provides an overview of various modes of online tutoring in the context of language education, including videoconferencing and teaching in 3D immersive environments. Related trends, perspectives, and challenges are

discussed in the first section. Several finished and ongoing pilot projects applying online tutoring for language education in the Czech Republic are briefly presented. Next, a substantial space is given to experiences gained in a project which was held in a period of one school year and which experimentally enriched English language classes at several Czech elementary schools. As a core of the project, language tutors working from the Philippines were assigned to conduct videoconferencing-based sessions with small groups of pupils. The potential of the ICT together with cultural difference between the tutors and pupils were notably exploited in the methodical materials created for the project to motivate pupils and assist them to gain not only the communicative competence, but also additional skills required by the curricular reform, which is ongoing in the Czech Republic. A summary information on data collected through a questionnaire during the project follows, showing the level of acceptance of the method and perceived benefits among the involved pupils and their parents. Then, a specific research question, whether involving foreign tutors through online tutoring is less suitable for lower grades (four and five, pupils aged ten to eleven who just started learning English language) than for higher grades based on their subjective perception, is analysed and the results are presented. Finally, limitations of the used research methods are discussed, and our further plans, both for application and research, are indicated.

19. D. Zejda, “An Overview of Various Modes of Online Tutoring in the Context of Language Education”, Excellence in Education 2015 – book of abstracts, International Centre for Innovation in Education (ICIE), Paris

Abstract: Classrooms no longer mean a room full of students, sitting on school desks, while listening intently to an instructor lecture before them. Technology has long changed that view of education. Videoconferencing and 3D Virtual Reality are discussed in the first section of the paper with emphasis on application for educational purposes. Relevant definitions, history, state of the art and potential for future use are touched. Then, three case studies from the Czech Republic are briefly presented. Two of them are ongoing joint projects of seven different institutions applying videoconferencing and virtual reality in English language courses for adults. More than 300 students from two regions of the Czech Republic, mostly working professionals, are benefiting from the trials of the newly created courses. The third case study is a successfully finished project organised by two institutions for several hundred students at six elementary schools. Language tutors working directly from the Philippines were conducting videoconference sessions for small groups of students. The potential of the Information and Communications Technology (ICT) together with cultural differences between the tutors and the students were notably exploited in the methodical materials created for the project to motivate students and to assist them to gain not only the communicative competence, but also additional skills required by the curricular reform. A summary information on data collected through a questionnaire during the project follows, showing the level of acceptance of the method and perceived benefits among the involved students. Finally, a specific research question, whether involving foreign tutors through online tutoring is less suitable for lower grades (four and five, students aged ten to eleven who just started learning English language) than for higher grades based on their subjective perception, is analysed.

20. D. Zejda, “Constructing Consumers' Mental Models: Towards Technology-rich Products Tuned for the Needs of the Elderly”, International journal of management cases, ISSN 1741-6264, Access press UK, Darwen, UK, 2016

Abstract: Intelligent and technology-rich systems, such as assistive robots, or whole smart homes have a great potential to improve lives of the elderly. Cutting-edge knowledge from variety of fields has to be combined to develop and manufacture such a product, which escalates the relevant costs. Even subtle psychological or sociological aspects, likely unexpected or underestimated, play significant role in how consumers perceive and either accept, or refuse products. Under such conditions it is a serious challenge for managers, designers, engineers, and others involved to prevent a business failure. Our ongoing interdisciplinary research, based primarily on cognitive science, rational choice theory, and applied technology, has concluded in a proposal of an engineering approach, which elevates innermost feelings of potential consumers to a centre of design gravity, for all stages of design, development and subsequent marketing. On top of the findings, we have constructed a chain of models providing structured view on consumer reasoning and behaviour starting from a moment when a potential consumer is about to buy or accept a product, and then in the stages which follow. The models demonstrate, how consumers' feelings act as reinforcers during the process, eventually leading to either refusal or final appropriation. Both rational assessment and common cognitive biases causing irrationality in consumers' judgement have been involved in the models. The research has brought up implications applicable in design, development, and marketing communication, such as about the role of enthusiasm in the process of evaluation. Though the research aims primarily the elderly, proposed principles are not limited for this specific target group. The paper summarises our previous work, provides a quick overview of available methods and techniques aiming to understand needs of consumers, and identifies intersections with other works on consumer behaviour.

21. P. Zejda, D. Zejda, “Exploitation of the Virtual Worlds in Tourism and Tourism Education”, Czech journal of tourism. Volume 2, ISSN: 1805-3580, Masarykova univerzita, 2016

Abstract: Academics perceive a great potential of virtual worlds in various areas, including tourism and education. Efforts adapting the virtual worlds in practice are, however, still marginal. There is no clear definition of the virtual world. Therefore the author of this article attempts to provide one. The paper also focuses on the barriers of a wider exploitation of the virtual worlds and discusses the principles that might help to increase their potential in tourism area. One of the principles – gamification – favours a wider adaptation of the virtual worlds in tourism. Applying gamification principles provides visitors with some unique experiences while serving as a powerful marketing tool for institutions. The benefits of implementing tourism education activities based on cooperative principles set in an immersive environment of the virtual

worlds are depicted afterwards. Finally, this paper includes successful case studies, which show advantages and drawbacks of some approaches in exploiting the virtual worlds in tourism and tourism education.

22. D. Zejda, "Social Software to the Benefit of the Elderly – Planning an Experiment", Hradecké ekonomické dny 2018. Gaudeamus, Hradec Králové, 2018

Abstract: After an investigation on consumer thinking and behaviour with specific focus on adopting advanced technology by the elderly, we are proposing an experiment to evaluate the findings achieved so far. The plan involves designing and implementation of a new prototype social software with certain unique functions. Statistical research conducted with the help of the proposed software will involve collection of both soft data, such as experiences and opinions of application users collected in their natural settings within the software, and hard data consisting of statistics about usage of the software, such as interactions with other users. The data will be matched and compared to evaluate three hypotheses about the process of a technology evaluation. The paper is presenting research-in-progress. Among the goals of the paper is to raise awareness of the specifics of developing a software with inexperienced elderly users on the mind, and also to get a feedback regarding the outlined application and the intended experiments.

23. D. Zejda, J. Zelenka, "Intelligent Software Tour Guide as a Visitor Management Tool", under review for Current Issues in Tourism, Taylor & Francis, ISSN 13683500

Abstract: Visitor management in protected land areas requires knowledge of visitor numbers, their motivation, time-space curves and another behaviour as an important input. Based on the systematic and knowledge-based analysis, comparison and discussion of visitor monitoring methods with the focus on methods for individual tracking, the concept of individual tracking using an advanced intelligent software tour guide is presented. The method allows not only comprehensive monitoring of visitors' time-space behaviour, but also understanding their socio-demographics, goals, preferences, feelings and the resulting impressions. In addition, the flows of visitors may be interactively influenced in a personalized way by the application, leading to better individual impressions, with full respect for the psychological and ecological carrying capacity of the territory. The stimulation of visitors to use the application is discussed. The tour guide may be implemented as a part of a comprehensive destination application reflecting the state of the destination system in real-time.

24. D. Zejda, J. Zelenka, "A Model-driven Destination Application for Optimizing Tourism Traffic to Protected Areas", under review for Tourism Management, Butterworth-Heinemann, ISSN 02615177

Abstract: The basic starting point for the sustainability of tourism in protected areas is to find harmony between the protection of nature and the interests and needs of visitors, local communities, entrepreneurs and other tourism actors. The necessary condition is not to exceed the carrying capacity of the territory for tourism. In the paper, the theory of bearing capacity concept was added and operationalized using a system approach to a protected area, a multidimensional concept of dynamic and locally dependent carrying capacity, defining an effective carrying capacity, introducing the concept of visitor optimum, building a destination model and applying it within the concept of effective carrying capacity. A comprehensive methodology for the design of the destination model and the destination application as a tool that can actively support visitor management of protected areas by actively influencing visitors is provided. Presented concepts and methodology for protected areas can also be adjusted for visitor management of historic city centres, cultural attractions, amusement parks and other types of destinations.

Author also participated on the following courses and publications:

- M.G. Bantol, D. Zejda, Adapting language teaching to the needs of adult learners, Open-IT, 2015, 72 pages (monography)
- D. Zejda, J. Mošner, Jazykové vzdělávání v Královéhradeckém kraji, Open-IT, 2015, 120 pages (monography)
- P. Zejda, D. Zejda, OZ - Zavádění videokonferenční výuky, 93 pages (course)
- E. Canoy, D. Zejda, OM - Communicating advantages of online education, 31 pages (course)
- E. Canoy, L. Ramos, E. Woock, D. Zejda, OR - Teaching languages in videoconference and in virtual worlds, 63 pages (course)
- P. Zejda, J. Mošner, A. Ates, R. Tizon, D. Zejda, OTI Zavádění online lektorství v jazykových školách, 144 pages (course)
- P. Zejda, J. Mošner, A. Ates, R. Tizon, D. Zejda, OTM Marketing a propagace online lektorství v DV dospělých, 68 pages (course)
- B. Frýbová, D. Zejda, BE1 Anglický jazyk pro začátečníky zkrácený, 113 pages (course)
- A. Puršová, D. Zejda, BE2 Anglický jazyk pro začátečníky, 86 pages (course)
- A. Puršová, D. Zejda, BE3 Anglický jazyk pro pokročilé začátečníky, 105 pages (course)
- B. Frýbová, D. Zejda, BE4 Anglický jazyk pro mírně pokročilé, 100 pages (course)
- B. Merrifield, D. Zejda, AE1 Anglický jazyk pro pokročilé, 231 pages (course)
- B. Merrifield, D. Zejda, AE2 Anglický jazyk pro více pokročilé, 236 pages (course)
- A. Peers, D. Zejda, AE3 Anglický jazyk pro velmi pokročilé, 97 pages (course)
- J. Zimová, D. Zejda, SPE0 Příprava na zkoušky KET, 92 pages (course)

- E. C. Lev, D. Zejda, SPE1 Příprava na zkoušky PET, 162 pages (course)
- B. Merrifield, D. Zejda, SPE2 Příprava na zkoušky FCE, 90 pages (course)
- J. Zimová, D. Zejda, AEC0 Konverzace v angličtině ke zkoušce KET, 44 pages (course)
- E. C. Lev, D. Zejda, AEC1 Konverzace v angličtině ke zkoušce PET, 82 pages (course)
- B. Merrifield, D. Zejda, AEC2 Konverzace v angličtině ke zkoušce FCE, 66 pages (course)
- A. Puršová, D. Zejda, AST Angličtina v cestovním ruchu, 94 pages (course)
- D. Zejda a kol., AIND Individuální výuka angličtiny, 196 pages (course)
- A. Ates, E. Canoy, D. Zejda, AVR1/5 Angličtina ve VR pro začátečníky, 312 pages (course)
- S. Breitenbach, E. Canoy, A. Ates, D. Zejda, AVR2/5 Angličtina ve VR pro mírně pokročilé, 302 pages (course)
- S. Breitenbach, A. Ates, D. Zejda, AVR3/5 Angličtina ve VR pro více pokročilé, 288 pages (course)

10.3 RELEVANT EXPERIENCE

- Reviewer and opponent for TAČR⁶², MŠMT⁶³, Prague City⁶⁴, and Slovak APVV⁶⁵. Reviewed hundreds of R&D projects so far, including big projects, such as Competence centres⁶⁶, Gama⁶⁷, OP VVV excellent research teams⁶⁸, or strategic university development projects⁶⁹.
- Planned and in charge of 3 successfully finished innovative educational projects supported by OP VK⁷⁰ aimed at using advanced web-conferencing solutions and 3D virtual reality in education, which involved coordination of teams spanning 3 continents from 8 participating institutions.
- Planned and in charge of an ongoing project “Reducing negative impacts of tourism on ecosystems through an intelligent software tourist guide” supported by TAČR ÉTA.
- Participated on university projects, such as OPVK INDOP, OPVK INKOV, GAČR SMEW, and SPEV projects including one where the author was the principal researcher.
- Participated on research and experimental development of visible light communication devices and advanced multi-way routing software. Contributed to development of various open-source systems. Participated on more educational and research projects.
- Gained more than 20 years of experience as a software developer, more than 15 years of experience with computer network planning and systems administration, more than 10 years with management.
- Europass curriculum vitae with more details available at www.zejda.net/CV.pdf.

62 Technological Agency of the Czech Republic (TACR)

63 Ministry of Education Youth and Sports

64 <https://prazskyyvoucher.cz/>

65 Slovak Research and Development Agency (SRDA)

66 <https://www.tacr.cz/index.php/en/programmes/competence-centres.html>

67 <https://www.tacr.cz/index.php/en/programmes/gama-programme.html>

68 E.g. <http://www.msmt.cz/strukturalni-fondy-1/vyzva-c-02-15-003-podpora-excelentnich-vyzkumnych-tymu-v>

69 E.g. <http://www.msmt.cz/strukturalni-fondy-1/vyzva-c-02-16-015-esf-vyzva-pro-vysoke-skoly>

70 Operational Programme Education for Competitiveness (ECOP)

11 APPENDIX A – THE PROTOTYPE BACK END ARCHITECTURE

The back-end part of the system contains all permanent data and most of the logic.

11.1 ARCHITECTURE OVERVIEW

11.1.1 CORE CLASSES

The system in its current state at the time of writing the thesis contains around 120 python classes. Most of them are subclasses of some of the core classes, which provide the framework for the whole system's architecture. The following are some of the most important core classes:

`CtContent` – whatever the user may be served with, is a subclass of content; e.g. a picture, video, a question

`CtTag`, `CtTagAssignment`, `CtTagLike`, `CtTagger`, `CtCategory` – related to metadata assigned to the content

`CtProvider` – content providers prepare, store and provide any kind of content to be displayed to the user

`CtFormatter` – transforms content into a format requested by a service call, such as an HTML

`CtUser` – represent any person - user of the system, family member, administrator

`CtAction` – actions handle all incoming requests from the user

`CtDispatcher` – decides which content provider to call to handle new content requests from users

`CtProviderUserSetting`, `CtSettingFormatter`, `CtSettingValidator` – for per-user per-provider settings

`CtXmlContent`, `CtXmlPing`, `CtXmlError` – formatting and parsing of XML returned as system service calls

`CtAPI` – baseclass of APIs to provide access to services on the Internet, such as YouTube, Imagga, etc.

`CtMultilangString`, `CtTranslator` – providing automatic translation of content

`CtException`, `CtWarning` – to handle errors and exceptions in the processing of user requests systematically

11.1.2 COOPERATION OF CLASSES IN HANDLING REQUESTS

The following sequence diagram⁷¹ on Figure 28 illustrates how different parts of the back end cooperate in handling the basic action call which merely requests a new content. The request arrives as an HTTP GET or POST call with a key identifying the user and argument 'next' identifying the requested action call from the front end server. In the scenario, based on the history of previous requests, user preferences and according to its algorithm, the dispatcher chooses Flickr Content Provider. Flickr provider reveals in its data stored in the database that it has a suitable image in its queue from one of the previous requests, but still, it has to load metadata about the picture, so it contacts the Flickr service via the Flickr API library. Later, according to the settings, two tagging services are used to provide semantics to the picture – a tagger which utilises tags returned by Flickr among other metadata and Imagga tagger which adds more tags based on image recognition AI. Further, Yandex translating service is called via the relevant translator implementation and the API library to translate the picture label. Then, the content instance is formatted into HTML snipped by the image formatter and encapsulated into an XML response, which is returned to the front end server. The front end then takes and parses the XML response, creates the HTML page and serves the user's browser. More detailed description of both the system architecture and its functions follows.

⁷¹ As a respected standard, we use UML diagrams throughout the document. Their purpose is to illustrate various aspects of the system. For the sake of simplicity and clarity, we sometimes sacrifice a full adherence to the official UML notation. PlantUML, an open-source tool that uses simple textual descriptions to draw UML diagrams has been used (Arnaud, n.d.).

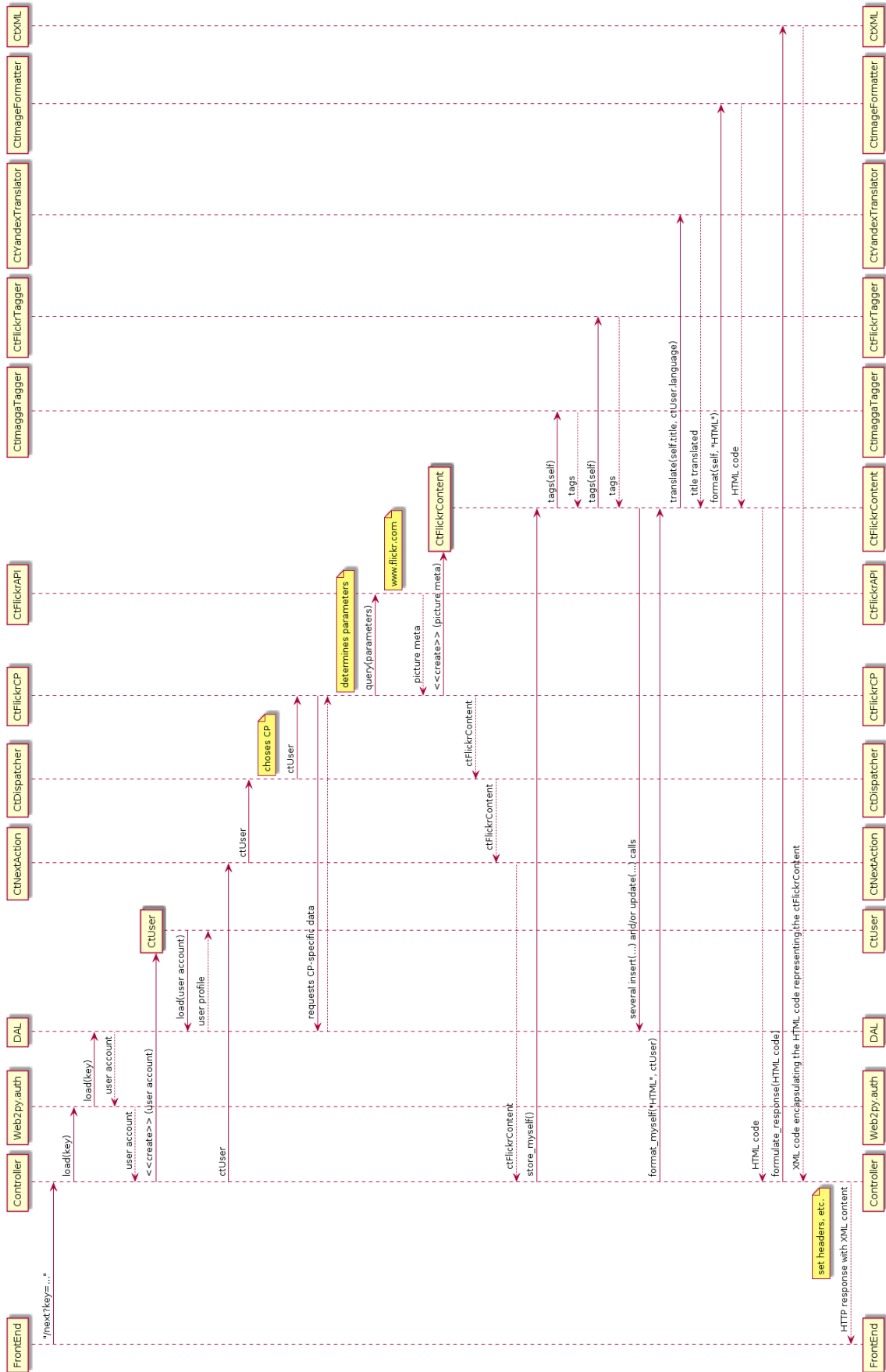


Figure 28: A sequence diagram how the back end is handling an example request

11.1.3 CUSTOM SERVICE APIs

As mentioned earlier, instead of relying on API libraries provided by service providers, we prefer implementing our own lightweight API libraries. Each of them can communicate with the relevant cloud service, but its functions are limited to just fulfil the needs of other parts of the system infrastructure – content providers and translation and tagging services. We implemented such a simple API for services clarifai.com, flickr.com, imagga.com, jw.org, youtube.com so far. Each of them is a piece of code not dependent on any other parts of the system or any external libraries beyond standard Python libraries. Besides composing calls to a cloud service and parsing and interpreting the results, the API libraries also provide service configuration and authentication handling, which involves storage and retrieval of keys, passwords, authentication tokens and similar authentication data, which is specific per-service.

Separating the direct communication with a cloud service into a relatively simple library file helps to make the system more maintainable. For example, if the API of Flickr service gets updated, there won't be any need to change anything in the relatively complex code of the relevant content provider, but just the API library itself. Such a separation layer also allows easier switching between underlying services, such as from Flickr to Picassa, or from YouTube to Vimeo, if there is a need for such a change.

11.2 THE CONTENT

The idea of content providers is one of the central parts of the system architecture, provides significant modularity, allows the system to be extended and contributes to the quality and maintainability of the code strictly separating generic functionality from specific functionality. The core classes provide a backbone for the whole back end. Among the classes defined in the core, there are also abstract classes for the whole content provider concept. Each content provider implementation is required to subclass at least CtProvider core class and implement few compulsory methods. Other methods' default behaviour may be overridden, if needed and other classes are also available for sub-classing to give developers enough freedom for various content provider implementations. While content providers necessarily depend on the system core, the dependence has to be only one-directional-only, which means that no class from the core should depend on any class from a content provider implementation. Figure 29 illustrates this feature of the system architecture.

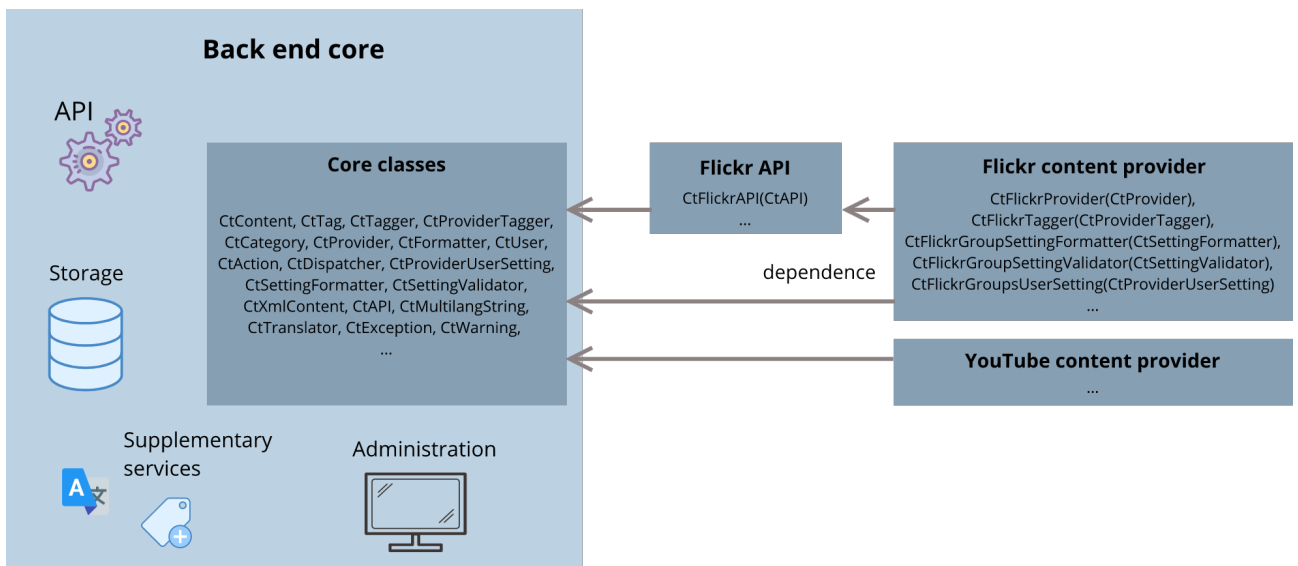


Figure 29: Back end architecture – dependence between the code of content providers and the system core

We have developed several content providers so far, but the architecture is designed in a way which allows other developers to provide *their own content providers*. From the semantic point-of-view, there serve two types of content, explained in the following sections.

11.2.1 MEDIA CONTENT

The first of them returns the kind of content objects which represent a piece of data destined to be consumed by the user. Purpose of a typical media content provider is to open a gate to a source of online content to the user. Though we did not set any limitations regarding the type of the data or an amount of data per one object, in general, the content object should be coherent and big just right to fulfil a given purpose for a user from the target group per one his request call. An example of a meaningful content suitable for one content object is one photography, one book chapter, or one music video. But for a different user, book chapter might be too much, in other cases one photography won't be enough. Technically, exactly one object is returned when a user asks a new content. Then, the system has to transform it into a form, which will allow the front end to serve it in a pleasant way to the user who requested it.

11.2.2 SYSTEM CONTENT

Besides media content, providers may offer a system content, such as a welcome notice, instructions about new functions, or a question with answer options. There is a semantic difference because from user's point-of-view a system content is not to be consumed but provides, e.g. guidance or means to set something up. But technically, the two types of content are not much different. A content provider provides both they and go through a similar chain of transformations before being served to the user. Only relatively few parts of the system need to know whether they are dealing with media or system content. To allow them to determine it, a proper category has to be set to the content by its provider.

11.2.3 PERSISTENCE OF CONTENT ITEMS

The back end defines its core database model via the Web2py data abstraction layer. There is one table which stores the main data about all content items in the system. The key fields defined are the following:

- *UUID* – allows unique identification of any content item even among more instances of the system
- *name* – the name of the content item; regardless of the type of the content, there should be a name filled-in
- *category* – such as system, image, or video; content providers may define their own categories
- *provider id* – reference to the content provider which is responsible for the content
- *associated actions* – “content actions”, such as answer options for a question content or media controls
- *original language* – the information is used to choose proper translation language-pair during formatting
- *original content id* – reference to a content from which the current content was derived as similar (if any)
- *validity* – used if it is necessary to declare a content item as no longer accessible or invalid
- *created on* – just a date of creation

Besides those, there is one field for “custom variables” and are two more fields without any specific meaning, which are left for any use by content providers. These fields significantly simplify both the database model and implementation of content providers. Though we did not try any related benchmarking, it is likely that they may provide a performance advantage over a solution, which would require a lot of database searches, perhaps with joins, just to load content items from the database. Our opinion is that these advantages outbalance the fact, that these multi-purpose fields violate normality of the table.

The custom attribute is utilised by a set of `CtContent` functions which allow storage and retrieval of unlimited number string variables. The functions know how to connect them using separators and split them again into a directory of `variable_name:values` pairs. If there are the characters used as a separator in variable values or variable names, proper character escaping is performed to avoid any confusion. An example how data for a particular Flickr image are stored in the custom database fields follows:

```
flickr_tags=jindřichův, hradec, hrad, zámek, zrcadlení, voda, večer, odraz, světlá|
flickr_license=0|flickr_photopage=https://www.flickr.com/photos/138502864@N02/35847389930/|
image_sizes=https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_s.jpg^75^75
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_q.jpg^150^150
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_t.jpg^100^67
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_m.jpg^240^160
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_n.jpg^320^213
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6.jpg^500^333
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_z.jpg^640^426
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_c.jpg^800^532
https://farm5.staticflickr.com/4319/35847389930_d330d6a3d6_b.jpg^1024^681
https://farm5.staticflickr.com/4319/35847389930_31da68f65c_h.jpg^1600^1064
https://farm5.staticflickr.com/4319/35847389930_d28f711c20_k.jpg^2048^1362
https://farm5.staticflickr.com/4319/35847389930_874b363833_o.jpg^3008^2000|flickr_date_taken=2017-
05-27 20:35:30|flickr_owner_realname=Miloš Stanko|flickr_location=<location accuracy%%escaPed%%"12"
context%%escaPed%%"0" latitude%%escaPed%%"49.142077" longitude%%escaPed%%"15.000801" place_id%
%escaPed%%"pOWDsgNwW7rOnDI" woeid%%escaPed%%"790843">
<locality place_id%%escaPed%%"pOWDsgNwW7rOnDI" woeid%%escaPed%%"790843">Jindrichuv
Hradec</locality>
<county place_id%%escaPed%%"WJGj_eFQUL9cPVTu9w" woeid%%escaPed%%"12582539">Jindrichuv
Hradec</county>
<region place_id%%escaPed%%"GM4hIp5TUrrCPy5ZCQ" woeid%%escaPed%%"20070502">South Bohemian
Region</region>
<country place_id%%escaPed%%"5iL78XNTU6Q0TIacg" woeid%%escaPed%%"23424810">Czech
Republic</country>
</location>|flickr_owner_username=toulavej54|CtFlickrProvider=:spring%%escAped%%442531@N22
```

Extra table fields are recommended to be used for those kinds of variables which are likely to be used in search queries. So, for example, Flickr Content Provider uses the extra field to store the Flickr image ID. Though not enforced but for the sake of good development practices, it is strongly recommended for content provider implementations to avoid direct calls to data abstraction layer. Instead of dealing directly with the database, the content provider should call methods of the object and set or read object attributes. So, the core class model adds an additional separation layer which helps to keep the code less error-prone and more maintainable. For example, if a change in the underlying database model necessary, likely the implementation of the core classes may be adjusted in a way, which will preserve backwards compatibility for content providers. The separation of layers is illustrated in Figure 30.

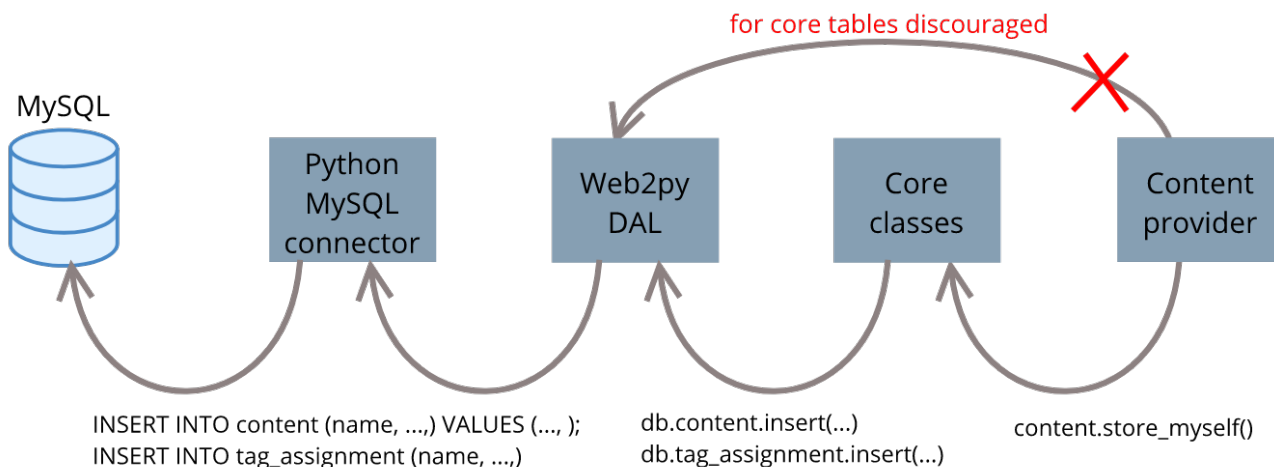


Figure 30: Layers of persistence abstraction for the data required by the system core

Preserving backwards compatibility for the core classes is even more critical because we count with the possibility of other developers creating their own content providers compatible with our system.

11.2.4 CUSTOM STORAGE FOR CONTENT PROVIDERS

In addition to the mechanism described above which allows storing custom content data, each content provider may define its own database tables if needed. So, for example, Flickr provider defines a table to store results of search queries for future use (so it won't have to repeat the same query again and again upon

every relevant request), a table for invalid combinations of image groups and tags which do not return any results (to avoid them next time) and table which keeps metadata about Flickr groups. The recommended approach to define the tables on the level of Web2py DAL, so the definition looks, for example, this way:

```
db.define_table('content_provider_flickr_queue',
    Field('query', "string"),
    Field('flickr_id', "bigint"),
    Field('title', "string"),
    Field('results_page', "integer"),
    Field('found_on', 'datetime', default=request.now),
)
```

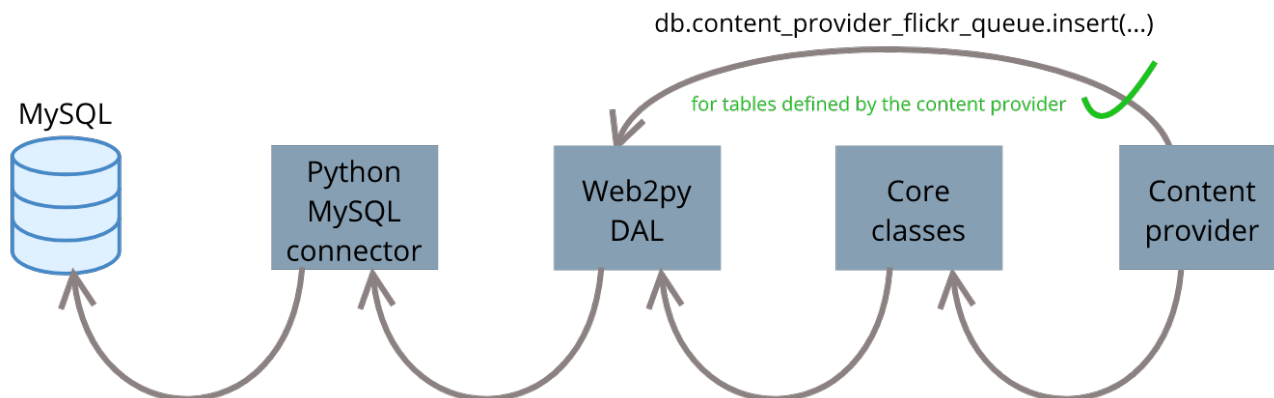


Figure 31: Layers of persistence abstraction for the data required by a content provider

Content provider should stick to a recommended naming scheme, so names of tables defined by different content providers won't cause name conflicts. Tables defined by the content provider may be accessed directly by the content provider code via DAL, as illustrated in the Figure 31. In this case, the direct access won't break the quality of design, because the developer of the content provider has full control over both the database model and the code dealing with the data. Of course, the object-oriented approach may be applied as well on the level of content provider implementation in a similar way it has been done at the core level to put a separation layer between particular algorithms, but if it is up to the content provider developer to decide.

11.2.5 USER SETTINGS

The back end also provides a management interface which gives access to both system-level and user-level parameters. The central management interface defined at the level of system core has to provide access also to settings defined at the level of content provider, but not breaking the one-directional-only dependence rule. It makes the design of the management interface more complicated.

So, to solve the problem, we put the content provider settings functionality in the core but allowed each content provider to override the related classes `CtProviderUserSetting`, `CtSettingFormatter`, and `CtSettingValidator`. These classes define which information the management interface needs to know about the settings to generate the management user interface. It requires at least the following information:

1. What is the name of the content-provider user-specific variable.
2. Whether it is supposed to contain multiple values or not.
3. Where to find candidate values for the user. The candidate values are values already known to the provider, but not yet listed in user's settings.
4. Whether it should be able to accept a new value as an input, or only selection from candidate values is allowed.

5. How the value should formally look like, its format⁷².
6. Provided that an input value is formally valid, how to check if it is truly valid – e.g. if it exists.
7. Whether to do something else beyond appending the validate value in user's settings, such as storing an entry in a provider-defined table.
8. Instructions for the administrator regarding which values are accepted, etc.

So, for example, Flickr Content Provider keeps a list of Flickr groups where pictures for a certain user are searched. The list may be directly changed by the content provider algorithm as the content provider learns more about the user preferences. But it has also to be viewed and adjusted by the management interface. So, the Flickr Provider needs to provide an implementation of the relevant classes which provide the answers:

1. The variable is named groups.
2. It is supposed to contain multiple values.
3. A code which returns candidate values looked-up in `content_provider_flickr_group` table.
4. That a new value could be provided as an input.
5. A code which checks if a value matches a regular expression of a formally valid Flickr group ID.
6. A code which calls Flickr API to check if the group ID exists and is publicly accessible.
7. A code which puts a value validated by Flickr API in the `content_provider_flickr_group` together with the group name and other metadata loaded via the validating call.
8. Textual information for the administrator about how Flickr provider deals with groups.

All these information are provided systematically by sub-classing the relevant core classes on just about 50 lines of code. The part of the back end core responsible for the management interface takes the information and generates a simple but functional interface as shown in the following screenshot Figure 32.

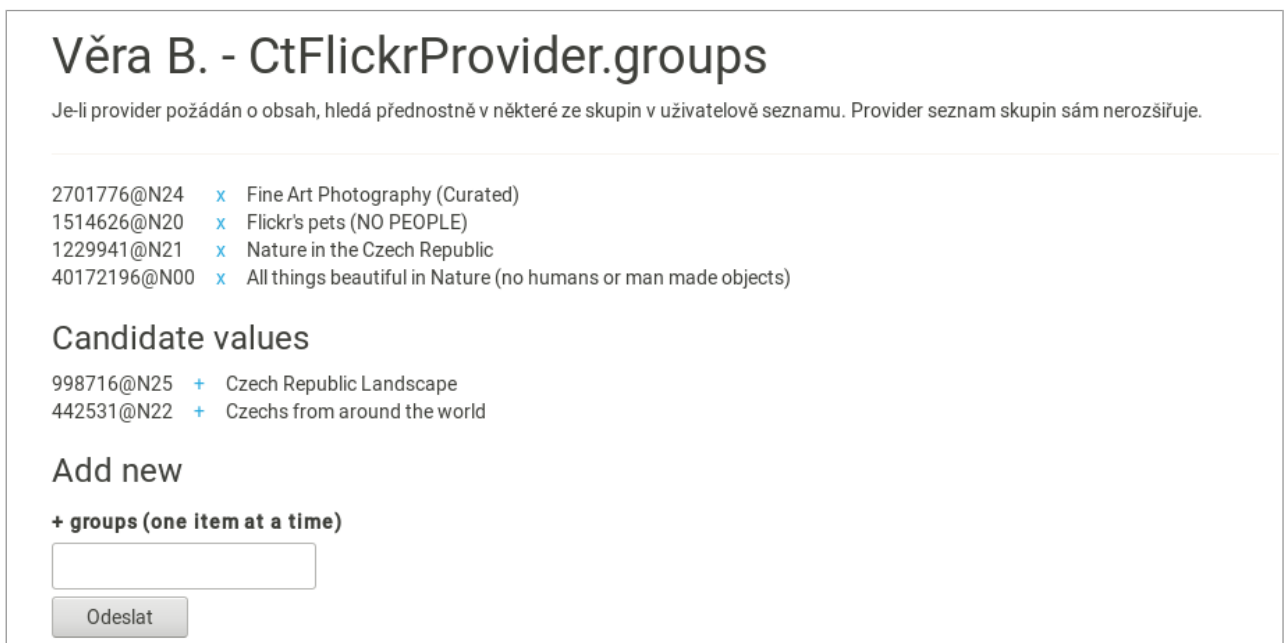


Figure 32: A sample piece of management user interface generated from the content provider model

⁷² We do not work with data types; all content provider-specific user variables are considered strings. We decided that adding a specific support for various data types in variable definition would complicate the design without providing sufficient benefits. A content provider may transform or simply cast a value into just any data type it needs, as long as the data type allows string representation. Having means to formally validate a value, the format may be checked either via JavaScript on the client side, or on the back end side, but before contacting any external validating service, which is a good design principle.

11.2.6 USAGE OF UNIVERSALLY UNIQUE IDENTIFIERS

Universally Unique Identifier, UUIDs or similar concepts are increasingly used, as the name suggests, to identify objects uniquely. Often they are being used even as primary database keys instead of autoincremented integers, which helps to simplify interoperability between databases. UUIDs are also well-supported, sometimes even recommended or required, by object-relational-mapping technologies. They also allow separating the id generation from the database, giving more control to the application code. UUIDs as primary keys enable knowing the primary key before insertion, which avoids a round trip database query and simplifies the transactional logic. But with Web2py these inconveniences are already solved by DAL, so no longer affecting the code. UUIDs also do not reveal information about data – for example, if someone knows that there is an entry with id 1557, he may be tempted to try to access 1556 or 1558.

On the other hand, they are harder to read. E.g., during debugging, UUIDs can't be used to sort rows meaningfully. They also require more space, and they may affect performance, especially in complicated joins. Further, though it is possible to use UUIDs with Web2py DAL and there is even official support for them with advice how to do it, they make the code less straightforward, thus more error-prone.

Comparing advantages and disadvantages of various approaches, we decided for a compromise. One of the attributes assigned to each content object and each content row in the underlying database is a generated UUID. Anytime we are referencing a content item externally, out of bounds of the back end, we use its UUID. So, as a part of a response returned to the front end server there is a UUID of the content object, whereas the database id is kept internal. But for referencing the content internally, we still stick to the default auto-incremented database-generated integers. We are planning to use similar approach also for other objects – keep their database-generated ids as an internal mechanism and if there is a need to reference them from outside, use UUIDs. Because each publicly-referable object in our approach has two unique identifiers (id and UUID), it violates database normality. But it allows us to avoid publicly exposing primary key *ever*, which is a good design practice. Actually, after designing the back end the way it is, we have noticed an article by Harrison (2017), which covers the advantages and disadvantages of UUID in the database, which comes to similar conclusions based on years of experience with big databases. Others, such as Clayton (2015) are also somewhat sceptical about UUIDs.

11.2.7 CONTENT PROVIDER IMPLEMENTATIONS

A relatively large portion of the system, several thousand of lines and about 20 % of the source code size of the whole system, falls on the implementation of individual content providers. Most of the code cover the logic which chooses content based on user profile and his preferences. So far we have implemented:

- YouTube provider
- Flickr provider
- Audiobook provider
- System provider
- Testing provider

Each of them is introduced briefly in its respective section on the following lines. We mention some of the notable decisions we had to make in connection with the design of each of the content provider to solve various issues. Some issues were common for more than just one content provider, such as mechanisms to deal with errors or exceptions or adjustments to the code to support both touchscreen devices and devices with pointer-based screen navigation. We cover these common issues in later sections

11.2.8 YOUTUBE PROVIDER

As explained in the architecture overview, the content provider returns just a snippet of HTML, CSS and JS code together with additional meta information. But when put together by the by the default HTML-based front end (see chapter 12) and rendered by a browser, the result looks like in the following screenshot

(Figure 33). You can see the media controls in the right bottom part of the content pane. Buttons generated for declared system actions by the front end are in the action pane on the right side.

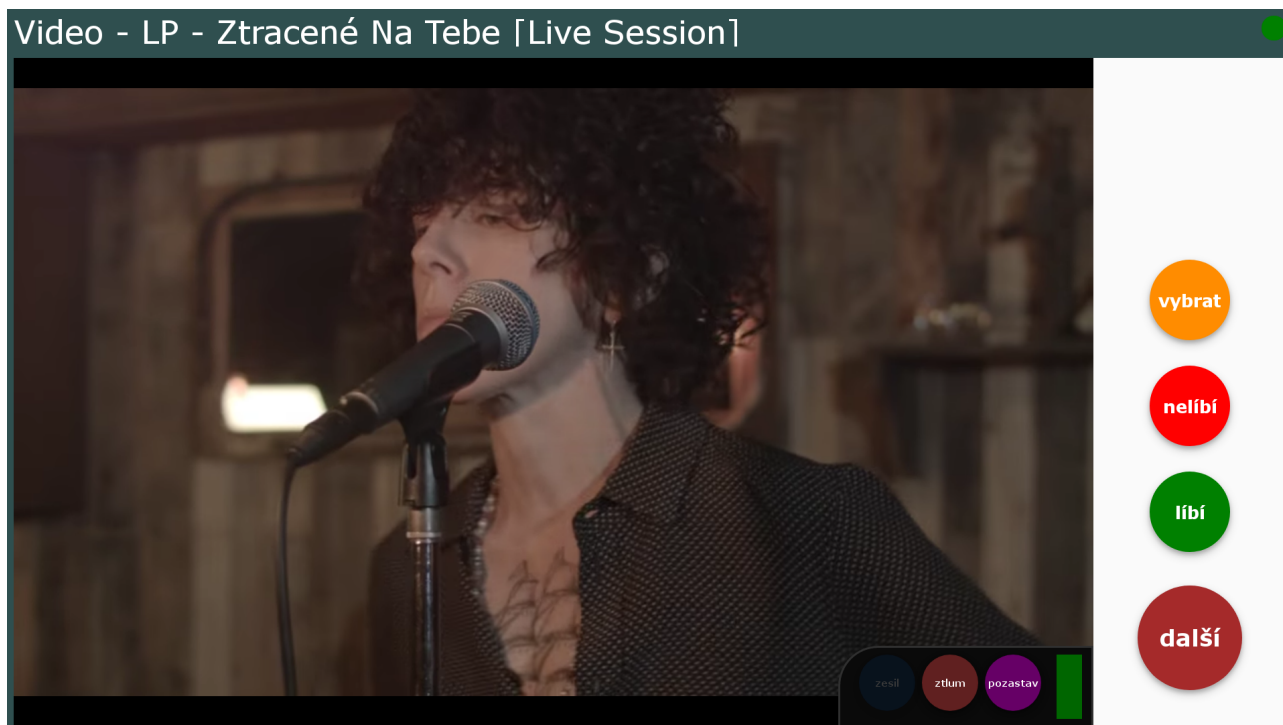


Figure 33: Sample screenshot of the viewer with a content sample from the YouTube Provider

Content selection. In the beginning, each user starts with a list of predefined videos. Subsequently, more videos are looked up. To find them, the content provider calls functions from our minimalistic library which deals directly with YouTube API. YouTube API is quite rich and allows various search methods. Available criteria include channel id, channel type, location, Freebase topic, caption, category, duration, etc. Search queries may further contain logical operators. After some initial but not satisfying tests with tag-based searching, we decided to base searches mainly on similarity – the `relatedToVideoId` search parameter of the YouTube API. It is fairly simple and provides acceptable results.

Custom controls. The code to embed a YouTube video in HTML content is well documented and easy to implement. Because we wished to provide users with consistent user interface across different content providers, it made the embedding a bit more tricky. We could not stick to the default media controls to play, pause, and adjust the playback volume. Instead, we created our own media controls, which allow uniform styling and behaviour. As shown on the screenshot, the controls have been designed in a way which does not obstruct the video excessively. But on the other hand, they do not disappear because it might confuse users.

Feedback. Custom-made control elements allow us to gather the information about user's interaction with the video whenever he clicks a control, to evaluate his skills and adjust the interface or functions if needed. We also report back to the system errors, such as if the video does not load successfully. Also, when a user is leaving the page for a next one, we record the position of the playback for the case we should resume the playback from a certain point in the future. The implementation for Chrome is different from other browsers:

```
var _wasPageCleanedUp = false;

function pageCleanup() {
  if (!_wasPageCleanedUp)
    recordInteraction(closing_code, onClosingCallDone, false);
}

function onClosingCallDone() {
  _wasPageCleanedUp = true;
}
```

```
$(window).on("beforeunload", function () {
  //this will work only for Chrome
  pageCleanup();
});

$(window).on("unload", function () {
  //this will work for other browsers
  pageCleanup();
});
```

We could also make a “heartbeat call” via AJAX every few seconds, which could provide more precise information about the playback, such as if the user watched the video more times⁷³. Such a solution might even replace the current solution because we do not have to know the position which the user reached accurately.

Autoplay. We had to solve a dilemma whether to automatically start the video playback on load or let the user start it. Based on the feedback from the initial focus group we decided that in favour of it. But automatically-triggered playback poses a challenge in modern browsers. According to Google, “*web browsers are moving towards stricter autoplay policies to improve the user experience, minimise incentives to install ad blockers, and reduce data consumption on expensive and/or constrained networks. These changes are intended to give greater control of playback to users and to benefit publishers with legitimate use cases.*” (Beaufort, 2018) Current Chrome's policies allow autoplay of muted content. Autoplay with sound is allowed if user has interacted with the domain (click, tap, etc.). Autoplay with sound is allowed on a desktop if the user's Media Engagement Index threshold has been crossed⁷⁴. On a mobile it is allowed if the user has added the site to his or her home screen. Top HTML frames may delegate autoplay permission to their iframes. According to our testing, the Chrome v. 64 was not always respecting the rule, that on mobile the autoplay should be allowed if the user has added the site to his or her home screen. Usually, after several attempts, the video started being played automatically, which might be related to the algorithm computing user's media engagement index. We did not investigate this problem further, but to avoid confusion and ensure consistent behaviour we adjusted the experimental flag `chrome://flags/#autoplay-policy` of Chrome in the testing tablets. Such a solution is applicable only for devices within our control.

Suppress links. Even when we disabled the related videos, controls, annotations, title and other info, prevented full screen, and set branding to modest, the player still occasionally keeps showing related videos or other unwanted information. It wouldn't be a big problem if the annotations or related videos were not clickable, directing the user out of the software interface. We had to solve the issue putting a transparent `div` over the `iframe` with the video player. All user interaction with the overlaying `iframe` is being intercepted, and its propagation is stopped with a JavaScript function:

```
<style>
#player_pane {
  min-width:100%; min-height:100%;
  position:relative;
  overflow:hidden;
}

#player_pane iframe {
  position:absolute;
  top:0; left:0;
  width:100%; height:100%;
}

#player_pane div.iframe_over {
  z-index: 10;
  position: absolute;
  width:100%; height:100%;
  top: 0; left: 0;
  background: rgba(0, 0, 0, 0.0);
}
</style>
```

73 Currently, we play the current video in a loop. The behaviour might change if we get negative feedback.

74 The engagement index typically grows if the user plays video with sound on specific domain.

```

<script>
function consumeEvent() {
    event.stopPropagation();
    event.preventDefault();
    return false;
}
</script>

<div id="player_pane">
  <div id="player"></div>
  <div class="iframe_over"
    id="iframe_over"
    onclick="javascript:consumeEvent();"></div>
</div>

```

Custom persistence. The provider defines two custom tables. One is for API queries, so it is possible to continue with searches for results on subsequent pages using the `next_page_token` mechanism defined by the YouTube API. The other table stores results which become queues for subsequent related content requests.

Possible improvements. Based on the feedback from the testing: With lengthy content on the mind, such as audiobooks, an action 'continue later' should be added. The user could stop the playback, move to the next offered content and continue listening on a future occasion. Also, because the list of predefined videos has been composed intuitively, we might think of doing research how to compose it more rigorously.

11.2.9 FLICKR PROVIDER

The generated content is minimalistic. Only the picture and the title are prepared by the content provider to be shown, as illustrated by the Figure 34.

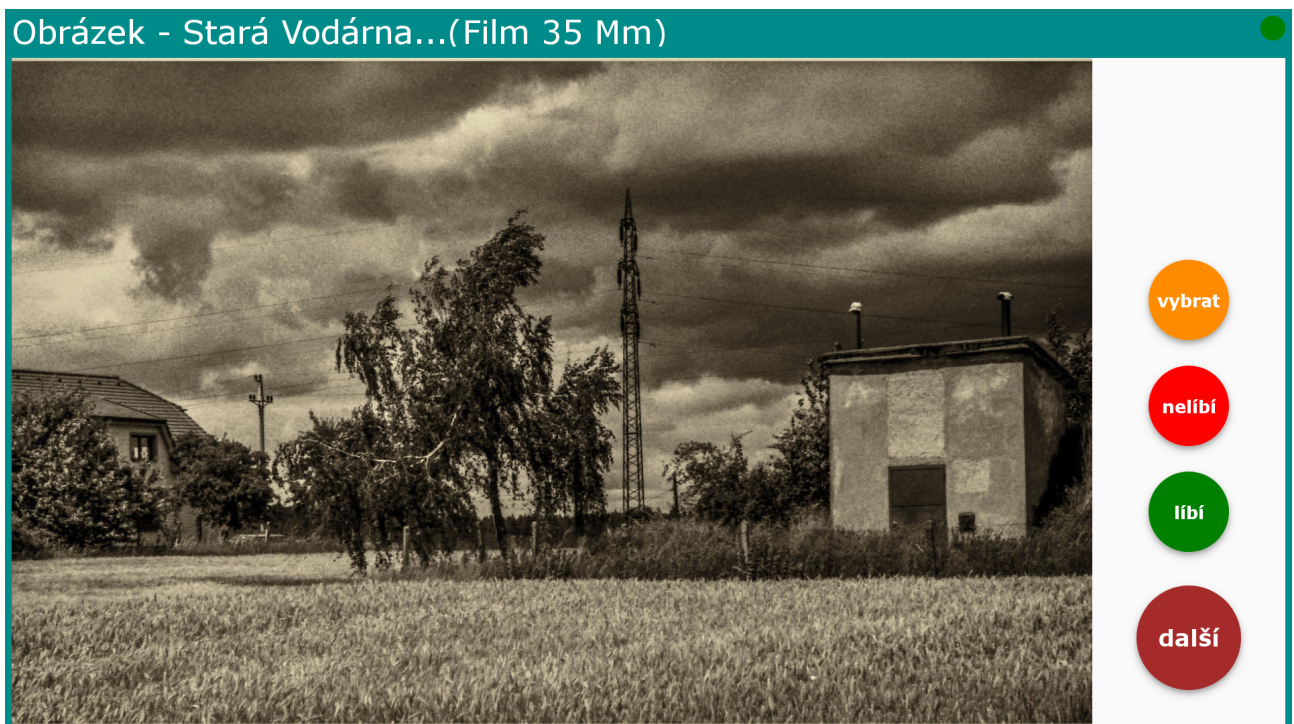


Figure 34: Sample screenshot of the viewer with a content sample from the Flickr Provider

API calls. Similarly to YouTube Content Provider, also Flickr content provider use our minimalistic API library instead of a full-fledged library provided by Flickr. Flickr API is more extensive than YouTube API,

but its clear design makes it relatively easy-to-understand and easy-to-use⁷⁵. We considered and tested various API methods. For example, `galleries.getPhotos` pulls rather small collections of pictures, usually with an artistic value. But only a very limited portion of Flickr content is available through galleries. Function `groups.pools.getPhotos` provide better results because a much bigger portion of the content is available through groups. Searches such as `groups.pools.getContext` or `photos.getContext` might be useful if our user likes a picture because they allow getting list through pictures uploaded in the same batch by the same author. But we have not implemented such behaviour, or at least not at the time of writing this text. Functions `interestingess.getList`, `photos.getPopular`, `stats.getPopularPhotos`, or `tags.getHotList` return pictures liked by the community of Flickr users. Then there are functions which allow geolocation-based searches, such as `photos.geo.photosForLocation` or several functions from the section `places`, which might be useful, e.g. to search pictures related to a place important for our user. Eventually, for the prototype implementation we have chosen inconspicuous, but powerful `photos.search` function. It allows combining several tens of search criteria including tags, interestingness, publication date, location, presence in a group, full-text, etc. We also need `photos.getSizes`, `photos.getInfo`, and `groups.getInfo` functions to fetch relevant metadata.

Content selection. The content-selection mechanism is illustrated by the activity diagram in Figure 35.

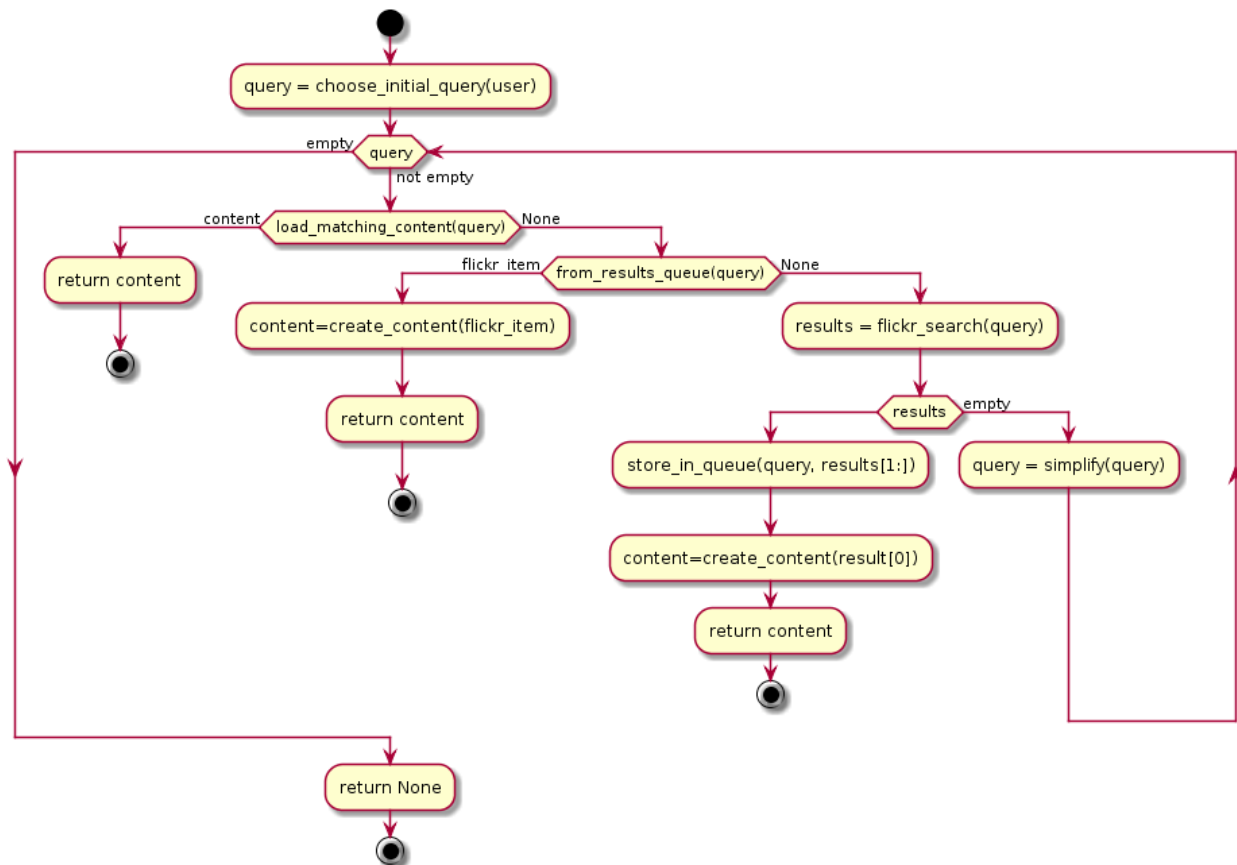


Figure 35: Activity diagram of the algorithm which the Flickr Provider uses to decide which content to serve

When Flickr provider is enabled for a user for the first time, the provider assigns a predefined set of source Flickr groups. This may be further adjusted either via the management interface or by the content provider algorithm itself. Upon a content request, at the beginning, the content provider algorithm chooses a query, which may involve, e.g. a tag and a Flickr group, selected according to user tag preferences and preferences toward Flickr groups. If there is any content already stored which matches the query which has not been

⁷⁵ The design of the Flickr API is slightly obfuscated with the redundancy of its functions. It causes, that a task may be often solved in several ways, calling different API functions, but with identical or very similar results.

served to the current user, the algorithm will pick from the database and serve it immediately. Otherwise, it is recursively attempted to look up for new matching Flickr data. In each attempt, the query is matched against a queue of previous Flickr searches stored in a table. If there is no match in the queue, finally, Flickr is contacted and search invoked. The number of requested results per each Flickr API search is set to be reasonable. The first result is used as a basis to create a new content item which will be returned to the dispatcher. A subsequent Flickr API call is needed to fetch details about the item. Any remaining search results are stored in the queue for subsequent attempts of the same query. If the Flickr search does not return any results, a simpler query is attempted. This approach keeps the number of Flickr API calls to a reasonable minimum. Even though Flickr API does not set any hard quotas, such sparse approach is a good practice.

Storage. Pictures are not stored on the back-end server. We keep just the links; pictures are pulled directly from Flickr storage to the client. Such a solution has advantages – we don't load our server with unnecessary storage requirements and with related data transfers. In the case user is asking a content for the first time, the response is not delayed by the data transfers between Flickr and our server, which leads to a better user experience. Last, it is more in harmony with the fair content usage terms of Flickr. Flickr e.g. requires to synchronize content status information – e.g. if picture rights owner decides to take a picture away from Flickr, all sites have to take it away as well. We implemented a solution to handle such situations on the client side as a part of the service worker, which is described later in 12.3.2.

Responsiveness. The content provider returns not just a picture, but an HTML code which ensures responsiveness. The picture always centres both horizontally and vertically into the content pane. It keeps its aspect ratio and fills the available space. Overlapping parts, if any, are hidden. The main portion of the CSS code facilitating the responsiveness of images is relatively simple:

```
{
  min-height:100%;
  position:relative;
  top:50%;
  left:50%;
  transform:translateY(-50%) translateX(-50%);
  -webkit-transform:translateY(-50%) translateX(-50%);
  -ms-transform:translateY(-50%) translateX(-50%);
}
```

Besides this, to provide a responsive and bandwidth-undemanding response, we use the HTML `srcset` attribute to let the browser choose, which size of the image to download to match the available space and real screen resolution⁷⁶:

```

```

Consistency across image providers. There might be other content providers in the future pulling images from other sources than Flickr. We wish to make it easier to provide consistent user experience across content providers. So, the formatting itself has been implemented in a source-neutral way into an image formatter, defined at the core level. So, Flickr Content Provider merely delegates formatting to this generic formatter.

Possible improvements. In the future, other types of Flickr searches might be used, such as similarity search if the user likes a certain picture or location-based searches.

76 Device with the retina-type display may have even several-times more pixels for the same resolution as a device with an ordinary display with 1:1 pixel density.

11.2.10 AUDIOBOOK PROVIDER

We wanted to develop an audiobook provider which would allow parallel display of text and voice playback. During the brainstorming session, we noticed voices calling for a spiritually uplifting type of content. So, we have searched for a source which would satisfy the request. Eventually, we came across a web page [jw.org](https://www.jw.org)⁷⁷ and its offshoot wol.jw.org. Combining content from these two sites we were able to get the content in a form suitable for our purpose. It was quite tricky because none of the sites provides any official API. Reverse engineering techniques allowed us to create an API library which communicates with the websites, send requests and parse results. Though we are quite confident we are not violating the terms of use of these sites with our approach, before pushing the development from the prototype phase to the production it would be better to negotiate with the copyright owner and reach an official agreement.

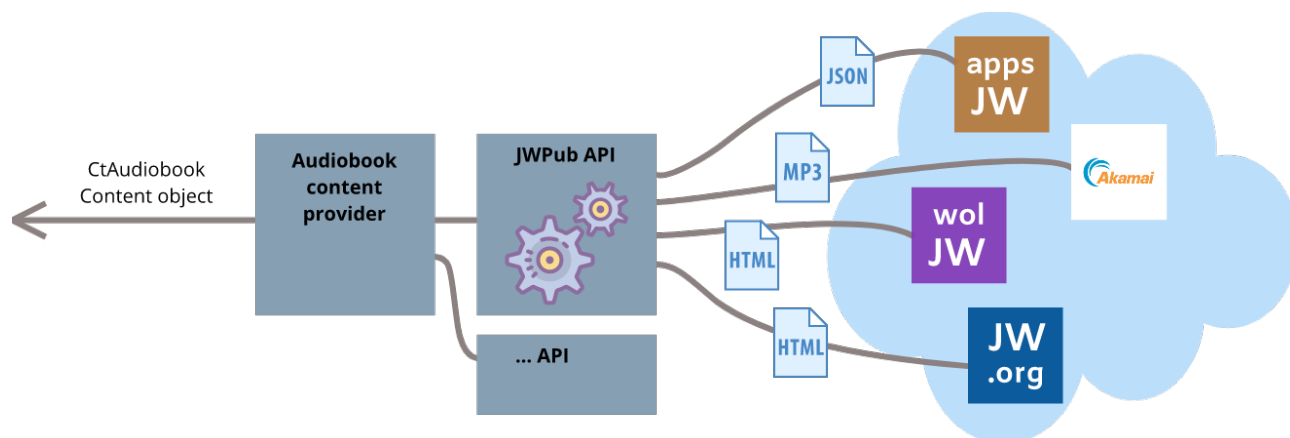


Figure 36: Audiobook Content Provider combines several data sources to provide a synchronised text and playback

The Bible. The content for which we implemented full support so far is The Bible. As a source of text, we parse HTML pages from wol.jw.org site. Its well-structured and consistent code allows automatic parsing. To implement parsing rules we used `HTMLParser` from the standard Python library. As a source of relevant audio, we use the www.jw.org site. Study of the source code revealed that the site uses services provided by another site called apps.jw.org. These services return standard easy-to-interpret JSON responses. One such call returns, for example, a link to MP3 file with the audio of a book chapter stored at an Akamai server, and, what is essential, markers which identify exact divides between verses of the chapter. Combination of the sources is illustrated by the diagram in Figure 36. We were able to combine these and create a compound player/reader, which plays a chapter and shows the text which is being read. The result resembles karaoke. Thanks to the fact that the source sites provide multilingual content, the reader supports almost 200 languages for which either the whole Bible or at least its portions are available. Please, refer to the following Figure 37 which contains a relevant screenshot.

Settings. The audiobook provider allows adjusting its behaviour. For example, it is possible to set whether the contents should be served sequentially or in random order. It is possible to fine-adjust the source, so for example, for the Bible, which consists of 66 smaller “books”, it is possible to set via the Management interface which books shall be involved.

Storage. The audio contents are not stored on the back-end server. The textual content is only cached to prevent unnecessary calls to the sites which source the content. Permanent storage of the copyrighted material might also violate the terms of use. We also do not want to load our server with unnecessary storage requirements and with related data transfers. The solution where our back end provides just a proxy between the client and the source also leads to lower response times.

⁷⁷ Both <https://www.jw.org> and <https://wol.jw.org> are operated by Jehovah's Witnesses. Interestingly, e.g. according to Oasdom (2016), www.jw.org is the most translated website in the world, offering content in more than 900 languages. It provides access to a massive amount of media including text, imagery, audio, and video.

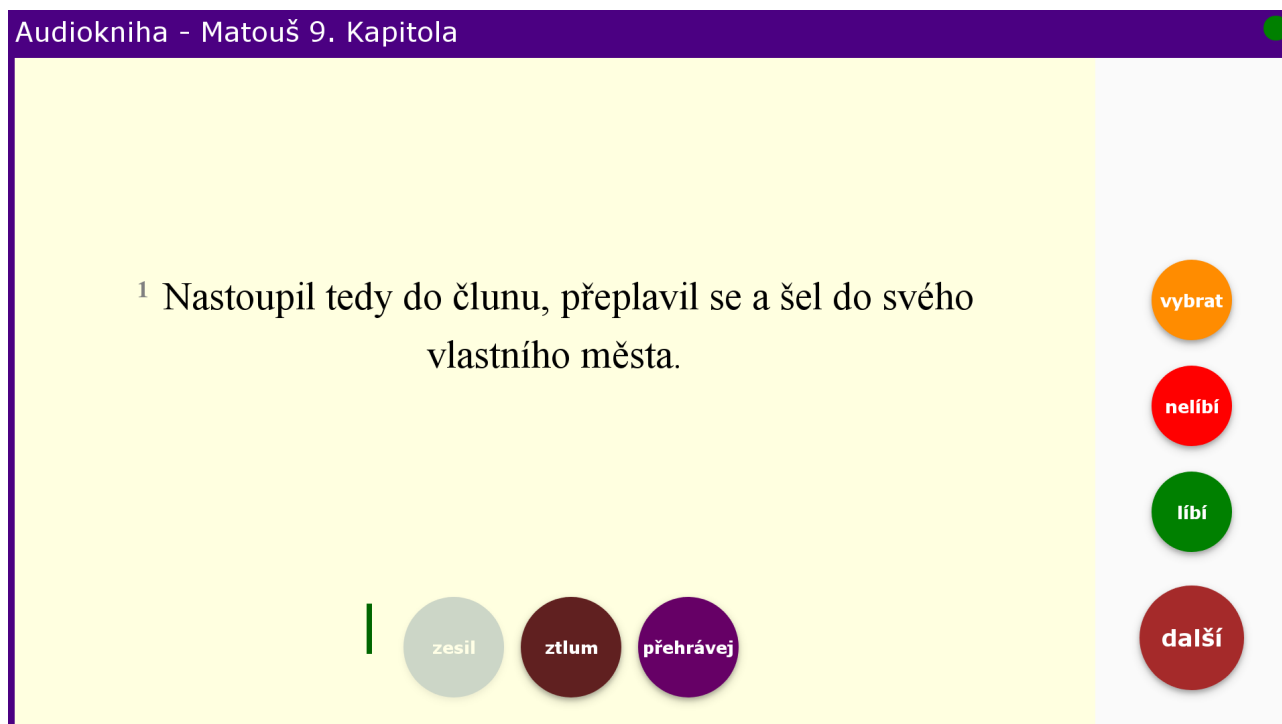


Figure 37: Sample screenshot of the viewer with a content sample from the Audiobook Provider

Language encoding. The point at which we get stuck for a while when developing the Audiobook Content Provider and the relevant API was related to encoding of non-ASCII characters. It required several hours to identify the cause why `UnicodeDecodeError` or `UnicodeEncodeError` is being thrown on some occasions and why some pieces of code do not behave as expected. The following three lines solved a good deal of these problems:

```
import sys
reload(sys)
sys.setdefaultencoding('utf-8')
```

Dealing with various encodings is not a strength of Python v. 2.x, which is the developer community aware of. For example, Selph (2012) notices, that a significant source of troubles with encoding in Python v. 2.x is related to the ambiguity of `str`: “Probably the biggest problem with Python 2’s text encoding boils down to a naming problem. In Python 2, you have a datatype called `str` and one called `unicode`. These names are simply wrong. A `str` object is basically an array of bytes (numbers between 0 to 255). For any `str` object in your code, it could either be the bytes of an encoded string, or the decoded bytes of an ASCII string.” Better handling of language encoding is one of the main improvements of Python v. 3.x over v. 2.x. But sadly, Python v. 3.x to solve problems like this breaks the backwards compatibility. Migration a code to Python 3.x often means fixing plenty of subtle bugs that may have never been noticed. Web2py supports only Python 2.7 so far. It poses a true challenge for Web2py developers to identify all the areas which require adjustments and then do them in a way, which *won’t break* the backwards compatibility, as promised.

Possible improvements. Though it will likely pose new challenges, many more content sources might be considered for both audiobooks and eBooks, such as public domain sharing platform librivox.org.

11.2.11 MAIN SYSTEM PROVIDER

Main System Provider, as apparent from its name, serves not a media content, but a system content. The provider is responsible for welcoming users and helping them to understand system functions and the user interface. It may also offer new features, such as new system actions, represented by the viewer as new buttons in the action pane. Unlike to the previous three content providers described earlier, the Main System Provider is not connected to any external service. A screenshot with an example content coming from the

Main System Provider is in the following screenshot Figure 38. It is rendered in Czech and asks the user if he wishes to get a new button called 'select'. Then it explains briefly, what is the purpose of the button.

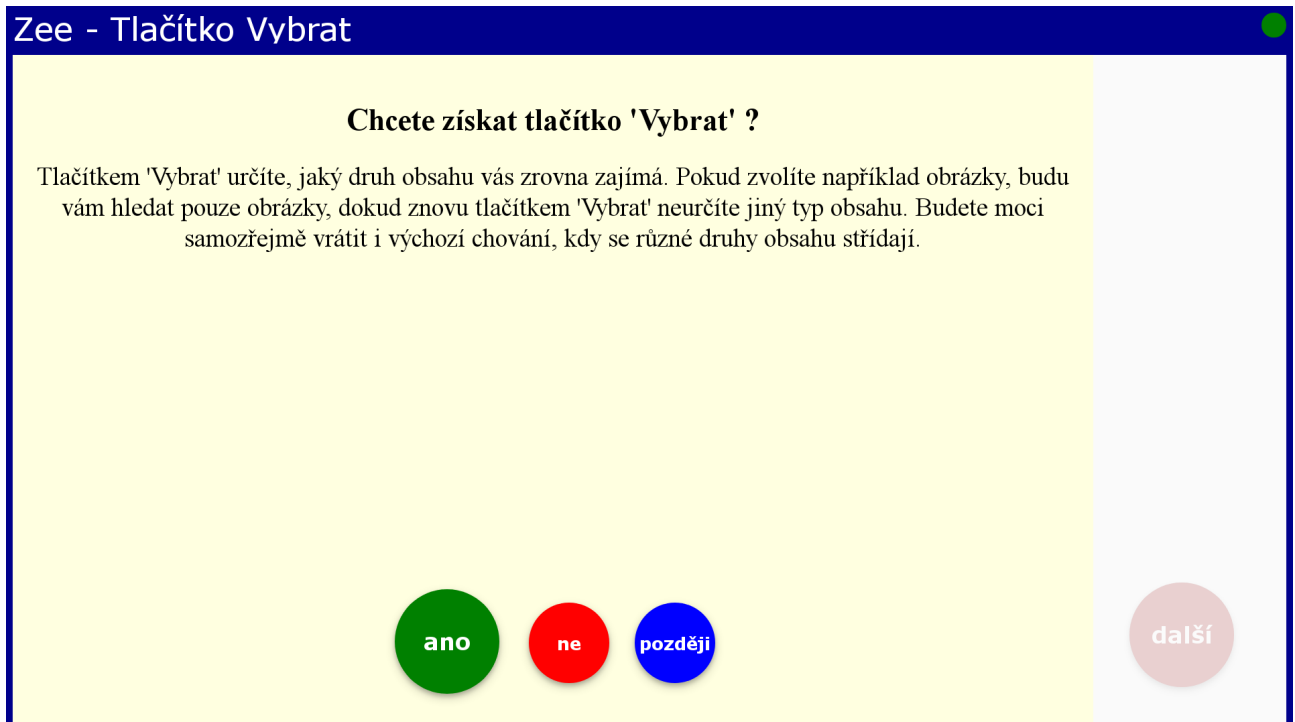


Figure 38: Sample screenshot of the viewer with a content sample from the Main System Provider

Model. The system provider offers its contents according to a model which defines which content should be offered on which condition. The following code shows an example of a model which defines just two “pages”, i.e. pieces of system content. First one is a welcome page which only gives a textual notice to the user and is to be offered as a very first item provided to the user. Because the follow-up interval is not defined, it would be offered just once and never repeated again. The second defined page offers a new button. It should be offered if the user successfully consumed at least 15 pieces of other content. If he postpones the offer clicking 'later', it should be repeated after another 30 pieces of content displayed. There are no background images defined for the pages. The `T` puts the strings into the Web2py localisation engine, so that they may be put into the list of strings waiting for translation, and if a translation matching user's language is provided, they will be replaced on the fly.

```
yes_no_later = (CtYesSystemAction(),
               CtNoInquiryAction(),
               CtLaterInquiryAction())
self.model = (
    CtInquiryModelPage(first_offer=0,
                       followup_offer_interval=None,
                       page="welcome1",
                       name=T("Welcome"),
                       message=T("You are willing to try something new ..."),
                       text=T("I am your new electronic companion ..."),
                       actions=(),
                       image=None
    ),
    CtInquiryModelPage(first_offer=15,
                       followup_offer_interval=30,
                       page="like",
                       name=T("Button 'Like'"),
                       message=T("Would you like to get a new 'Like' button?"),
                       text=T("The like button will allow you to ..."),
                       actions=yes_no_later,
                       image=None
    ),
)
```

The decision whether to serve a page may be made based on the count of content items served to the user since the beginning or since an event (views-count-based choice), as in the example above. Or a particular time may be required to pass since an event (elapsed-time-based decision).

Extendable UI. System provider does not only define which new functions to offer but also defines the behaviour of the functions themselves. For example, – the implementation of the action handler for the 'select' action offered on the screenshot above is not defined anywhere in the system core, but in a `CtSelectContentSystemAction` class, a descendant of a core-level `CtAction` class. Such separation of code keeps the system core compact. It also puts related pieces of algorithms in one place, which makes the code easier to manage and extend.

With this architecture, implementation of new actions and the logic which define on which condition to offer the actions to users is pretty straightforward. As an example, the following code shows a very simple implementation of the 'like' action, which has been defined by the model mentioned above to be offered to users:

```
class CtLikeSystemAction(CtMainAction):

    def work(self, user, action_vars):
        user.like_last_content(like=True)

    def followup(self, user, action_vars):
        response.status = 204
        return None

    def get_name(self):
        return "like"

    def get_color(self):
        return "green"

    def not_for_categories(self):
        return (CtSystemCategory, CtInquiryCategory)
```

According to the code, the 'like' action calls merely a method of `CtUser` class to mark a content item as 'liked'. But if there was no such straightforward implementation available in the system core, we might have provided own code to perform the desired task. The action also defines, that no content is to be returned by the back end in response to this particular action but a status code. Name of the action, which matches with the name used in the model and recommended colour of a relevant control element are defined. Finally, it is defined that the system action is not relevant to content which belongs in categories “system” or “inquiry” because we decided that there is no point in letting user rate, for example, welcome pages or survey questions. The code above is all that a developer has to define to create a functional action, which would get handled by the system.

In addition to this, it is possible to override further the default behaviour of the action, which is defined by its parents. For example, we may define a custom “client handler” which is to be executed by the browser on the client side⁷⁸ instead of the default one. This way we may project the action in the user interface. The following example uses a JavaScript to hide the 'like' and 'despise' buttons and to change a class of the containing action pane, which is reflected in the change of its appearance as defined in a relevant CSS, on a successful 'like' call.

```
def custom_client_handler(self):
    code = """
    let actionUrl = SERVICE_URL+"%(action)s?key=" + KEY;
    let actionEl = document.getElementById('action_%(action)s');
    let despiseEl = document.getElementById('action_%(despise)s');
    let actionspanEl = document.getElementById('actions_pan');
    let xhr = new XMLHttpRequest();
    return new Promise(function(resolve, reject) {
        xhr.onload = function() {
            setTimeout(function() {
                actionEl.style.visibility="hidden";
                despiseEl.style.visibility="hidden";
            });
        }
    });
    """
```

⁷⁸ The code is relevant only in the case of the HTML-based front end.

```

        actionspanEl.className += " liked";
    }, 1000);
    resolve(true);
};
xhr.onerror = function() {
    actionEl.innerHTML="?";
    reject(false);
};
xhr.open('HEAD', actionUrl, true);
xhr.send();
});

""" % dict(action=self.get_name(), despise="despise")
return code

```

What is essential, the described architecture enables *other developers* to create not just their own media content providers, but even system providers. So, anyone may come up with extensions to the user interface and the system behaviour without the need to access the source codes of the system core and even with just a partial knowledge about the system internals. The following Figure 39 illustrates this extensibility.

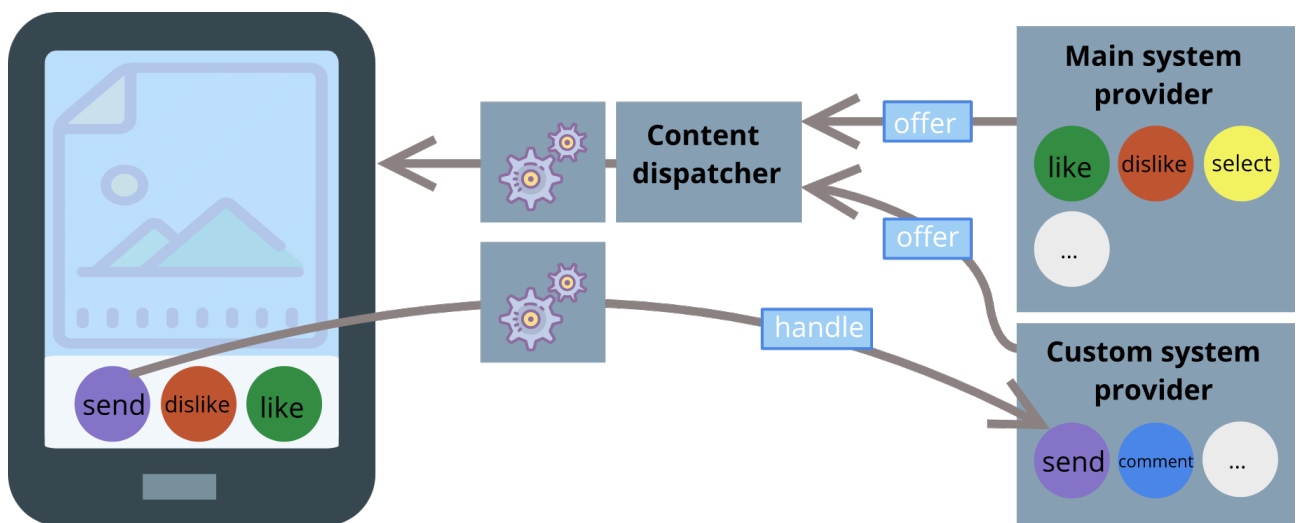


Figure 39: Combining activity controls from different content providers in the user interface of the viewer

A brief description of system actions implemented by the Main System Provider at the time of writing this text is in a dedicated chapter which comes later.

11.2.12 SURVEY PROVIDER

To provide support for questionnaires⁷⁹ and structured feedback from users, we implemented survey provider. A sample page with a question defined by the Survey Provider is in the following Figure 40.

Model. The content of the Survey Provider is defined in a “model” which has an analogous form to the Main System Provider “model”. The main difference between the example of the system provider model definition is in applying pattern mechanism which allows more precise definition when each page should be served. In the following example, a user shall be asked how is he feeling twice a day from Sunday to Saturday (every weekday), once in the morning (between 4.00 AM and 11.00 AM) and once in the late afternoon (between 3.00 PM and 11 PM).

```

self.model = (
    CtInquiryModelPage(
        first_offer=20,
        time_scheduler =
            self.sch((dict(day_pattern="1-7",

```

79 The survey provider is perfectly applicable for questionnaires according to the DREAM data collection method, which is discussed in the concluding part which describes the potential of the system.

```

        hour_pattern="4-11",
        daily=True,
        frequency=1),
    dict(day_pattern="1-7",
        hour_pattern="15-23",
        daily=True,
        frequency=1)
    ),
    page="feeling",
    name=T("How are you feeling?"),
    message=T("How are you feeling?"),
    text=T("Please, choose between 1 and 5 as at school."),
    actions=[CtRateSurveyAction(a) for a in xrange(1,6)],
    image=None
),
)

```

Extendable. Both system and survey content provider have to keep track of the content provided by themselves and user's replies in the form of related content actions. They also share the format to define their model and the algorithm to execute the model. Because the Main System Provider and the Survey Provider share much of the internal logic, they have been implemented as ancestors of a parent class `CtInquiryProvider`. It makes the creation of similar questions-based content providers simple – in a typical case, the main portion of the `CtInquiryProvider`-based content provider code would be the definition of its model. So, anyone may easily come up with his own questionnaire.

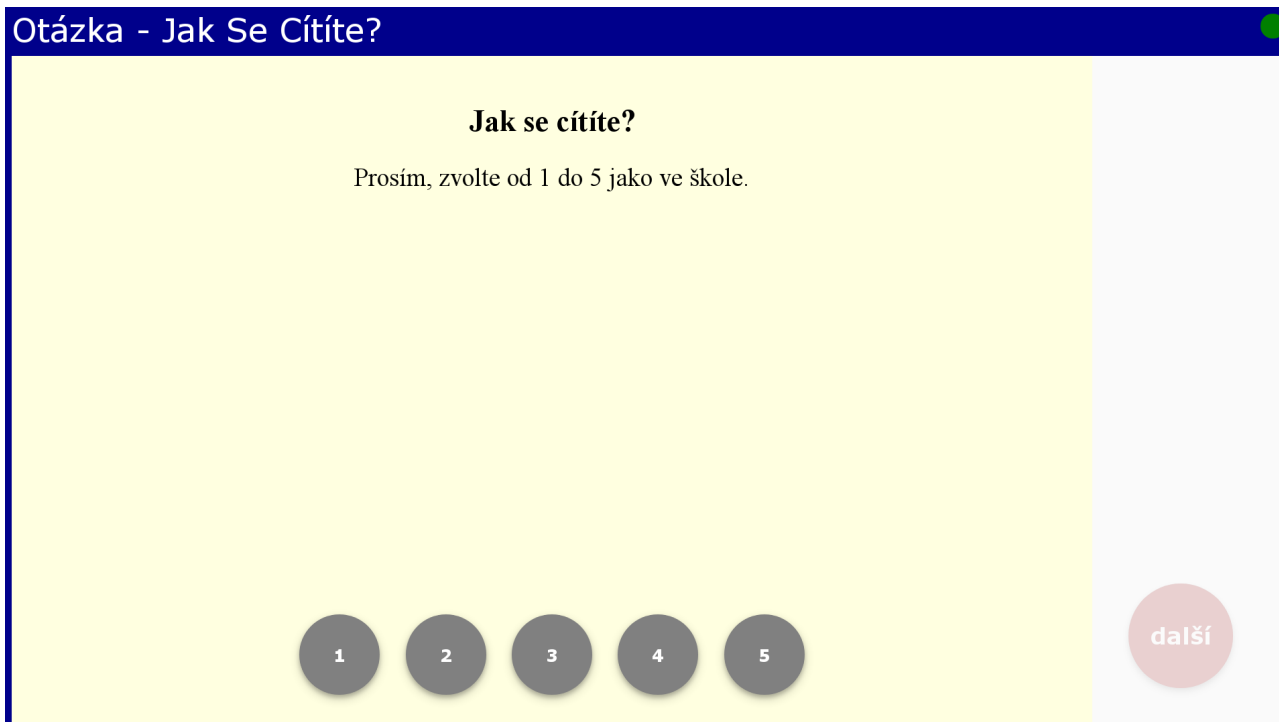


Figure 40: Sample screenshot of the viewer with a content sample from the Survey provider

Possible improvements. We are planning to make a subclass of `CtInquiryProvider` which would allow a definition of the model via the management interface with persistence provided by the database. So, creating surveys won't require programming at all.

11.2.13 TESTING PROVIDER

We have one more content provider implemented, but it is not intended for real users. It serves an easily configurable content, so it is useful for development and debugging. An example screenshot follows, with a content sample entitled by a random title generator, showing selected metadata (Figure 41).

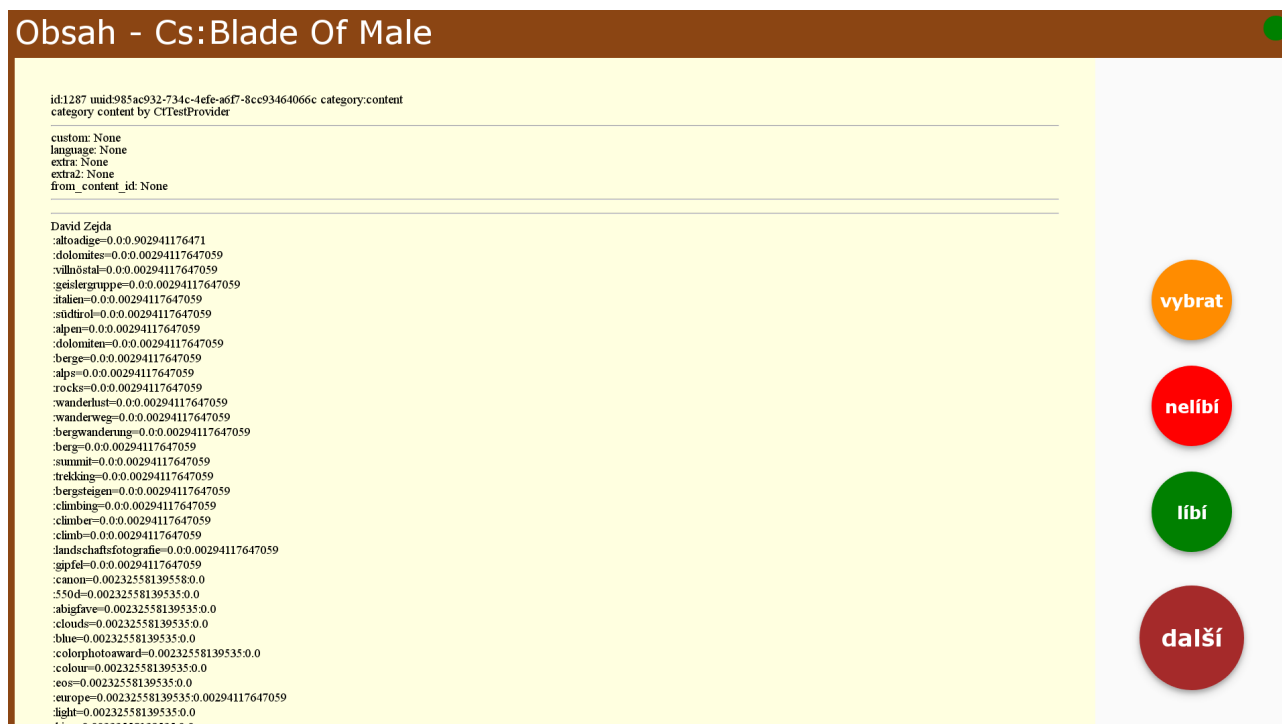


Figure 41: Sample screenshot of the viewer with a content sample from the Testing Provider

11.3 CONTENT FORMATTING

The front end does not know anything about the classes defined in the back end. So, the responsibility to transform the content data into a form which allows the front end to present it to the user lies on the back end. Formatters provide the part of the back end architecture, which allows encapsulating the code dealing with the content-to-something transformation code and reuse it across content providers returning same types of the content, or even across non-identical, but similar content types. For example, a hypothetical Picassa content provider would require different implementation of the communication with the source service than Flickr provider, but the result may be formatted identically, so to format its results we would not need to provide a new implementation.

Though we did not wish to rule out support for other types of front ends, for now, only a front end which speaks HTML is supported. It concretises and simplifies the ambiguously defined transformation task to the *transformation of any content to an embeddable HTML snippet*, which may be treated by an HTML-capable front end uniformly.

11.3.1 CONTENT-TO-IMAGE FORMATTERS (REJECTED)

Our first idea was sending most of the static content to the front end in the form of images. If a text, an image, a set of images or combination of textual and graphical content has to be displayed, a transformation into a plain image would be performed. As one of the inputs, the desired size of the picture would be sent by the viewer. The advantage of this solution is simplicity on the front end side, and it would make it easier to implement different viewers. Actually, we were working on this idea when a native Android client was considered as a default implementation of the front end. But we abandoned the idea for several reasons. First, the content provider would have to create at least two variants of the target picture, one for the horizontally-positioned and one for the vertically-positioned target device. The transformation would be relatively CPU-intensive. In the case of textual content, it would waste the capacity of the data transfer channel – a big disadvantage for users on a metered data plan. And lastly, it wouldn't be a universal solution - it wouldn't be usable, e.g. for video or audio. Though we turned the idea of formatting most content into images, it is still true that pictures may be merged, resized, watermarked, or manipulated in other ways, if needed. More details about the front end are in the respective chapter 12.

11.3.2 CONTENT-TO-HTML FORMATTERS

Richness. HTML format has been chosen instead. Especially in combination with JavaScript, it provides great versatility, which is well demonstrated, e.g. by the Audiobook Content Provider which allows playing an audio in parallel with showing the relevant text to the user, or the YouTube Provider which benefits from the embeddable player provided by Google and the relevant API. All this functionality may be implemented on the back end, and an HTML-capable front end just picks the result up and embeds it in an appropriate place of the generated page.

Responsiveness. Recent HTML technologies provide a lot of tools to make applications compatible with various devices with different display sizes. The techniques involve but are not limited to media selectors, image `srcsets`, relative units, style-side calculations. They allow adjusting both the application view and behaviour to any aspect ratio and any display density. How we use some of the techniques is discussed in sections about the Flickr Provider or about the front end, which has to put all the pieces of HTML together to create the resulting page.

Drawbacks. The content-to-HTML solution has its drawbacks too. In all cases, the result of the formatting process should be ready for display in a content pane of an HTML-based viewer. It may contain HTML code, related CSS and even JavaScript, if necessary. The fact that JavaScript may be returned directly as a part of a formatted content gives content provider implementers powerful tools, but on the other hand, it may lead to poor design, which breaks the separation of MVC⁸⁰ layers, which is a bad design practice. The issues related to having HTML+CSS+JS code returned by the back end should be further examined from the systems-design point-of-view.

11.3.3 THE ROLE OF FORMATTERS

Code reuse. The main purpose of formatters is to facilitate proper code reuse. Various transformations may take place during the formatting. For example, in the case of a hypothetical content provider pulling its data from a digital library of family photos stored on an FTP server, we could not benefit from size-variants of each picture, as it is in the case of Flickr. So, we would have to implement a code which for a link to an image returns an `img` tag with `srcset`, containing not just the original image in the full resolution, leading to the original source, but also reduced versions with links to the back end. So, if the client requests a reduced picture, in the reaction the back end may download the original picture, resize it, and return it in response to the client. To increase the performance of subsequent requests for the same picture it might also put it in a cache on the back end side. Such a piece of code would be valuable and reusable for other content providers. So it would be a good idea to implement it as a new formatter, which, to reuse the formatting code already available in `CtImageFormatter`, should be defined as its subclass. There was even an idea that formatters might be chained, e.g. an image formatter would format the image returned from Flickr, a text formatter would add some captions on top and finally a location formatter would add a relevant cut of a map based on the received geolocation metadata. But because of its high complexity, the idea of chaining formatters has been turned down in favour of inheritance.

Possible improvements. Formatters into other formats than HTML may be implemented as well if there is a need for them from other than HTML-based viewers. Currently, such an implementation is not a priority.

11.4 THE EXECUTION

Back end exposes its functionality as services. Action on the side of the client is delivered to the back end controller as a service call. The service call is handled by the respective action handler defined in a `CtAction` subclass. The result of the action, if any, is formatted into XML as a service call response and returned to the client side. If a new content item is expected as a result of the action, the task to find the content is delegated to the content dispatcher, which in turn ask individual providers for a content – a process called dispatching. A sequence diagram in the architecture overview section at the beginning of chapter 11 provides an overview of an example of such control and execution flow.

11.4.1 DISPATCHING

Content dispatcher. A content dispatcher is responsible for selecting which content provider will be asked for a content item on each request. On the system core level, there is a `CtDispatcher` abstract class defined. It allows implementation of content dispatchers adopting various dispatching strategies.

Default content dispatcher. So far, we implemented just one subclass, the `CtDefaultDispatcher`. The default dispatcher considers the priority levels set by each content provider assigned to a particular user and asks the providers with higher priority ahead of those with lower priority. If there are more providers with the same priority level, it selects their order according to stored user preferences in most cases, but randomly sometimes. Such combination provided better results than sticking to user preferences only, because during our tests if a user often clicked 'like' for a content provided by a specific content provider, other providers got suppressed almost entirely, which users complained about. Currently, the ratio between random and preference-based choice is set to 40:60, but more testing should take place to adjust it well. More content dispatcher implementations may be implemented in the future.

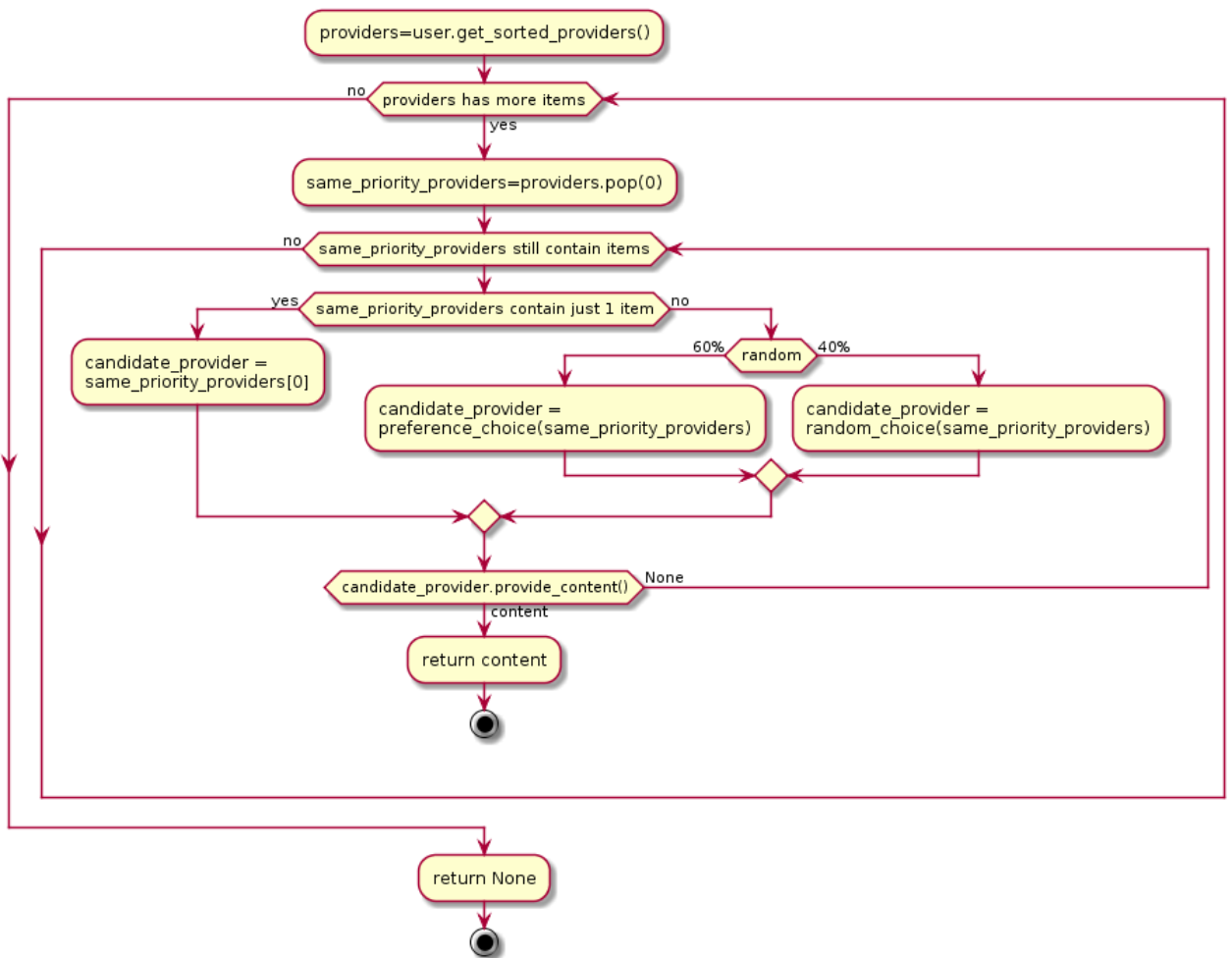


Figure 42: Content dispatching activity diagram

Dispatcher-provider cooperation. As described earlier, the dispatcher asks content providers according to its algorithm to provide a content item. Each content provider may return either a content object or `None`. As soon as a content provider returns a content object, it is being returned by the dispatcher⁸¹. So, for the final decision which content is to be served to the user, both algorithms of the chosen dispatcher and registered content providers play a role.

81 At least, this is true for the default dispatcher. Other dispatchers may implement different behaviour.

Content provider priority. The activity diagram in Figure 42 illustrates the crucial part of the algorithm of the default dispatcher. Various content providers may take different strategies to decide, according to their purpose. For example, YouTube, Flickr, or Audiobook content providers may simply return content any time they are being asked. In their case, the decision is made instead by the dispatcher. On the other hand, the Main System Provider returns content only if the current state matches the conditions defined in its model. For example, it offers a sequence of welcome screens at the beginning. Then always after some time, it offers a new function. For survey content provider its model may set a frequency and specific time intervals – for example, “*every day once in the morning and once in the late afternoon*”. Other strategies might be implemented by, e.g. a therapeutic content provider aimed at preserving or improving users' memory or cognitive skills. Serving strategy of content providers with unlimited content source has to be developed in harmony with the priority the content provider declares. For example, the Flickr Provider returns content on every attempt. If it had the highest priority set, the dispatcher would be forced to choose it always, so no other content would ever be served to the user. On the other hand, a content provider which would parse messages sent directly to the user (e.g. SMS or emails) may both have high priority and on normal circumstances return every content it receives, because the source of its content is limited.

Data limits. In some countries, like in the Czech Republic, no affordable mobile Internet plans with relaxed data limits are available. So, a mechanism to decide whether to serve data-intensive content such as videos, based on user's Internet connection plan limits, would be useful. But, currently, it is not easy to detect on the side of the browser if a particular user is on data-limited connection or not. There is a technology called Network Information API which might allow to find out the connection type on the browser-side, but it is still in experimental stage, with an insufficient browser support. And, sadly, from one of the initial ambitious proposals, which promised to tell whether the connection is metered or not, the current version just distinguishes between Wi-Fi and cellular, which may be misleading in some cases. So, for now, the only way to set whether a user is on metered or unlimited data plan, is by hand via the management interface.

Possible improvement. There might be an indication of the content which is coming next in the user interface. It would improve the user experience and reduce a risk that the user gets frightened by an unexpected type of content. It might be implemented as a queue if content items where at each request both current and the following content would be returned. It has to be evaluated in which cases the queued content should be actually replaced by something different. E.g. the system is displaying a picture right now and indicating that the next content will be a video, but user performs 'select' action, which should cause that a selection menu should be inserted before the content in the queue. It would be an improvement, but it is not an essential function which would have to be implemented for the prototype.

11.4.2 ACTIONS AND SERVICES

Action types. If an action is meant to be triggered directly by the user, the front end has to generate a control element, typically a button. System actions are relevant to a variety of content types, if not even for all. Content actions are on the contrary relevant only to the content which originates from the same content provider, which also defines the actions. Though it depends on the front end implementation, there is also a difference in the way how the actions are supposed to be presented to the user. For example, in the default HTML front end, system actions are displayed in a dedicated action pane, whereas content actions are placed in the content pane together with the content itself. The following paragraphs cover actions implemented so far. Then the action execution flow is briefly explained.

11.4.3 SYSTEM ACTIONS

Next action. Lets merely dispatcher provide a new content, which is returned in the response to the service call. As a basic key action, it is implemented directly in the back end core as `CtNextAction`.

Like action. Records the information that user likes the content being displayed. Is responsible for changing weights in user preferences, which help the system to provide content relevant to the user. A later section 11.7 explains how it is implemented. HTTP response 204 by the server is returned to confirm that the like has been successfully recorded. There might be an update of the UI done on the client side to notify the user, e.g. the 'like' and 'despise' buttons disappear and the fact that the user likes the content is reflected, e.g. as a colour change. We have an implementation of such a change for HTML-based viewers as

a `client_side_handler`, which is described in the section about the Main System Provider, under which the action itself is also implemented as `CtLikeSystemAction`. The behaviour of the action has been changed from an initial version, which was immediately directing users to the following content. Testing let us reveal, that it leads to confusion when users did not wait for playback to end and were disappointed, when touching 'like' caused interruption and loading of a new content item.



Figure 43: Sample screenshot of the viewer with a content selection menu

Despise action. Records the information that user dislikes the content being displayed. It is analogous to the like action, but its flow is different. Despise lets the dispatcher provide a new content which is immediately returned as a response. The action may also trigger an immediate update of the UI on the client side, but it is effective only until the new content is processed and displayed. The action is implemented as `CtDespiseSystemAction` under the Main System Provider.

Select menu action. It has been implemented in reaction to the feedback from the trial. It allows users to choose the kind of content they wish to receive – like switching channels between images, videos, audiobooks. They may also return to the default, where the kind of content is chosen according to the internal algorithm. The menu is implemented as a system content item with the available options as content actions, which is returned as a response in select menu action. The default HTML-based front end renders the menu as shown in the following screenshot (Figure 19). The action is implemented as `CtSelectMenuSystemAction` under the Main System Provider.

Bad click action. An action which is not supposed to have any dedicated control element on the side of the user interface. It records bad interactions. For example, on a touchscreen device, whenever a user touches the display in a place, where there is no dedicated control element. The purpose of the action is to have means to assess how is a particular user dealing with the UI. The information may be used then, e.g. to decide whether to provide a new function or to adjust something to fit user's needs and skills. There might be a mild reaction on the client side, such as a highlight of currently available action buttons, to help the user to interact in the correct way. There is no implementation for the UI feedback on the back-end side. The action just returns HTTP response 204. Implementation of the action is part of the system core as `CtBadClickAction`.

11.4.4 CONTENT ACTIONS

Currently, two types of content actions are implemented - Media actions and Answer actions.

Media event action. Buttons such as play, pause, volume-up, volume-down operate playback of a media, both video and audio. The interaction with media is handled on the client side via JavaScript, but information about the interaction is also reported to the back and as a Media event action. The information retrieved may be used to assess user's skills, preferences and behaviours. The currently implemented YouTube and Audiobook content providers share the action implementation by `CtMediaEventAction` class under the system core. As a response to the action HTTP 204 is returned back to the front end. Any updates in the UI, such as displaying the current sound level, are done on the client side via JavaScript. The respective content provider provides the JavaScript as a part of the content HTML snippet.

Answer action. An action defined by an inquiry-type content provider, either Main system and Survey providers. The answer such as 'yes', 'no', 'later', or a numeric rating such as '1' or '5' is recorded in the context of the relevant question. Then new content is provided by the dispatcher. Either Main system provider or Survey provider implements the actions. All are subclasses of `CtInquiryAction` with the general behaviour for answer-type actions and is implemented under the abstract Inquiry content provider.

11.4.5 ACTION SELECTION BY THE CONTROLLER

The controller is the part of the back end which exposes the system services and is responsible for picking the correct action to handle received service calls. The control flow is a cascade of choices where to direct the service call to be handled appropriately. First, for performance reasons, a ping service call is processed by the controller itself immediately. Otherwise, the controller tries to find the relevant action among system actions. If not successful, it checks if the call is to be delegated to a content action handler of the content provider which served the last content to the calling user. Otherwise, if no registered action handler relevant to the action call is available or if an exception interrupts handling of the call, controller lets the fallback provider return its no-more content object. The cascade of choices is illustrated by the following activity diagram in Figure 44.

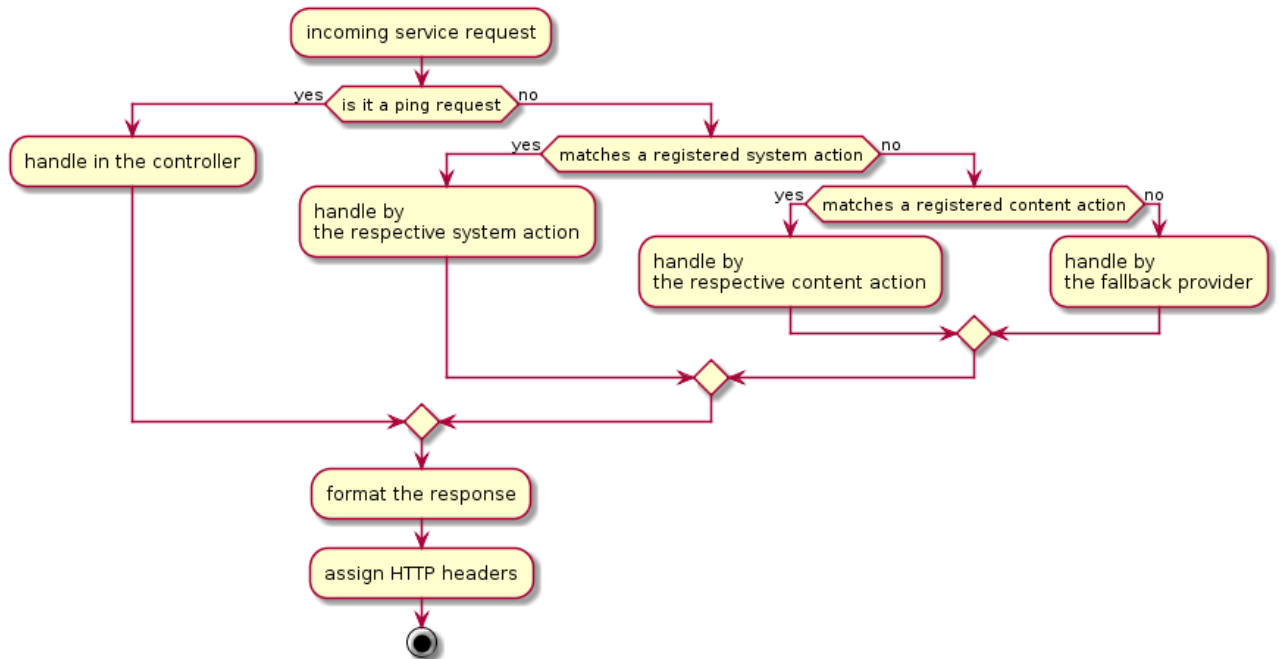


Figure 44: The activity diagram of the back-end controller

Because the actions relevant to the incoming service request are selected by their declared name, the controller's logic determines, that content action names can't overlap with system action names, because they would never be matched. On the other hand, it would not harm if two content actions implemented

under different content providers are named equally because the controller chooses content actions only from the options provided by the content provider which served the content in whose context the service has been called.

11.4.6 ACTION EXECUTION FLOW

The action base class `CtAction` defines the main steps of the action execution flow. When the controller passes a call to an action, it calls its `handle_call` function. The function executes the following sequence of steps. First, it calls `on_action_before_work` callback of the relevant content provider⁸². Then it calls `work` function defined by the action class itself. Then `on_action_after_work` callback of the relevant content provider. Finally, it calls `followup` function defined by the action class, which returns the result to the controller. Each of the functions receives the `CtUser` object which represents the user who has sent the service request and a dictionary with variables which have been passed as a part of the request. For each of the functions, the base class `CtAction` provides a default implementation. So, each subclass may override only the necessary portion of the default execution flow, which helps to avoid duplication of code and to promote consistent behaviour throughout the system. Default `work` implementation is to do nothing. Default `followup` implementation is to call `CtNextAction.handle_call`, which secures, that a content item will be returned in the service call response. The sequence diagram in Figure 44 illustrates the execution flow.

So, for example, actions which are supposed to record specific value in the database and then return a fresh content in response may override only `work` function. Actions which should not return any content but just an HTTP code may override the `followup` function. The callbacks to the content provider allow to reuse the implementation of actions across content providers, but still giving the content providers means to perform additional steps. For example, if a user clicks 'like' on a picture, a 'like' service call delivered to the back-end controller. The implementation of the 'like' action secures, that the information that a particular user likes particular content item is stored and also that his preferences are updated. But after all these operations, the content provider which offered the picture is also allowed via the `on_action_after_work` callback to do something additional. It may for example, save in its settings, that the next time the content is asked by the user, a picture from the same gallery should be returned, overriding the default semi-random selection mechanism. Each content provider may come up with its own specific implementation.

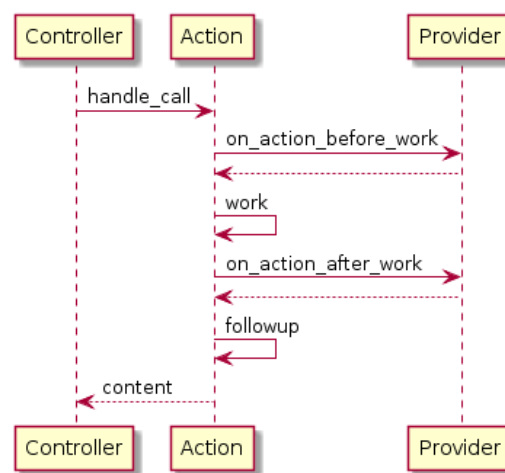


Figure 45: Sequence diagram of an action execution

11.4.7 AN ACTION RESULTS INTO A SERVICE RESPONSE

XML export/parsing library. The service controller is further responsible for converting the action result, which is normally a `CtContent` instance, into the XML response, according to the back end API specification. To separate the XML-related code, we created a `ct_xml` library which can perform the serialisation of content objects into XML. The same library provides the parsing and validating functions for the produced XML. The XML library is shared between the back end and our default HTML front end, where the parsing of the resulting XML takes place.

An example of the XML produced by the XML library for a content item from Flickr follows. The orange portion of the XML, inner contents of a `content` tag, is the HTML snippet generated by `CtImageFormatter`. The blue portion, inner content of the `handler` tag, is a JavaScript code generated by the `custom_client_handler` function of `CtLikeSystemAction`. Strings are translated according to user's

⁸² The content provider which provided the last content served to the user. The content defines a *context* of an action.

preferences by the translation machine explained in one of the later sections. Though the front end is not required to respect them, labels, recommended colours and prominence of action controls help the front end to decide how to present the content and defined actions to the user. Prominence denotes how important a particular function is, so the front end may, for example, adjust the size of control elements to help the user to focus his attention on the right controls.

```
<?xml version="1.0" encoding="utf8"?>
<result function="next" locale="cs_CZ" state="success">
  <item cacheable="1" uuid="aceae24-bf86-4182-ba92-294d25cf7da1">
    <content title="Zkroucené">
      
    </content>
    <meta>
      <category>
        <name>image</name>
        <label>obrázek</label>
        <color>DarkCyan</color>
      </category>
    </meta>
    <main_actions>
      <action id="like">
        <label>líbí</label>
        <color>Green</color>
        <prominence>1</prominence>
        <handler>
          let actionUrl = SERVICE_URL+"like?key=" + KEY;
          let actionEl = document.getElementById('action_like');
          let despiseEl = document.getElementById('action_despise');
          let actionspanEl = document.getElementById('actions_pan');
          let xhr = new XMLHttpRequest();
          return new Promise(function(resolve, reject) {
            xhr.onload = function() {
              setTimeout(function() {
                actionEl.style.visibility="hidden";
                despiseEl.style.visibility="hidden";
                actionspanEl.className += " liked";
              }, 1000);
              //actionspanEl.classList.add("liked");
              resolve(true);
            };
            xhr.onerror = function() {
              actionEl.innerHTML="?";
              reject(false);
            };
            xhr.open('HEAD', actionUrl, true);
            xhr.send();
          });
        </handler>
      </action>
      <action id="next">
        <label>další</label>
        <color>brown</color>
        <prominence>1.3</prominence>
        <handler/>
      </action>
    </main_actions>
  </item>
</result>
```

Results generated for other types of content may be slightly different, for example, there might also be content actions defined besides just system actions as in the example, but the overall structure is the same. More tags and attributes will be likely involved in the future, as more functions get implemented, such as information about which users like the content being displayed, if it is a content created (owned) by a particular user, etc. A detailed specification for the response format shall be provided later to facilitate the development of alternative front ends. The `ct_xml` library helps to keep the code responsible for generating the XML content and its parsing synchronised.

Reasons for XML. Regarding the chosen format, we decided to use XML over other variants, such as JSON, because it is straightforward and concise even for relatively complicated data with inner structure, such as pieces of HTML and JS code. There is good support for XML-based content across almost all programming languages. The format of an XML-based language may be defined precisely using standard technologies such as XML Schema. Validation against a schema allows assessing whether a certain piece of XML code respects the given specification of the XML-based language. These and other technologies contribute to the potential of XML for seamless integration of services. But XML is not necessarily the only format in which the back could communicate. Other formats such as JSON may be implemented if it seems practical.

Measures to preserve MVC. The fact that the code handling content actions are executed on the client side, but provided by the back end, may be considered a drawback and breakage of the MVC principle. It might lead to problems in particular when pieces of code generated by the back end integrate with the code provided by the front end. It may also limit the variability of client implementations. But, we opted for this solution, knowing that it is a compromise to the system architecture, for the sake of simplicity. It allows keeping all the code which is specific to a content source at one place. To preserve to MVC separation, we will have to analyse the problem more in detail and, perhaps, provide clear instructions for both content provider developers and front-end developers to limit the related issues to the minimum level. Notably, we should return to the problem during the transition from the prototype stage.

Support for non-HTML front ends. In the future, the back end might be able to provide content proper not only in HTML+JS but in alternative formats more suitable for other types of viewers. But to involve such support, it will require an extension of the code both on the side of the system core and on the side of individual content providers.

11.4.8 ERROR HANDLING

It is obvious that user experience suffers if software misbehaves. But to attract seniors or people with mental disorders, who are often inexperienced, in decline of cognitive skills, with limited patience, low self-confidence, etc. and to keep their interest long enough, proper prevention of software misbehaviour becomes an essential requirement. Notifying a user that something went wrong using a strange-looking alert page in a cryptic technical language might be the last message to be shown ever. But, it is not a simple task to create an error-free complex software. Though we applied various strategies and techniques to improve the quality of the code, it was not possible to test every single detail, especially when dealing with external systems. Because we are in the early prototype stage, where components of the systems were evolving in ways which were not fully predictable, we did not, for example, apply proper unit testing. Still, we wished to make the experience for the users involved in our trial as smooth as possible but get enough information about the problem which occurred, so that we might tackle it. To do so, we combined several techniques and approaches. Some of them are listed below.

Python assertions. Undoubtedly, the best way to deal with errors, exceptions and unexpected behaviour is to avoid them. So, we made an effort to apply good practices. One of those not mentioned yet are assertions which provide easy-to-use and easy-to-read means to test specific conditions before passing the algorithm to its further phase. We use assertions throughout the code.

Web2py ticketing mechanism. Web2py provides a mechanism which creates a “ticket” with a detailed report about any unhandled exception, which is stored in the database. The ticket contains the traceback, argument values of functions involved, environment variables, details about the request, the client, etc. As a default behaviour, a ticket ID is issued to the client with a link to the Web2py administrative interface. Only the system administrator can access the details, so the user does not have to struggle to understand what exactly

has happened. The mechanism is useful for development, and it is good to have it as a last-resort solution for unrecoverable errors.

Internal recovery. Similarly, warnings are reported whenever system gets into an unexpected, but internally recoverable state. If a thrown Exception caused the state, the exception details are stored as a part of the warning. For example, an attempt to load content from Flickr fails in an uncommon way, so a warning is issued. But the content provider tries to recover using a modified query. If none of the recovery attempts by the content provider is successful, the content provider returns `None`. Then, the content dispatcher may try a different content provider. Lastly, if no content provider can provide any content, the fallback provider is asked to serve its “Let’s make a break”. Mechanisms to cope with errors are used at all levels of the code, not only in the back end but also in the front end and on the browser-side. They include, for example, browser-side caching and browser-side error handling of failed network requests, which are briefly introduced later. The internal error-recovery is illustrated in Figure 46.

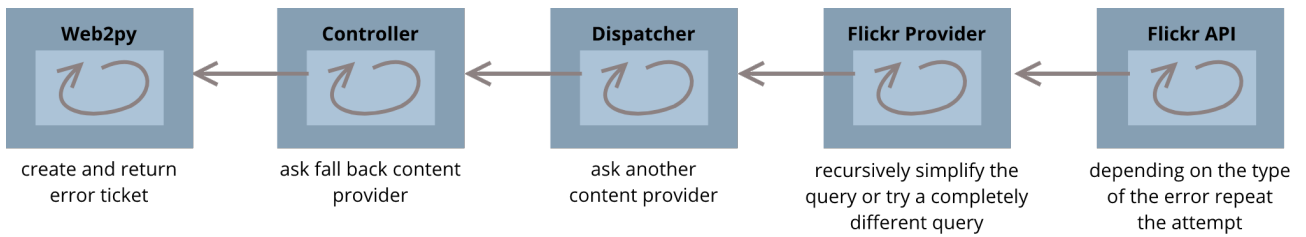


Figure 46: Internal recovery from errors and exceptions

Fallback content provider. We did not want the user to be bothered even with the information about a ticket being issued. So, we implemented a very simple fallback content provider, which serves nothing but a `CtNoMoreContent` object. The object, when received and formatted, does not tell the user that there was a problem, but tells him “Let’s make a break. Resting for a while is good. Please come back a bit later.” The page is formatted like any other with all common control elements, so it does not disturb or make the user feel anxious. When an exception occurs, behind the scenes, the incident is recorded with all the necessary information for debugging and reported to an administrator via email.

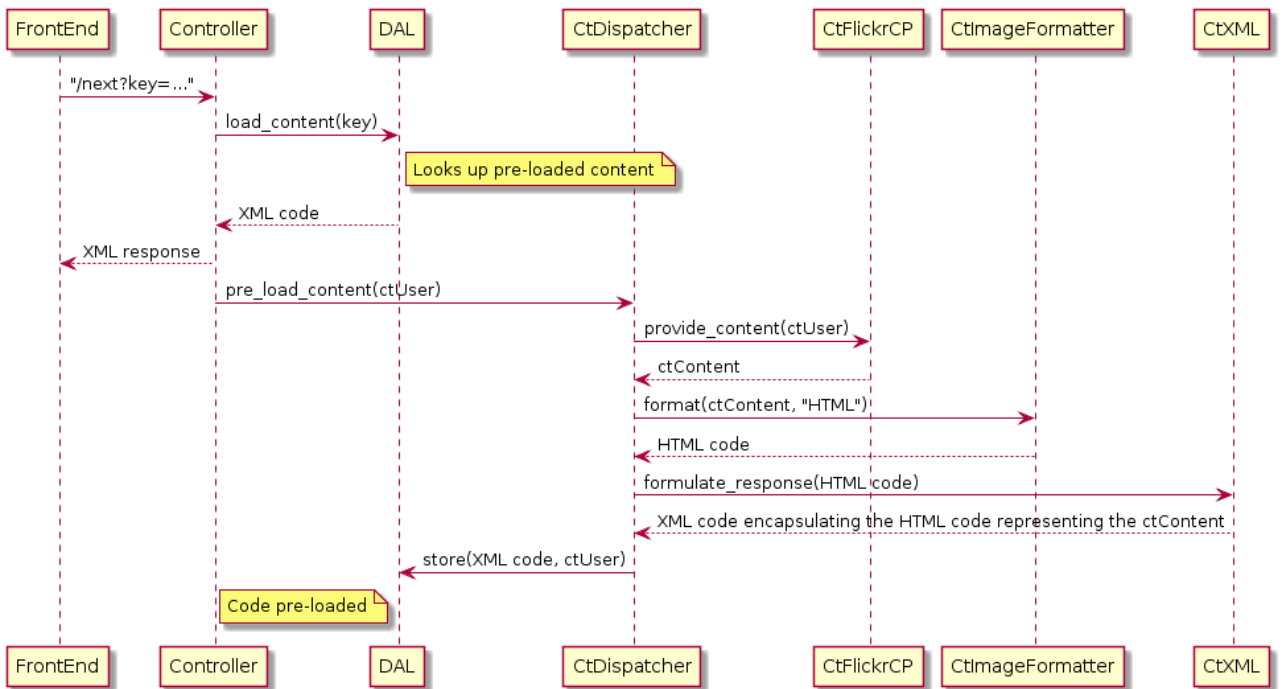


Figure 47: Sequence diagram of the idea of content pre-loading

11.4.9 PRE-LOADING OF CONTENT (POSSIBLE EXTENSION)

Currently, the system invokes all its logic upon user request. It might pose an unnecessary bottleneck to the performance leading to longer response times. Instead, the system might apply a strategy which would pre-load a content for a user *before* user's request. For example, as soon as a request has been served, the system might invoke a pre-loading code which would make a content ready in temporary storage, so the next time the user asks more content, the content item would be retrieved instantly. Or as another option, the content pre-loading could be done at idle times, or by a parallel process or a service. Advantages and drawbacks of different solutions, such as scalability or performance footprint, would have to be considered. The following simplified sequence diagram in Figure 47 illustrates the idea.

11.5 THE PERSISTENCE

Currently, for the storage we use MySQL database. But because the communication with the database goes through the data abstraction layer provided by Web2py, a change of the storage provider in the future would be relatively easy.

11.5.1 DATA ABSTRACTION LAYER

The Web2py DAL allows to define database tables directly in the Python language:

```
db.define_table('content',
    Field('uuid', length=64, requires=IS_NOT_EMPTY,
        default=lambda: str(uuid4())),
    Field('name', 'string', label="Content name"),
    Field('created_on', 'datetime', default=request.now),
    Field('provider_id', "reference content_provider",
        requires=IS_IN_DB(db, 'content_provider.id', "%(class_name)s"),
        represent=ref_repr(db.content_provider, "class_name"),
        label="Content provider"),
    ...
```

The data abstraction layer allows composing virtually any kind of SQL query directly in the Python language. Just to illustrate the syntax, the following code snippets perform a select, insert and update:

```
row = db((db.content.provider_id == self.id) &
    (db.content.uuid == uuid)).select(db.content.ALL)

db.content.insert(name=self.name,
    category=self.category.name,
    provider_id=self.provider_id,
    uuid=self.uuid,
    ...

db(db.content.id == self.id).update(name=self.name,
    category=self.category.name)
```

Data abstraction layer helps to keep the code database-agnostic, so switching database, e.g. from SQLite to MySQL, does not require significant changes in the code.

11.5.2 DATABASE INDEXES

Though since the beginning we knew we will have to deal with indexing of the data stored in MySQL before the system leaves an early prototype phase, the need to set up indexing become evident during the second week of testing, when the database already contained more than a thousand of content items, about 10 thousand tags and more than 20 thousand tag assignments. Average request processing time has grown over five seconds, and some requests were taking even longer. The delays were negatively affecting user experience⁸³.

83 We discuss user reaction in chapter 6.

Indexes for primary keys and reference fields are created automatically by MySQL. Analysis of the purpose of fields defined in the database model and the code which uses the fields for searches has revealed a need to add indexes to at least 50 more fields. Web2py DAL does not support index creation. Such decision has been taken by the developers intentionally. The documentation puts the reason this way: “*Currently the DAL API does not provide a command to create indexes on tables, but this can be done using the `executesql` command. This is because the existence of indexes can make migrations complex, and it is better to deal with them explicitly. Indexes may be needed for those fields that are used in recurrent queries.*” (Di Pierro, 2017c) Sadly, there is no SQL standard for indexes and implementation varies greatly. Because indexes are related to the physical representation of the data by the database's storage engine, syntax and support for indexes sometimes vary even for the same version of a database. It further adds to the complexity of the issue.

We conclude, that simple per-attribute defined indexes will satisfy the need. But we wanted to define the indexes in a manageable and fail-safe manner, which won't sacrifice the ease of database model definition and which provide at least basic abstraction layer between the database-specific syntax and the model-definition code.

11.5.3 CUSTOM EXTENSION OF WEB2PY DAL

Our solution for the problem with database indexing involves an extension for the Web2py DAL. At the beginning of the code which defines data model for the system core, we declared a new variable `idx`. Its purpose is to keep the definition of all indexes needed by the system, except those created automatically⁸⁴. The information of indexes is not needed by any part of our system, except by a very specific function which (re)creates indexes on request by the system administrator when called from the management interface. So, the `idx` variable contains any values only when dealing with request which should trigger the index creation:

```
if request.controller == "manage" and request.function == "create_indexes":
    idx = []
else:
    idx = None
```

Now, to define that we need an index for a field `class_name` of a table `content_provider`, we add the following tuple in the `idx` variable:

```
idx.append(('content_provider', 'class_name', 32))
```

Then we have a function, which generates SQL to create the index for each of the tuples from `idx`. Because MySQL does not support any intuitive syntax to create an index on condition it does not exist yet, such as `'CREATE INDEX IF NOT EXISTS name_index ON person (name)'`, the resulting SQL is relatively complicated. It consists of three queries invoked in a sequence. The first one defines a conditional statement, so the index is created only if it is not present in the statistics table of `information_schema` database:

```
SELECT IF (
  EXISTS(
    SELECT DISTINCT index_name FROM information_schema.statistics
    WHERE table_schema = "closetouch"
    AND table_name = "content_provider"
    AND index_name like "class_name_ct"
  )
, 'SELECT 'index class_name_ct exists for content_provider' as _____;'
, 'CREATE INDEX `class_name_ct` ON `auth_user`(`class_name` (32))' ) into @a;
PREPARE statement1 FROM @a;
EXECUTE statement1;
DEALLOCATE PREPARE statement1;
```

Simpler but still functional code would just try to create an index with a name defined, which fails if an index of the same name exists. But it is not a good programming approach to trigger errors or exceptions as

⁸⁴ Indexes for primary keys and reference fields are created automatically.

an intentional part of program flow. The chosen solution is cleaner. But there was one more problem to solve. It is possible to define indexes just below the table definition, as shown in the following example.

```
db.define_table('content_provider',
    Field('class_name', 'string'),
)
idx.append(('content_provider', 'class_name', 32))
```

But such definition is not error-prone, especially for more complicated tables with plenty of fields. It would be easy to forget to update the index definition after a change in the table definition. So, to allow a neater definition of indexes immediately in place with field definition, we created a simple wrapper function for the Web2py DAL Field constructor and for the `db.define_table` function:

```
def fld(name, type, **kwargs):
    indval = None
    if "index" in kwargs.keys():
        indval = kwargs["index"]
        del kwargs["index"]
    return Field(name, type, **kwargs), indval

def dbtab(*args):
    fields = []
    for field, index in args[1:]:
        fields.append(field)
        if (idx != None) and index:
            idx.append((args[0], field.name, index))
    db.define_table(args[0], *fields)
```

Now, using these wrapper functions we may define index in a very simple and natural way together with the rest of the database model definition, such as:

```
dbtab('content_provider',
    fld('class_name', 'string', index=32),
)
```

Staying database agnostic. Someone might argue, that our approach mingles database model with physical parameters of the database, which is not a clean solution. But we are convinced that the simplicity and clarity of the code and avoidance of duplicates, such as table and field names, is more important. We are aware, that we sacrificed the independence on the database providers in some degree, so in the case, there is a need to change the database from MySQL to something else, it would require adjustments to our code. We have to bear this on the mind before transitioning from the early prototype stage, rethink the implications and adjust the solution if needed.

11.6 TRANSLATORS

11.6.1 WEB2PY MECHANISM FOR LOCALIZATION

Web2py offer an easy-to-use mechanism for localisation of strings. Simply, at all places where a string is required, a `T` object may be used instead. As explained in the Web2py documentation (Di Pierro, 2017b), the object `T` is the language translator. It constitutes a single global instance of the Web2py class `gluon.language.translator`. Web2py identifies strings that are marked with `T` as needing language translation; they will be put in a file which keeps all strings for translation when the code is executed. If the string waiting for translation is not a constant but a variable, it will be added to the translation file at runtime. The syntax to mark a plain string for translation is straightforward:

```
a = T("hello world")
```

Strings marked with `T`, as soon as found by the Web2py, are placed in available translation files. For example, in a `cs.py` file in `application/languages` folder:

```
{
    '!=': '!=',
```

```

'!langcode!': 'cs-cz',
'!langname!': 'čeština',
'a translated string': 'přeložený řetězec',
'hello world': 'hello world',
}

```

Then, the developer or someone else has to provide the translation. The `T` object can also contain interpolated variables and supports multiple equivalent syntaxes. Our preferred syntax is:

```
a = T("my name is %(name)s", dict(name='Tim'))
```

Which goes into the translation file as:

```
'my name is %(name)s': 'my name is %(name)s',
```

It is supposed to be translated to something like:

```
'my name is %(name)s': 'jmenuji se %(name)s',
```

Normally, Web2py determines the target language by the `Accept-Language` field in the HTTP header, but this selection can be overridden programmatically. That's what we do – if a user has a language specified in his preferences, which are accessible by the management interface, we respect it, but if not, we use the HTTP header as a fallback mechanism. The `T` syntax also allows to force a per-string language:

```
T("Hello World", language="it-it")
```

11.6.2 MECHANISM FOR AUTOMATIC TRANSLATION

The Web2py localisation mechanism is suitable mainly for strings which are used to form the user interface. But, because it depends on manual translation, it is not suitable for strings which are part of a content item. We needed a mechanism which will provide automatic translation of such strings on-the-fly. To provide such, we created our own `CtMultilangString` class and a helper method `TRN`, which supports similar syntax to the `T` method defined by Web2py:

```
TRN("Hello World")
```

But the signature of the method is the following – it allows to specify both original and target language and also a context.

```
def TRN(name, language_code=None, context=None, original_language=None):
```

The context allows having more translations of the same string depending on their source and purpose. For example, strings marked for translation by individual content providers should be treated independently, because we don't wish the content providers to influence one another's behaviour in unpredictable ways. Though, for now, we allow choosing not more than one translation service which handles all `TRNS`, likely we will allow having the default setting overridden by per-user and per-provider settings. Then, an identical original string will get more translations according to its `context`. The strings marked with the `TRN` function won't go into translation files, but in the translation table in the database. It stores the original string, original language, resulting string, resulting language, context and a reference to the translating service which provided the translation.

11.6.3 EXTERNAL MACHINE TRANSLATION SERVICES

Yandex is the only one external translating service for which we implemented support so far. In a similar manner as with content sources, we implemented a simple library which calls the Yandex API and on top of it the translator itself. Yandex API is straightforward. For the translation, it requires POST HTTP request with data formatted as JSON. The results are also returned in the form of JSON. A big advantage of Yandex

over other services we considered is the price – for the amount of data we needed to translate for our trial, it was free-of-charge.

In comparison with other translation services, such as Google Translation API or Microsoft Translator, we subjectively found the quality of the Yandex translation rather mediocre. The other services probably gained the quality advantage applying neural networks on massive corpora of the textual data they have access to. For example, in a Google PR article Turovsky (2016), the product lead of the translation team, announces these improvements on late 2016. Looper (2017) quotes him later, providing more details. According to the article, Google uses self-built tensor processor units, which make the system a processing time three times faster than on a CPU and eight times faster than on a GPU. Turovsky (2016) also says that the company can also use multilingual neural nets for languages that are similar linguistically. But, as the main drawback, these translation services do not offer a free service tier. For example, Google currently charges 20 \$ per 1,000,000 characters. It is also slightly more complicated to use their API. After tests with the available services, we concluded that for the prototype, Yandex would suffice, but the choice of translation service should be considered again before moving from the prototype stage.

Fake translator. For testing purposes, we also implemented also a fake translator. It just prepend a constant to the original string, so we could easily test if the translation mechanism is being invoked by the system as expected without really calling any external service.

11.7 TAGGERS

Similarly to translators, also taggers provide access to a category of supplementary services. Tags are something like keywords assigned to a content item. They convey valuable meta information. They allow revealing tacit connections between content items. If combined with the track of user interaction with content, they help to learn user's preferences gradually. The advantage of tags, which probably helped to make them widely applied, is their simplicity and universality. Many services, including, for example, Flickr, use them to mark their content and also as a source of information which helps their internal algorithms to build knowledge about the content and users. But, on the other hand, because tags are loosely defined, and there is no generally agreed standard covering them, it complicates work with them. For example, a particular tag may have completely different semantic meanings, depending on the context. Some solve the problem using namespaces. But again, the lack of standard complicates even reuse of namespaces.

11.7.1 TAGGERS IN THE SYSTEM ARCHITECTURE

At first, we thought that assigning tags may be left on the shoulders of content providers. So, in the initial implementation of, for example, Flickr Content Provider was doing the tagging⁸⁵ itself, using the tags returned from Flickr. But, the ambiguity of tags and significant differences in the way various content sources use them, lead us to the decision to *separate the logic* which assigns tags into a dedicated tagging part of the system architecture.

In the current layout of the architecture blocks, the back end core defines an abstract class `CtTagger` with a shared tagging functionality and the tagging itself is performed by its subclasses. The subclasses may acquire the tags from various sources. They may contact an external service dedicated to tagging a specific type of content, use metadata stored by the content provider, or even analyse the content itself to identify related tags. So far, we implemented three taggers. All three can deal only with image data. Two of them are dedicated tagging services, Imagga and Clarify. The remaining one is a tagger which uses the tags provided by the Flickr API.

11.7.2 FLICKR TAGGER

We separated the logic which assigns `CtTag` instances based on the tags in the form of strings received from the Flickr API in a `CtFlickrTagger` class. But the class is still together with the rest of the code which provides Flickr support for the back end. This way, though the code is technically separated into different

85 With 'tagging' we mean assigning a `CtTag` instance or instances to a `CtContent` instance.

classes, it is still in its logical place from the perspective of its developer. If a developer wishes to implement support for a new content source which can provide its own tags, he is just supposed to subclass both `CtProvider` and `CtTagger`. Further, we put one more class in the system core called `CtProviderTagger`, which simplifies the development of taggers based on tags received from a content provider's source service to the minimum.

Implementation for Flickr content is a good example. Whenever it fetches the image metadata calling `photos.getInfo` of Flickr API via the API library, `CtFlickrProvider` saves the tags received in a content's custom variable `flickr_tags`:

```
cont.set_custom_variable("flickr_tags", "", ".join(info["tags"])
```

Then, the implementation of the relevant tagger is nothing more than the three lines of code:

```
class CtFlickrTagger(CtProviderTagger):
    def __init__(self):
        super(CtFlickrTagger, self).__init__("CtFlickrProvider", "flickr_tags")
```

Now, for all contents loaded from Flickr by `CtFlickrProvider` the `CtFlickrTagger` is invoked to assign the tags received from Flickr and stored in the custom variable *on condition*, `CtFlickrTagger` is enabled by the system. Enabling or disabling specific taggers may be done for example, via the management interface. Thus, the developer of a tagger just provides the functionality, but he is not the one who decides when or whether it will be used.

11.7.3 IMAGGA AND CLARIFAI TAGGERS

Imagga.com is a dedicated image recognition service. Its primary functions are image tagging and image categorisation. Besides this, the service offers intelligent colour extraction, intelligent content-aware cropping, and content moderation⁸⁶. It also allows customizable machine learning to adjust the detection results to custom scenarios. As in other cases, we created a lightweight library to connect to Imagga API. Communication with the service is effortless. To get tags from the default tagging engine, it is just a matter of selecting a proper size of the image and passing its link to Imagga as an HTTP GET. The resulting tags are returned as JSON, each of them with a relevant confidence level.

Clarifai.com is a direct competitor to Imagga, offering a similar set of functions. It also supports training of customers' own models. Functions include moderation and similarity search. Besides images, Clarifai also supports videos – but the recognition is performed from video still shots, not the video as a whole, which makes it quite expensive. Again, we created a simple API library. The Clarifai API requires a request in the form of JSON and JSON results contain a lot of additional data which we do not need, but it is not a problem.

We did not rigorously compare the quality of results or performance of the two services. Based on our subjective assessment, they both provide good and very similar results. There are various comparisons available, such as Janus' article (2016) which also concludes that both Imagga and Clarifai provide good results. According to the article, Clarifai can identify WordNet ontology links, which might be an advantage, if properly used. Clarifai has monthly limit 5000 images and Imagga 2000 in the free tier; both were enough for our trials.

11.7.4 OTHER RECOGNITION SERVICES (POSSIBLE EXTENSION)

Other available providers include but are not limited to the following. According to the publicly available information, all the services provide general image tagging. We mention their quota for the free tier as of the date of writing the text:

- *Wolfram ImageIdentify* (Wolfram Research, n.d.) offer 100 images monthly for free.

86 Detection of adult content.

- *MetaMind Einstein Vision* (Salesforce.com, n.d.) does not have any free plan.
- *Amazon Rekognition* (*Amazon Web Services, n.d.*), formerly Orbeus, 5000 images monthly for free, but only for the first year.
- *IBM Watson*, (IBM, n.d.), formerly AlchemyAPI, offer only 30 days free trial.
- *Vize.ai*, (Vize, n.d.), a recent Czech start-up, offer 10000 images monthly.

Other services are focused on a slightly different field. For example, *CamFind/CloudSight* (CamFind, n.d.) with 500 images per month in the free tier generate a title instead. It supports various languages. As an example of its results, a black and white picture of a lady sitting in a train coupé gets a title in English “*female equestrian train in gray*” or in Czech “*žena jezdecký vlak ve stupních šedi*”, which is not bad, the title is definitely based on the meaning of objects in the photo, there is still room for improvement especially to put the identified objects into proper mutual relations. Besides this, currently, the service was comparably slow, with response times several times longer compared to Imagga or Clarifai tagging. Also, *Diffbot* (Diffbot, n.d.) focuses on generating a title, it has a free quota of 10000 images monthly, but at the time of our tests, the service was often not able to generate any result for a given image.

In summary, many other recognition services dealing with various types of data are available, either as part of some of the AI packages mentioned above, or specialised, such as *Aylien* (Aylien, n.d.) which provides advanced text analysis.

11.7.5 COMPUTATION AND USAGE OF TAGS IN THE SYSTEM

Work with tags can be divided into two phases – tag acquisition and tag utilisation. Most of the text above covered the first problem – where and how to get tags relevant to a content instance. Regarding the second phase, the utilisation, the tags serve two primary purposes – to understand user preferences toward contents and to allow similarity searches in our database of contents.

Tagger chaining. Regarding the acquisition phase, the architecture of the system allows chaining of taggers. It means that more taggers may be asked to assign tags to a particular content instance. The information about the source of each tag is preserved. The algorithms utilising the tags have to be able to deal with duplicities.

Fuzzy vs crisp. When we receive tags from dedicated tagging services, such as Imagga or Clarifai, they are returned with confidence levels. In contrast, content sources, such as Flickr, usually do not return any confidence levels. Some tags are assigned to the content manually by users – usually by the content author or uploader. Then the information about confidence or relevance of the tag to the content is simply missing, so the service does not have anything to return. Flickr currently performs its own automatic image tagging. But as we confirmed with the Flickr staff, these tags are currently not exposed via the API. And even if the support for them in the API gets implemented, it is likely that the confidence levels will be kept internal and not returned as a part of the API call response. So, as a result, we have to deal with both tags with a particular confidence level and tags with an unknown confidence level. Our algorithm might simply *defuzzify* the tags with a confidence level – set a confidence level threshold, discard all tags with confidence below the level and also the confidence levels of the tags preserved. Then, all tags would represent just a binary association of a tag to the content, or a membership value in a set, in crisp logic. Such solution would be easy to implement. But discarding the confidence levels, we would be losing a valuable information. So, we decided instead to store the confidence levels if known. To simplify algorithms dealing with tags, we decided to *fuzzify* the crisp tags instead.

User preference weights. Whenever user likes or dislikes a particular content item, the tags assigned to the content are used to update weights for tags in user's profile. The algorithm is invoked by the `like_last_content` method of `CtUser` class, which is typically called by 'like' or 'despise' action handler. The algorithm itself is part of `CtTagLike` implementation in its `update_taglikes` method. It is relatively simple, but at least it considers not only the current setting of weights in user's preferences and the tags assigned to the content and their confidence levels but also the history – how many items the user liked or disliked in the past. The impact of the current content's tags on user's tag weights may also be adjusted by a parameter of the `update_taglikes` method. The tag weights in user preferences are used by content

providers to serve content which is relevant for the user. The `update_taglikes` method is also used to calculate content provider preferences, which are being used by the content dispatcher to decide, which content provider on the same priority level to ask first.

11.7.6 POSSIBLE IMPROVEMENTS

Better semantics. Probably the biggest challenge regarding tags is to overcome their ambiguity. As mentioned at the beginning of the Taggers section, because of lack of standardisation, merging tags from different sources can lead to misleading results. Even if content sources can provide semantically richer tags, such as with namespaces assigned, again, there is no standard or consensus over the namespaces which should be used. Some tags may also be irrelevant, for example, many Flickr tags are related to technical aspects of the photos, such as the camera used. If we use them to identify user's preferences toward content, we will end up serving *technically related* content, which is not really what we wanted. Among the community of photographers, they may be used with a high frequency, which makes the problem even more significant. One of the solutions which might lie in the systematic adoption of ontologies⁸⁷.

Better fuzzification. Currently, rather as a workaround, we simply assign 50% membership to all crisp tags. Research into applicable methods of proper fuzzification should be done to improve it.

Other than image content. Though the architecture of the system does not limit the tagging to image-content only, currently, we have not implemented any tagging for different types of content. Some might be implemented in the future.

Our own image recognition service. The trace from Clarifai to WordNet lead us to assume, that the engine for general image recognition has been based mainly on publicly available huge training dataset ImageNet (Stanford University & Princeton University, 2016). The very similar results of both tested services indicate that also Imagga's recognition engine has been trained with ImageNet data. More open datasets for machine learning are available, some listed by de Oliveira and deeplearning4j.org (2017). The public availability of such quality training datasets breaks the hardest barrier to implementing an image recognition service. So, perhaps in the future, we may think of developing our own instead of depending on other paid services.

11.8 THE MANAGEMENT INTERFACE

The back end provides a management interface which allows dealing with both system-wide and user-specific settings and statistics.

11.8.1 SYSTEM-WIDE CONFIGURATION

It is possible to see all registered content providers, all registered content dispatchers, translators and taggers. The services may be enabled or disabled on the fly – translators and taggers on the system-wide level, content providers and dispatchers for each user individually. Please, refer to the Figure 48.

11.8.2 USER MANAGEMENT

Access to various sections of the user interface is granted using the Web2py *role-based authorisation mechanism*. The system currently defines just two roles user – content consumer, and administrator. But it is extendable enough to allow to implement any other meaningful roles, such as a family member, care-provider, physician, etc. Via the management interface, it is possible to manage *user accounts* and assign user their roles. Please, refer to Figure 49.

87 It is an area which the author was particularly interested in a few years ago (Zejda, 2005, 2009).

Uživatelé

- David Zejda
- Věra B.
- Josef M.
- Věras B.
- Anna S.
- Věra S.
- +

Úrovně oprávnění

- administrator - admin
- +

Registrované zdroje obsahu

- CtSystemProvider
- CtFallbackProvider
- CtTestProvider
- CtYoutubeProvider
- CtInternalProvider
- CtSurveyProvider
- CtJwpubProvider
- CtFlickrProvider

Registrované dispečery obsahu

- CtDefaultDispatcher

Registrované překladače

- CtTranslatorNone ***
- CtTranslatorYandex <- active
- CtTranslatorFake ***

Registrované tagovací služby

- CtYoutubeTagger -
- CtImaggaTagger +
- CtRandomTagger +
- CtFlickrTagger -

Figure 48: Screenshot of the main page of the management user interface

Správa » Účty

Účty

+ ADD RECORD SEARCH CLEAR

Id	Křestní jméno	Příjmení	E-mail	Key	
1	David	Zejda	dvid@atlas.cz	317cd1d4-66dd-4ec...	POHLED (VIEW) UPRAVIT SMAZAT
2	Věra	B.	dvra@atlas.cz	8e37b055-b9ea-4d2...	POHLED (VIEW) UPRAVIT SMAZAT
3	Josef	M.	jdavid5534@gmail.com	865421b9-1a6c-479...	POHLED (VIEW) UPRAVIT SMAZAT
4	Věras	B.	vdvra5534@gmail.com	6d43764b-30e8-40b...	POHLED (VIEW) UPRAVIT SMAZAT
5	Anna	S.	avvra5534@gmail.com	6aa2d0e7-47da-4d0...	POHLED (VIEW) UPRAVIT SMAZAT
6	Věra	S.	dvra5534@gmail.com	14370fa4-e5bb-48d...	POHLED (VIEW) UPRAVIT SMAZAT

Export: CSV CSV (HIDDEN COLS) HTML JSON TSV (SPREADSHEETS) TSV (SPREADSHEETS, HIDDEN COLS) XML

Figure 49: Screenshot of the user management page

11.8.3 USER SETTINGS AND STATISTICS

The interface also shows, which users are online and other *state information* about them, such as which system actions are available to them, the detected resolution of the device they use to access the system, etc. Further, there are *frequencies* calculated about their interactions – how many content items each day, how many “bad clicks”; also frequencies per content provider. The interface also shows users' *preferences* in the form of weights assigned to tags and weights assigned to content providers. Please, refer to Figure 50.

Přehled Věra S.

Aktuální stav

Unikátní klíč	14370fa4-e5bb-48db-8937-537e7808d555
Jazyk	cs
Zpřístupněná tlačítka	next, like, despise, select
Členství ve skupinách	0
Rozlišení	1790x810
Naposledy online	2018-03-08 10:15:23

Zdroje obsahu

CtSystemProvider	True
CtFallbackProvider	False
CtTestProvider	False
CtYoutubeProvider	True pivots=56 57 58 59 60 61 62 63 34 5 64 65 90 66 67 68 69 70 71 72 357 361 535 541 542 544 546 547 548 552 556
CtInternalProvider	False
CtSurveyProvider	True
CtJwpubProvider	True bbooks=1 8 40 41 42 43 44mode=1
CtFlickrProvider	True groups=2701776@N24 1514626@N20 998716@N25 442531@N22 1229941@N21 40172196@N00

Historie aktivity

	celkem	2018-03-06	2018-03-07	2018-03-08
Zpracovaný obsah	334	173	115	46
Špatná kliknutí	99	40	45	14
Samohodnocení	nemám			
Fyzický pohyb	nemám			

Zobrazený obsah dle zdroje

CtSystemProvider	30
CtFallbackProvider	1
CtYoutubeProvider	57
CtSurveyProvider	4
CtJwpubProvider	6
CtFlickrProvider	236

Preference dle klíčových slov

tag	like	dislike
:ushuaia	0.00526315789486	0.0
:argentine	0.00526315789474	0.0

Figure 50: Screenshot of the user details management page

11.8.4 CONTENT PROVIDER PER-USER SETTINGS

It is also possible to access state information for combinations of a content provider and a user, such as user's lists of favourite Flickr groups or YouTube pivot videos from which the content provider derives which content to serve. These content-provider specific settings could also be edited directly in the management interface. The mechanism we use to let the management interface know how to set-up content providers, but avoid being dependent on their code, has been explained earlier. Please, refer to the Figure 51. To provide *localisation* of the management user interface we use the Web2py translation-management system which parses source code, identifies strings tagged for translation and puts them in the dictionary which is being consulted to provide run-time translation to match browser preferred language.

11.8.5 POSSIBLE IMPROVEMENTS

API access. Currently, only the HTML-based interface is available. But its functions might be exposed as a service so that they could be called from external systems. With the support for API access to the management functions, the back end could be integrated, e.g. into elderly care institutions' information systems.

Support for multiple instances. Another potential improvement of the management interface might deal with multiple simultaneously running instances of the system. Each back end instance has its own database and its own management. In the case there would be more instances running in parallel in the production, it

might give a sense to allow management across more instances. It would require either shared user database or a common authentication mechanism. The idea is illustrated in the following Figure 52.

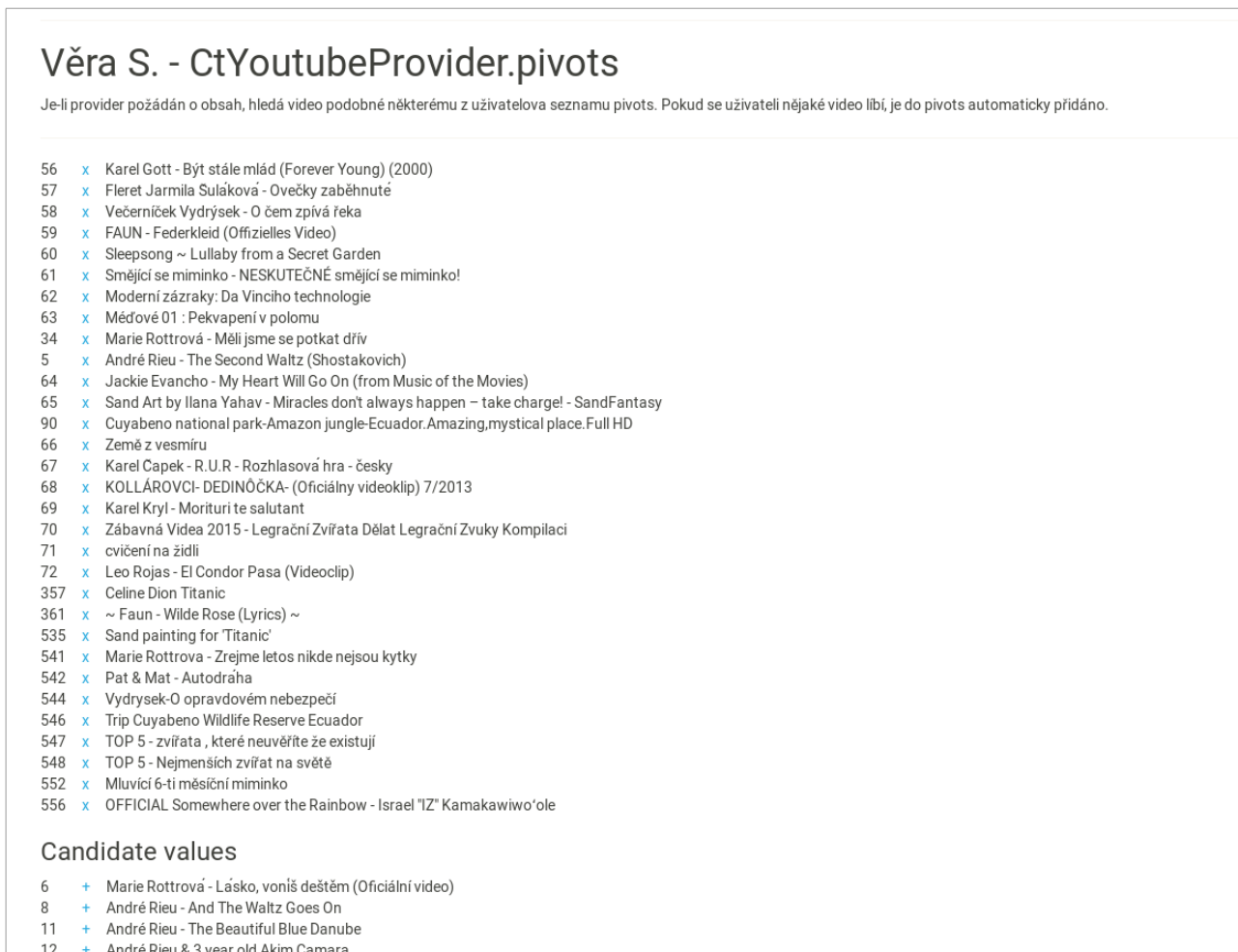


Figure 51: Screenshot of the YouTube Content Provider user settings

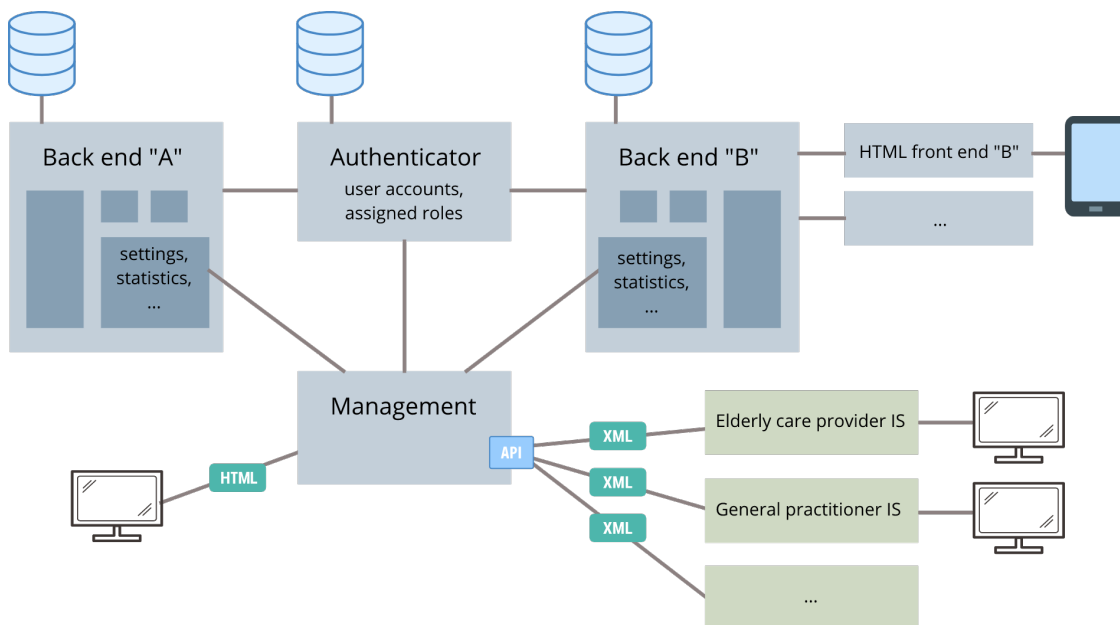


Figure 52: Possible improvements of the authentication mechanism

12 APPENDIX B – THE PROTOTYPE FRONT END ARCHITECTURE

The primary role of a front end is to present the XML responses from the back end to the user and to capture user's actions and other relevant events and pass them to the back end. Because most of the system logic and all permanent data are on the back end, the front end code may be comparably lightweight. All permanent data is stored on the back-end side, so there is no permanent data storage neither on the front-end side nor in the browser on the client device.

Based on the initial ideas and requirements, we thought, that the front-end part of the system should be implemented as a native application for a suitable mobile platform, most likely for Android. We had some good reasons for the assumption. A native application would provide the smoothest user experience achievable, because it may benefit from the full integration to the running environment, the best possible support for touchscreen-based user input, from various functions provided by the operating system or services running on the device. Not long ago, there would not be a viable alternative to a native application. Based on the assumption, we even started experimenting with the development of the default front end as a native application – we implemented and tested some elementary functions.

But soon after, we reconsidered the idea. Native applications also have their drawbacks. First, they are no-longer platform independent. Also, in comparison with web applications, they are less centrally controllable and manageable – but we wanted a solution which would update automatically behind the scenes, perhaps not even letting the user know. Thanks to the advancements in the relevant technologies, we were able to eventually combine the best from both worlds and develop the front end as a *progressive web application*. More details are covered later in 12.3.

Even though the default front end is a web application, we are not giving up on the idea of a native application. First, the main functionality of the whole system is in its back end. So, it is possible to develop an alternative front end as

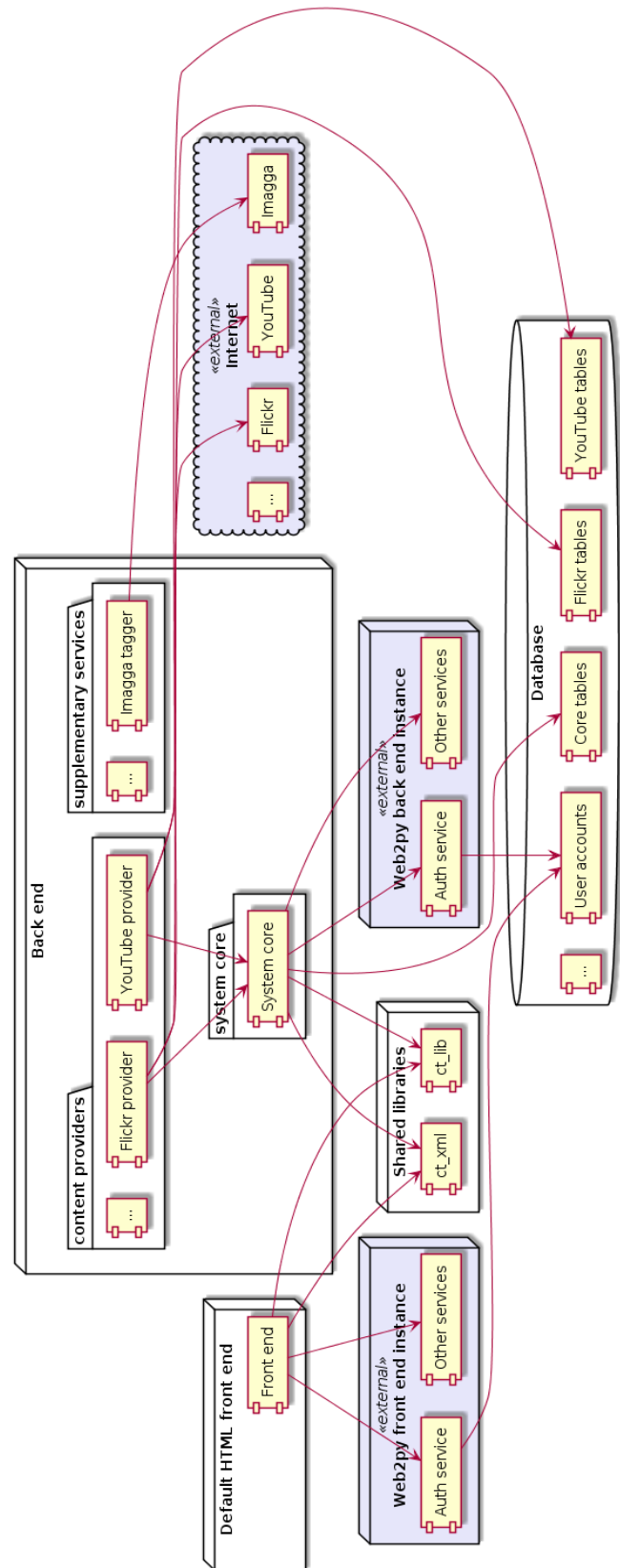


Figure 53: The front end and the back end – component diagram of the system building blocks

a native application. Further, we may also consider developing of *associated applications* as native. They could, for example, run on secondary gadgets, such as a smartwatch or a remote control. We could even think of implementing particular part of the system as a native *launcher* application. It would provide yet tighter integration and hide most of the unwanted functions and settings provided by the Android operating system and the default compulsory pre-installed applications.

12.1 THE SERVER PART

Front end should also facilitate offline experience, if possible. We have developed a *default HTML-based implementation* of the front end compatible with the back end described in the previous chapter. Other front end implementations may come up in the future, either implemented by ourselves or by others. They may serve, for example, clients with specific needs, such as blind or deaf or they may fit different clients' preferences, such as a viewer optimised for a big remote-controlled screen. A brief description of the areas a front end has to deal with and selected details about the implementation in the default HTML front end is in the following paragraphs.

Loose dependency on the back end. Default front end uses similar technologies as the back end, namely Python and Web2py. The default front-end implementation and the back end share two little libraries. First of them is `ct_xml` which is responsible for generating and for parsing the relevant XML. The other is `ct_lib` which defines `CtWarning` and `CtException` for systematic handling of errors and unexpected states and few other helper functions. And of course, the primary connection between front end and back end is via service calls. Thus, the default front end and the back end are only loosely coupled, which was our intention. In particular, there is no direct dependence of the front end code on the back end code or vice versa. So, for example, the choice of Python as a programming language and Web2py as a web framework, in no way limits other developers to create their own front end using completely different technologies.

The component diagram in Figure 53 illustrates these internal loose dependences. It also shows that both back end and front end use Web2py authentication mechanism which draws the user account data from a shared database. But we view this instead as a temporary solution for the prototype, and it should be changed later. Most likely, we will decouple the authentication into a separate service, which will be called by both back end and front end. The components with white background represent our own system, whereas the components with grey background represent external services we use.

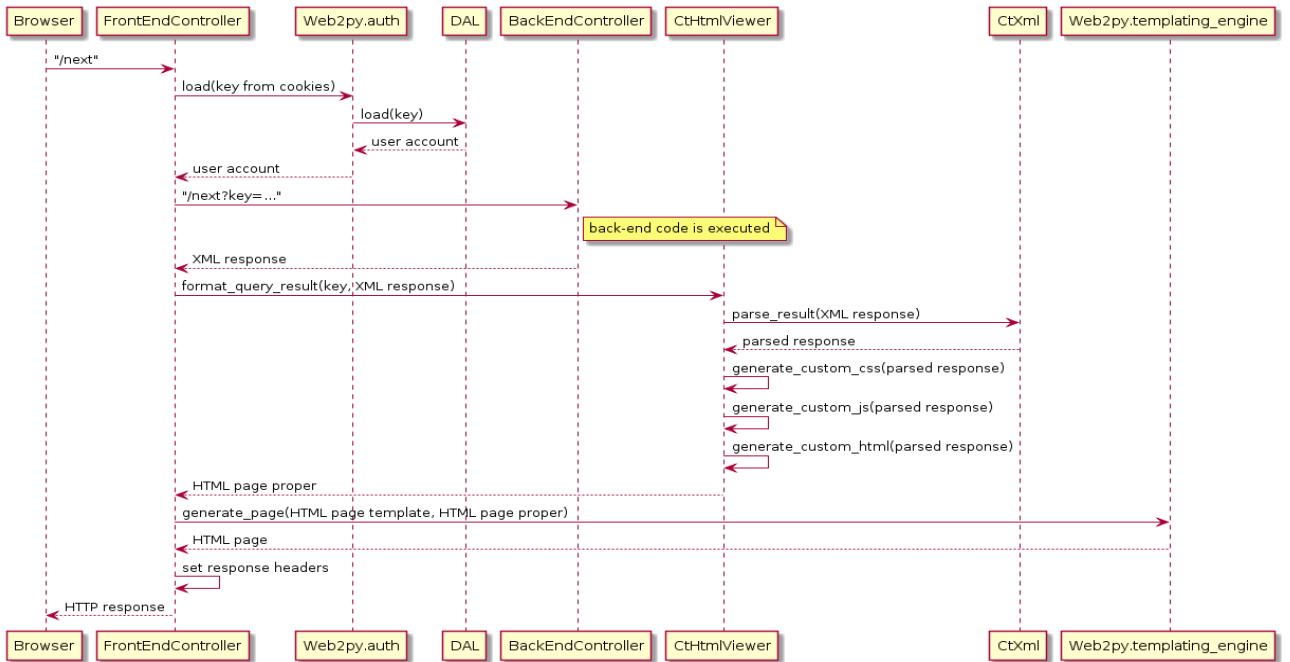


Figure 54: Sequence diagram – communication between front end and back end

Execution flow. The sequence diagram in 12.1 shows an example of the collaboration of parts of the front end in handling a request for a next content, which comes from a browser. First, the front end has to identify the user who is behind the incoming request. To do so, it loads a key from received cookies. The key is used to identify the user, so front end checks if the key belongs to a valid user. If so, it sends a service request to the back end. As soon as the response is received, it is being passed to `CtHtmlViewer` class where the most logic of the front end is implemented. The class asks `CtXml` class from the `ct_xml` library to parse the results. If the XML content matches the defined format, a python `dict` is returned. Then the `CtHtmlViewer` generates the main part of the page which includes HTML, JavaScript, and CSS code. It has to combine all pieces of information received from the back end, including HTML, JavaScript, and CSS snippets. Then, as the last step in generating the page, the Web2py templating machine is used to combine the content generated by `CtHtmlViewer` with a page template. The page template defines the static portions of HTML, JavaScript and CSS code – those, which do not change between requests. The result, seasoned with necessary HTTP headers, is returned to the browser.

Authentication. Logging-in is a step very familiar for regular users of Internet services, but it poses a challenge for the target group of our system. We wished to shield users in our trial from the need to remember their login credentials. So, currently, in the default front end, user login credentials are stored in a cookie shared to the browser. We don't use a session cookie, which expires when the user closes the browser, but a cookie with expiration set to one month. So, if a user gets authenticated on a device, if he accesses the system within this one-month period, he does not have to re-login. When the front end receives a cookie-authenticated action, such as a button-click, the key in the authentication cookie is used as a `key` argument of the relevant back end service call; no cookies are involved anymore at this stage. We also considered alternatives for the logging-in step, including cloud authentication services such as Google Auth Sign-In (Google, n.d.-c), Firebase (Google, n.d.-a), 1Password (AgileBits, n.d.), or PasswordWallet (Selznick Scientific Software, n.d.). But to focus on our primary objectives, we decided to leave the selection of the best authentication method for the proper time in the future.

Responsiveness. Our goal is to support as many meaningful target devices as possible. It means, besides else, to deal with different screen sizes and resolutions. To allow users to access HTML content which has been designed for a bigger screen, first generations of mobile browsers solved the problem simply; they just added horizontal rulers. The solution was universal, but it led to a poor user experience. Web users are used to scrolling vertically, but they find it inconvenient to scroll horizontally. So, big deal of effort on the part of browser functions, new standards and new web designs has been put in to come up with web page responsiveness. A typical responsive web, besides else, adjusts the layout of its elements to eliminate the need for horizontal scrolling even on small screens. So, to support various devices with our HTML content, we had to make it responsive. But we had to go a step further – not only that horizontal scrolling is unacceptable, but even vertical scrolling would likely affect the smoothness of experience for many users from our target group⁸⁸. So, we decided to eliminate the need for scrolling altogether. Of course, we applied the principles of responsive design. It includes the proper definition of `meta name="viewport"` in the HTML header, which helps the browser to decide how to control the page's dimensions and its scale. For the viewport we assigned the attribute `width="device-width"`, so the width of the page would be determined by the device-specific screen-width, and `initial-scale="1.0"` to set the initial zoom level when the page is first loaded. We also use relative CSS units, such as `em`, `ex`, `vw`, `vh`, `vmin`, `vmax` wherever it gives sense. Only a small portion of our CSS is defined in a static file; a larger piece has to be generated on-the-fly with use of the features of CSS3. They include `@media` selectors, which define different sizes and position of elements for different screen sizes and also CSS variables and CSS variable calculation with `calc()` function.

Cross-device support. The support for different devices had to go beyond the problem of various screen sizes. For example, initially, for control elements, we simply defined links and rendered them to appear as buttons via CSS, which is a common practice. But, the trial with users has revealed, that we could not rely on the default way how browsers handle user's clicks on HTML links or HTML buttons on touchscreen devices. We observed, that one of the first participants involved in our usability test was not able to touch

88 More research would be welcome to assess, how much the need for scrolling affects the experience of users from our target group and, perhaps, evaluate possible solutions.

them in a way, which would be appropriately interpreted as a click (6.2.1.2). She sometimes pressed the button for a while, or touched it and moved the finger. The unexpected reaction of the system made her feel frustrated. So, based on the experience, we tried defining controls instead as span elements with a `touchstart` listener to capture user interaction. It worked much better than relying on clicks. But `touchstart` events are not emitted on devices with pointer-based navigation. We wanted to come up with a universal solution, which would not sacrifice the support for devices with pointer-based navigation. The solution had to involve both code on the front end and the back end. Content providers or their formatters are allowed to directly include control elements for content actions as a part of the generated HTML code. So, we had to come up with a universal mechanism able to assign action handlers to the right events, based on the type of the client device. Eventually, we implemented the biggest part of the solution in the back end core. It generates a piece of JavaScript code, which may be passed to the front end. Because it is generated by the system core, all other parts of the system, including content providers, may rely on it. It allows registering control handlers for individual control elements. A function, which is invoked when the page loading finishes, assigns event listeners which are appropriate to the type of the device. This is the key part of the JavaScript code:

```
var REGISTERED_ACTIONS = []

function registerAction(button_id, handler) {
    REGISTERED_ACTIONS.push([button_id, handler]);
}

var IS_TOUCH_DEVICE='ontouchstart' in window || navigator.maxTouchPoints;
//first works on most browsers the second on IE10/11 and Surface

window.onload = function() {
    for (var i = 0; i < REGISTERED_ACTIONS.length; i++) {
        button_id = REGISTERED_ACTIONS[i][0];
        handler = REGISTERED_ACTIONS[i][1];
        let buttEl = document.getElementById(button_id);
        if (IS_TOUCH_DEVICE) {
            buttEl.ontouchstart = handler;
        }
        else {
            buttEl.onmousedown = handler;
        }
    }
    if (IS_TOUCH_DEVICE) {
        eventType = "touchstart";
    }
    else {
        eventType = "mousedown";
    }
}
```

Then, for example, a content provider won't have to know anything about the type of the client device. It simply registers its media control handlers. The following snippet states, that `raiseVolume` function is supposed to handle user interaction with element with `id="volume_up"`:

```
registerAction("volume_up", raiseVolume);
```

12.2 THE BROWSER-SIDE PART

Browser-side execution flow. The following sequence diagram Figure 55 shows, which steps are performed on the side of the browser when the browser accesses the page generated by the front end for the first time, then when the user asks for a following, turns the Internet connection off and asks for a following content again. The first request goes directly to the front end. When the browser receives an answer from the front end, it parses and renders the page contents. At the end of page load, an `onload` event is emitted and subsequently handled by the `onpageLoad` listener defined in a front end JavaScript code. It determines the type of the device, such as whether it has a touchscreen or not, handlers for action set initially by the back end are registered, service worker is registered. The JavaScript also starts a periodical check of the state of the connection. So, from now on, a function will try to ping the back end every 10 seconds⁸⁹.

89 The connection checks performed by a JavaScript timer are not included in the sequence diagram.

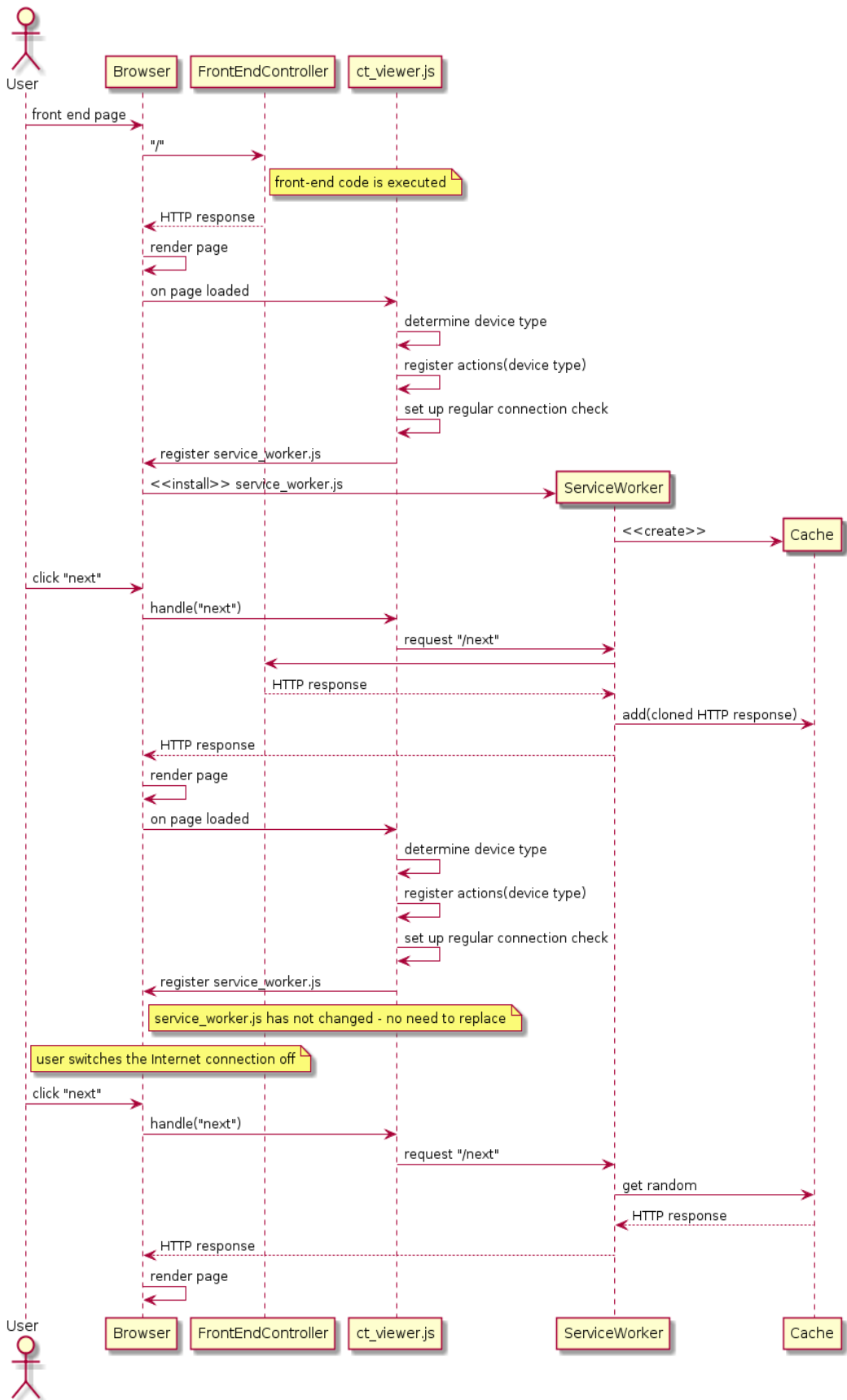


Figure 55: Sequence diagram – requests being handled by the code on the side of the browser

Because service worker is already running at this time, when the user asks for following content, the service worker intercepts the request. It passes it to the front end, but before returning the response to the browser, it stores a clone of the response in its cache. So, when the Internet connection is not available on the next content request, which the service worker reveals by a failed connection the front end, it fetches a content in the form of HTTP response from the cache and returns it to the browser. So, the application works offline, though in a degraded mode which does not allow full interaction. As soon as the connection is re-established, the full operation gets restored. More details are provided in the following paragraphs.

Detection of connection state. Ping service call to the back end is invoked every 10 seconds. If it fails, the connection indicator (a round dot in the top right corner of the interface) changes its colour from green to red and the user interface adjusts to the offline state. In the current implementation, in the offline state only 'next' button is left; other controls related to other system actions ('like', 'despise', 'select') get hidden. Clicking 'next' loads content from the cache managed by the service worker. As soon as the ping succeeds, the UI reverts to the online state, showing all controls again.

Direct browser communication with the back end. The ping service call is an example of a direct call from the browser to the back end, bypassing the front end. Similarly, media event actions and bad click actions are communicated directly to the back end, just passing through the service worker, but not involving the front end. It is related to the fact, that certain pieces of JavaScript code in the generated page originates in front end, but other pieces in the back end. Only calls which load a new content⁹⁰ are required to go through the front end. Driving the calls which return only state information, such as a 204 HTTP code, through the front end would not provide any benefit, but just a performance loss and waste of resources. The communication is illustrated in the following diagram in Figure 56.

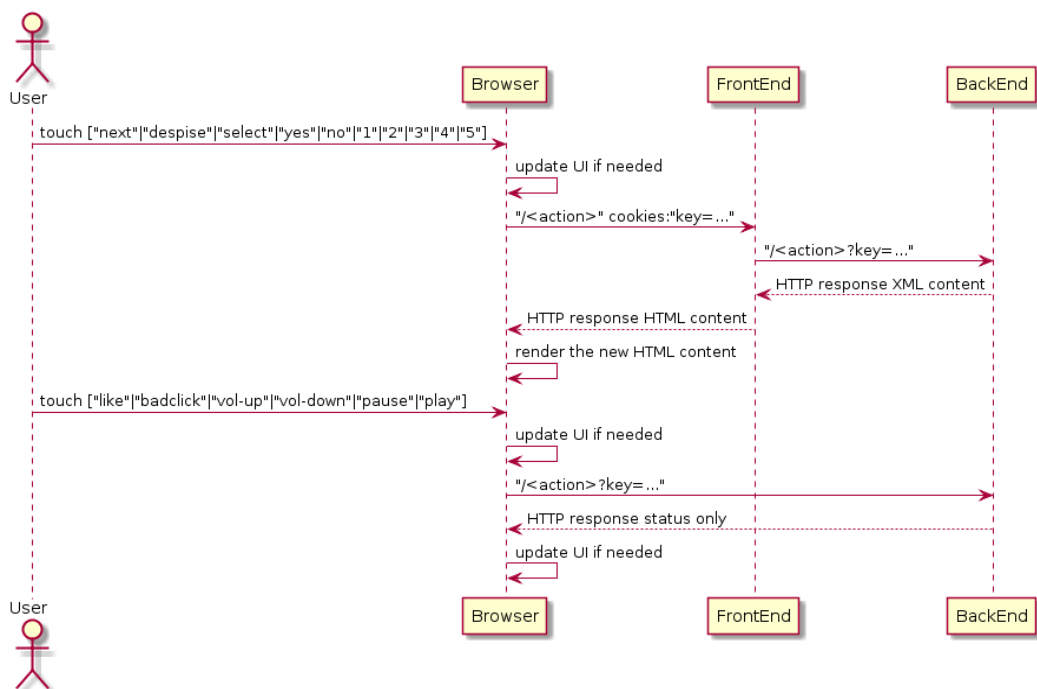


Figure 56: Sequence diagram – activities being handled either through the front end or directly by the back end

12.3 A PROGRESSIVE WEB APPLICATION

In the early years of the current century majority of the web pages were static, but technologies for dynamic content, such as PHP, or ASP started emerging. In 2005, term AJAX⁹¹ was used by Garrett (2005). These AJAX technologies, which include XHTML, CSS, DOM, JSON, XML, XMLHttpRequest, and JavaScript,

90 Either media content or system content according to the definitions from the section 11.4.

91 He used the word 'Ajax' with the first capitalised letter, but nowadays the fully-capitalised 'AJAX' is more common.

allowed to shift substantive portions of the dynamic behaviour to the browser. It in turn leads to quicker responses on user interactions and overall better user experiences. In parallel, technologies for responsive web design reached their maturity. But, despite early attempts since circa 2007, native applications were still excelling in the richness of user interface, response times on user interaction, loading times, etc. Packaged libraries and resources, direct access to the device hardware, limitations in Internet connection speed were among the factors behind the advantage of the native applications. However, in the recent years, enhancements in HTML5, CSS3, JavaScript and growing support for the new technologies in modern browsers, accompanied with advancements in hardware made hybrid applications, combining the good from both web and native applications, a viable option. In 2015, Russel (2015) introduced the term *progressive web app* to describe applications which leverage the available palette of relevant technologies. A progressive web app has to be reliable, fast, and engaging (Google, 2017a). It means, it has to be responsive, connectivity independent, offer app-like-interactions, fresh, safe, discoverable, re-engageable, installable, linkable (Russel, 2015). The key technologies to make a web application progressive include a *web app manifest*, a *service worker*, and SSL. In the following section, we cover the first two technologies. SSL is related to deployment and we talk about it in 13.1.

12.3.1 THE WEB APP MANIFEST

Web manifest is a piece of static JSON code linked from the page head section, which tells a browser that the page should be treated as progressive. It gives the developer the ability to control how the application shall appear to the user where they usually see native apps – such as a mobile device's home screen. It also sets, where a launch should lead to, and define the appearance at start (Gaunt & Kinlan, 2018). Our manifest declares the following parameters for our default HTML viewer:

```
{
  "name": "ZEE - Zero Effort Experience",
  "short_name": "ZEE",
  "lang": "en-US",
  "description": "Be connected. Zero effort. Specially designed for those who have never used
mobile electronic devices.",
  "orientation": "any",
  "scope": "/",
  "start_url": "/default/index/next",
  "theme_color": "#2196f3",
  "background_color": "#2196f3",
  "display": "fullscreen",
  "icons": [
    {
      "src": "/zee/static/images/icons/icon-72x72.png",
      "sizes": "72x72",
      "type": "image/png"
    },
    ...
  ]
}
```

12.3.2 THE SERVICE WORKER

Service worker is a JavaScript which is living in the browser in the context of a specific URL tree, but unlike to a common JavaScript, independently on individual pages. The typical purpose of a service worker is to provide offline experience and to increase the performance of the application. To do so, it intercepts HTTP calls coming from the context of the controlled URL tree, and perform actions according to its inner logic. The service worker technology extensively uses *promises*⁹². Promises allow providing a code which is executed depending on either success or failure of *asynchronously* executed actions.

Caching. We primarily use the service worker technology for the typical purpose – to provide offline functionality. To facilitate it, our service worker uses browser-side storage to cache received HTTP responses. The occupied space by the browser may be reclaimed by the system at any time if the device is running low on storage. The data may also be deleted easily by the user. So, our system keeps all permanent

92 Promises is a recent JavaScript technology well introduced by Archibald (2018a).

data on the back end and uses the client-side storage only for temporary caching. We use several caches for different purposes.

Static cache. It stores the data which does not normally change between requests, such as icons, static CSS and JS files. We also include a fallback page and a fallback image in the static cache. The static cache is populated at the service worker installation; only if it succeeds, the service worker becomes activated⁹³. So, the rest of the service worker may depend on the contents stored in the static cache.

Content cache. It serves as temporary storage for HTML pages generated by the front end. We stored all which are marked cacheable by the HTTP header. The content cacheability is determined by the content provider which is responsible for the content. Currently, audiobooks and images are declared as cacheable by the back end, because it is possible to cache both the HTML page with the content and the linked resources (images, MP3 files) and preserve the functionality even when offline. YouTube content is currently not treated as cacheable. The reason is twofold. The controls for a video in a YouTube embedded element work only online. We would have to implement different controls for a fully downloaded video. It would not be impossible, but there is one more reason – videos might quickly deplete the storage available for the whole application.

Resource caches. Then we have separate caches for individual content types, so one cache for MP3 files linked by the content from audiobook provider and another cache for images loaded from Flickr.

Cache management. Storing contents in more caches which helps to flush only portions of storage based on changes in the source codes. E.g. if just a CSS style has changed, maybe there is no need to flush the storage of cached content pages and resource caches, so only the static cache should be flushed. If the change involves changes in the structure of the HTML in content pages, the cached storage of content pages should be flushed as well, but resource caches might be preserved, depending on other conditions. The flushing of selected caches is done by the service worker, as a part of its life-cycle before activating. Because according to the life-cycle the old version of the service worker might be still in operation when the new service worker is being activated, we use cache versioning as a recommended practice for service workers. So, while the new service worker is being installed and its new caches are being populated, the old service worker still has access to the previous version of caches, and his behaviour won't get broken.

Content caching strategy. For the responses containing the content pages, we adopted a network-first strategy, named also “*Network falling back to cache*” by Archibald (2018b). The following code⁹⁴ is an example of the service worker code which is responsible for intercepting the requests leading to the front end and caching the response if it is set as cacheable by the HTTP header. The content UUID is used as a key which identifies the content in the cache. If the attempt to fetch the page from the front end fails, a random item is retrieved from the content cache. If it also fails, the fallback page from the static cache is returned, which is done by a function `matchFallbackPage` defined elsewhere in the service worker code.

```
if (/\/index\/\//.test(requestURL.pathname)) {
  event.respondWith(
    fetch(event.request)
      .then(
        function(response) {
          respClone = response.clone();
          if (respClone.headers.get("x-zee-cacheable") === "1") {
            caches.open(CONTENT_CACHE).then(
              function(cache) {
                var uuidToCache = respClone.headers.get("x-zee-uuid");
                cache.put(uuidToCache, respClone);
              });
          }
          return response;
        }
      )
  );
}
```

93 The process of replacing an old service worker with a new one if there is a change in its code is a part of service worker life-cycle is nicely described by Gaunt (2018) in his introduction to service workers.

94 The example code also illustrates that the promise-based JavaScript code with all the nested functions is not really easy-to-understand. JavaScript syntax which depends on curly brackets to enclose blocks of code and semicolons to end statements makes it worse, causing the development of asynchronous promise-based code error-prone. The impact the JavaScript syntax had on the progress of our development lead us to name the problem, with a bit of sarcasm, a *bracket hell*. Other languages, such as lisp, suffer a similar pain, though with a different variety of brackets involved. Python, which uses indentation to define blocks of code, stands up as one of few who is not guilty of spreading the bracket hell.

```

    })
    .catch(function(e) {
      return caches.open(CONTENT_CACHE)
        .then(function(cache) {
          return cache.keys()
            .then(function(keys) {
              var chosenKey = keys[ keys.length * Math.random() << 0 ];
              return cache.match(chosenKey)
                .then(function(response) {
                  return response;
                })
            })
        })
    })
    .catch(function(e) {
      return matchFallbackPage();
    })
  })
);
return; //so, no need to test the request against other rules
}

```

Other caching strategies. Other types of responses, e.g. those which contain linked resources, ping service call, or other back end service calls follow different caching strategies, according to their meaning and purpose. For example, if loading of a picture fails, a fallback image with neutral content is returned from the static cache. Or, 'despise' call gets intercepted by the service provider to remove the relevant page from the content cache before passing the request to the front end server, so the content wouldn't ever be served from the offline mode.

Role of HTTP headers. We mentioned HTTP headers several times. Because service worker does not have access to the document DOM, we use HTTP headers to carry the metadata which the service worker needs to know to handle intercepted requests and relevant responses appropriately. So, we use the `x-zee-cacheable` header to mark if the response carries a cacheable content item, the `x-zee-uuid` header with the unique identifier of the content. We also properly set *CORS headers* to allow cross-domain calls from the front end domain to the back-end domain when back-end services are called directly. These involve `access-control-allow-origin`, `access-control-max-age`, `access-control-allow-headers`, `access-control-allow-methods`. Further, we had to deal with caching-related headers, but it is related rather to deployment, so we cover the issue in the respective section.

12.3.1 POSSIBLE IMPROVEMENTS

There is still quite a lot what could or should be done to exploit the potential of the service worker technology to the full.

Reflect user likes in caching strategy. Regarding plans for service worker, the current caching mechanism could be improved to keep track of user preferences toward content also on the client side, so the preferred type of content might be served with priority even if the device is off-line. The implementation won't be difficult. The cache for pages should be divided into regular pages and liked pages. If new content is being served, based on the preference information which is returned in the response header, the response might be directed to the proper cache.

Cache-ahead strategy. It might be considered that at every request, besides the current content item, the following item would be returned as well – to implement one of the ideas mentioned during the initial brainstorming session. The following provided content item might be loaded and cached in the background. As soon as user invokes 'next' action, the cached response would be provided almost instantly from the cache, and the client code would download the following content on the background, while the user is consuming currently displayed content.

Improve reliability. Service worker may not only ensure that the application works in offline mode, but it may also further increase the reliability and smoothness of user experience. For example, failed calls to load content from external sources may be used to call a back-end service which will invalidate the related content, so it won't be offered to users anymore.

Implement pushed content. Service worker may help to process pushed content if there is any. Urgent types of content, such as messages sent to the user by someone directly, are typical candidates for pushing

Architectural improvements. The current implementation of the service worker is not clean from the architectural point-of-view. It is just one file, which combines both sections dealing with system files, and parts handling content-provider specific resources. It causes that the current code of the service worker is dependant on the code of content providers, which can't be left untouched for the production phase. We knowingly decided in favour of the temporary compromise to simplify the development and debugging of the service worker code.⁹⁵ In production state, the service worker should be composed of pieces of code or information provided by both the viewer and service providers.

Exemplary progressive web app. According to Google (2017b), an exemplary progressive web app provides schema.org metadata where appropriate, connects with social media, provides canonical URLs when necessary, uses history API instead of fragment identifiers, its content doesn't jump as the page loads, preserves scroll position when navigating between pages, ensures input elements are not hidden under software keyboard, its content is easily shareable via social networks, its install prompts are not used excessively, its installation is not offered at an inconvenient time, its first page loads very fast even on 3G, uses cache-first strategy, informs the user when offline, tells user about push notifications and does not offer them aggressively, dims when a permission is asked, its push notifications are timely, precise and relevant, provides controls to disable notifications, logging-in the app is performed via the Credential Management API, and Payment Request API is involved if payment is offered. We are planning to evaluate these and other recommendations in connection with the system.

95 The implementation of the service worker was quite frustrating. As a novel technology it has not reached the stage of full maturity yet regarding the support in browsers, tools, documentation, etc. The development has been stuck, for example when service workers were not replaced by new versions as expected. Just one line – calling the service worker `skipWaiting` function – helped. But several hours of testing being wasted.

13 APPENDIX C – THE PROTOTYPE DEPLOYMENT

In this chapter, we describe the steps we had to take to deploy the system on a server, so users involved in the trial could access it. To provide an overview of the devices and the software execution environments involved, we prepared the following deployment diagram as a Figure 57. For simplicity, it shows only 3 out of 10 tablets used for the trials. All devices were interconnected via the Internet, but for simplicity, we did not include the connections. Arrows and line styles are present to differentiate various kinds of links – dotted for connection between a browser and our system and dashed for WSGI connection between Apache web server and our system.

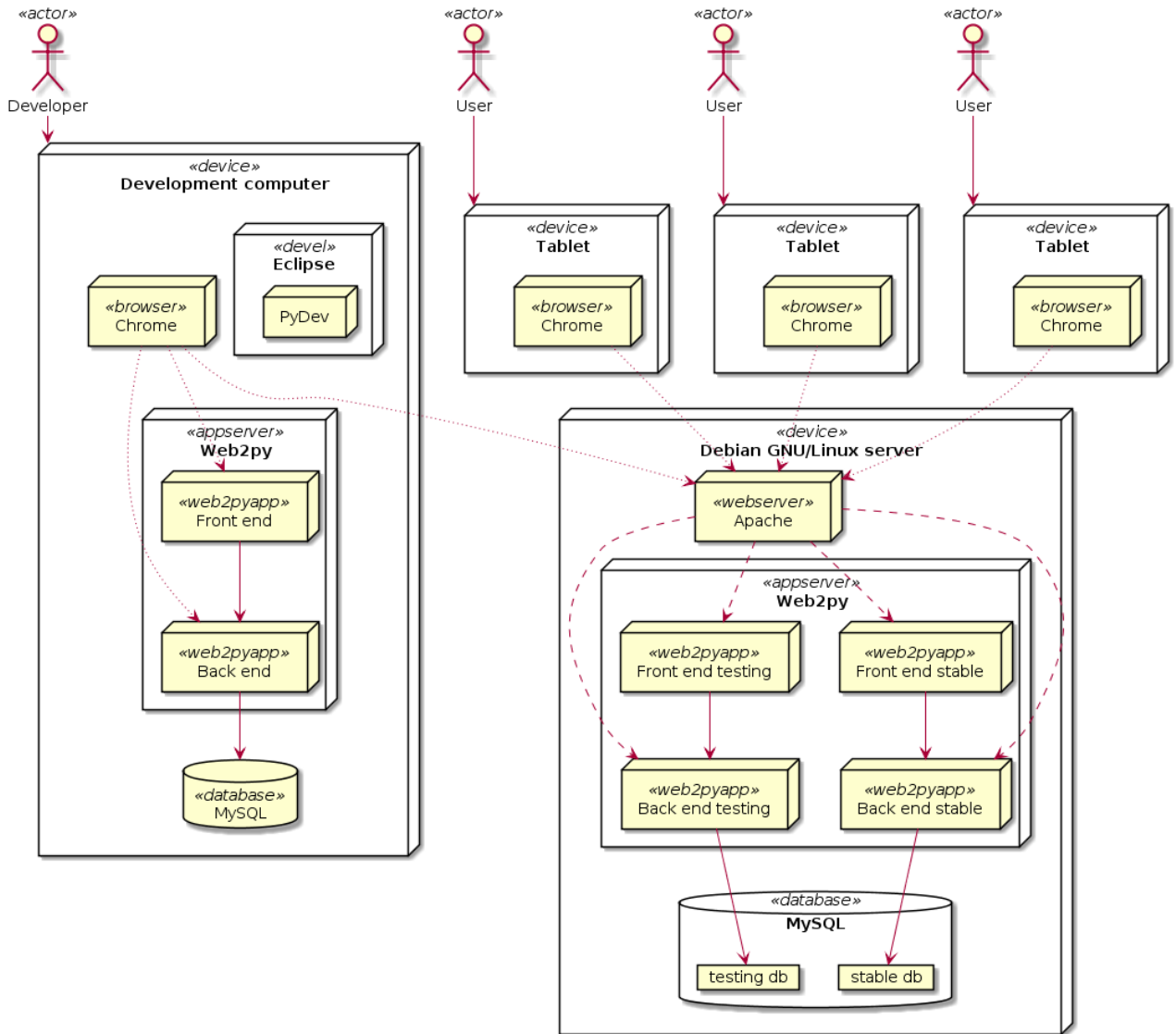


Figure 57: Current deployment diagram of the whole system for both development and the trial

We had a complete working environment, including a Web2py instance and MySQL database installed on the development machine. Two separate instances of back end and two instances of front end, together with a separate database for each of them, have been deployed on one instance of Web2py running on a server⁹⁶

96 The server was hosting other services at the same time, such as two virtual machines with BigBlueButton video conferencing system and an instance of OpenSimulator connected to the Metropolis Metaversum virtual world grid. Several more Web2py applications were running in the same Web2py instance as well.

equipped with i7-4770K CPU and 16 GB RAM running Debian GNU/Linux Jessie. We decided to deploy not just one, but two instances of our system on the server. One was dedicated to testing new code and the other one, considered 'stable' in the context of our scenario, was the one where the participants of our trial were connecting to. The separation of purposes has proven useful because we could update the 'stable' instances less frequently and only with reasonably tested code. The fact that the instances of both back end and front end were running in the same Web2py instance does not mean that can't be easily separated, if necessary. We prepared an alternative deployment diagram which illustrates how the system could be deployed for the production. It is at the end of the chapter 13.

13.1 SSL SUPPORT – LET'S ENCRYPT

For years it has been a recommended approach to secure websites with SSL to prevent various types of security issues, such as vulnerability to a man-in-the-middle attack. But, access to the benefits of SSL-secured communication was limited by the absence of a source of respected, but free-of-charge X.509 certificates for TLS. Of course, anyone might have issued his own SSL certificate which was technically valid. But if not certified by an authority included in lists of root certificate authorities in popular browsers, warning messages displayed by browsers about an untrusted certificate harmed the user experience and trust in a site significantly.

With growing push toward security from all sides, including browser developers, website owners, and web users, in parallel with the growing number of websites and the web traffic, the lack of a free-of-charge certificate authority became critical. That's why *Let's Encrypt* has been established and in 2016 officially launched (Cimpanu, 2016). Let's Encrypt is a certificate authority that provides free X.509 certificates for encryption. The processes of creation, validation, signing, installation, and renewal of certificates are *fully automated*. It reduces the amount of manual work, and it is one the reasons why the service may be offered free-of-charge. But it also saves the human resources on the side of the web hosting.

The availability of good-quality trusted free-of-charge certificates allowed to move forward with the plans to diminish the amount of unsecured web content gradually. According to Franceschi-Bicchierai (2016), Google wants everything on the web to be travelling over a secure channel. That's why in the future Chrome browser will flag all unencrypted websites as insecure. And that's also why every *progressive web application* has to be served over SSL. Unless secured, its service worker won't be registered in the browser and installation of the application on the home screen won't be offered. So, even for our tests, we had to go for SSL. For automatic generation of renewals of SSL certificates, we used `certbot`, a tool recommended by Let's Encrypt. The tool upon its installation defines new `cron`⁹⁷ jobs which automatically renew any certificates which are getting close to their expiration. To further automate the creation of SSL certificates for Web2py applications, we created a simple shell script called `newsslcert`:

```
#!/bin/sh
EXPECTED_ARGS=1
E_BADARGS=65
E_EXISTS=66

DOMAIN=$1

if [ $# -ne $EXPECTED_ARGS ];
then
    echo "Creates Let's Encrypt SSL cert; called automatically by /opt/web2pyapps/newapp"
    echo "Usage: $0 domain"
    exit $E_BADARGS
fi

ACMEROOT=/opt/web2py-acme

if [ -e $ACMEROOT/$DOMAIN ];
then
    echo "ACME dir $ACMEROOT/$DOMAIN exists, stopping"
    exit $E_EXISTS
fi

echo "Testing if acme_challenge dir is accessible"
```

97 Cron is a task scheduler on UNIX-based systems.

```

CHALLENGE=http://$DOMAIN/.well-known/test
curl -s --head "$CHALLENGE" | head -n 1 | grep "HTTP/1.[01] [23].." > /dev/null
# on success (page exists), $? will be 0;
# on failure (page does not exist or is unreachable), $? will be 1

if [ $? -eq "0" ]; then
    echo "OK"
else
    echo "Can't access $CHALLENGE, terminating. Setting the domain via Web2Py macro might help."
    exit 1
fi

cp -R $ACMEROOT/_skeleton $ACMEROOT/$DOMAIN
chown -R www-data:www-data $ACMEROOT/$DOMAIN

certbot certonly --webroot -w $ACMEROOT/$DOMAIN -d $DOMAIN

```

Before an attempt to generate a new certificate by the Let's encrypt service, we perform a test to check if the Web2py application is configured correctly to accept the validation challenge which is issued by Let's Encrypt as a part of the generation process. The script is called automatically by other parts of our deployment environment, namely by the `newapp` script.

13.2 APACHE WEB SERVER

Web2py contains *Rocket* (Farrell, 2011/2017), a multi-threaded and extensible web server. The Rocket web server is designed to handle web applications implemented in Python. It can serve WSGI applications and static files. Web2py switched to Rocket from the formerly used CherryPy for the better flexibility and concurrency.

WSGI stands for *Web Server Gateway Interface*. It is a Python specification for a universal interface between web servers and web frameworks or web applications. It can be traced back to 2003 when it was proposed by Eby (2003). Since then, it has been accepted as a de-facto standard for Python web application development. Apache offers a WSGI connector as one of its standard modules. We use the connector to facilitate the communication with Apache and Web2py. Though on the development machine we do not use Apache as an intermediary for handling requests from a browser, for production environments the use of Apache or another forward web server is recommended by the Web2py documentation (Di Pierro, 2017a). It has various advantages:

Non-Web2py sites. Web2py listens on its own port, such as 8000. It can be easily configured to listen directly on the default HTTP port 80, but if there are other than Web2py-powered websites on the same machine, it makes the configuration complicated, because Web2py is not intended for massive forwarding incoming requests outside of its scope. Performance would suffer significantly. A much better solution is to use a dedicated web server, such as Apache, let it listen on the standard port 80, and forward chosen requests to Web2py via WSGI.

Fast serving of static resources. Though Rocket provides fairly good performance and in some scenarios can compete with Apache, nginx or other main web servers. But mostly, especially in high-load, Apache performs better, it is more tested and more stable. When WSGI is involved, it further affects the performance. So, it is a good idea and a recommended approach to serve static files used by a Web2py application directly by Apache.

Better configurability. Another reason to use Apache in front of Web2py is much better configurability. Rocket is neither much configurable, nor extensible. All the things possible in Apache, such as pluggable modules, caching, headers, rewrites, logging, tuning, threading, error handling, etc. are either impossible or more complicated with Rocket.

Because we had to deploy *four* Web2py application instances behind Apache, not mentioning other applications running on the same server, to avoid duplicity in the deployment configuration, we decided to use the Apache `mod_macro`, which allowed us to define the necessary parameters only once. This is the macro definition:

```

<Macro Web2PySSL $domain $app>
<VirtualHost *:80>
    ServerName $domain

```

```

    Redirect permanent / https://$domain/
</VirtualHost>
<VirtualHost *:443>
    SSLEngine on
    SSLCertificateFile /etc/apache2/ssl/letsencrypt/$domain/fullchain.pem
    SSLCertificateKeyFile /etc/apache2/ssl/letsencrypt/$domain/privkey.pem
    ServerName $domain
    WSGIDaemonProcess $domain user=www-data group=www-data display-name=${GROUP}
    WSGIScriptAlias / /opt/web2py/wsgihandler.py
    WSGIProcessGroup $domain
    WSGIPassAuthorization On
    <Directory /opt/web2py>
        AllowOverride None
        Require all denied
        <Files wsgihandler.py>
            Require all granted
        </Files>
    </Directory>
    AliasMatch ^/static/(?:_[\d]+.[\d]+.[\d]+)?(.*) /opt/web2py/applications/$app/static/$1
    <Directory /opt/web2py/applications/*/static/>
        Options -Indexes
        Require all granted
        # NOTE - currently no caching is allowed
        Header set Cache-Control "no-cache, no-store, must-revalidate, \
            max-age=0, proxy-revalidate, no-transform"
        Header set Pragma "no-cache"
    </Directory>
    CustomLog /var/log/apache2/$domain.log common
    ErrorLog /var/log/apache2/$domain-error.log
</VirtualHost>
</Macro>

```

To use the macro for a Web2py application, we only add one line in the Apache configuration which calls it with the domain name and application name as parameters. The macro ensures, that any attempt for HTTP communication is redirected to HTTPS, sets the proper domain-specific SSL certificate, establishes the appropriate WSGI connection to Web2py, lets the static content be served directly by Apache, sets HTTP headers and custom logging.

Disable default caching. Regarding the HTTP headers, the development has been stuck for a while because an unwanted browser-side caching beyond the caching implemented by the service worker was taking place. So, even if we instructed the browser by the service worker to fetch a new version of static resources, including static JavaScript and CSS files, initially it did not work as expected. As the subsequent investigation revealed, the internal browser cache was interfering, serving cached contents to the service worker instead of asking the server for fresh versions. Proper headers setting on the server side helped to solve the issue.

13.3 DEPLOYMENT SHELL SCRIPTS

To make the process of deployment and upgrade of Web2py applications on the server as easy as possible, we created a set of shell scripts which facilitate the deployment process.

Set-up for a new Web2py application. The `newapp` creates the necessary Web2py folders, an application-specific `pickup` script discussed later, the database together with a new database user and relevant permissions, sets the Apache using the macro described earlier, updates Web2py routes settings⁹⁸, calls the `newsslcert` script to generate SSL certificates. Because it does not have to be fully automated, but rather a room for systems administrator's intervention should be left, the steps are performed one-by-one, and a confirmation is required for each of them. To complete the steps, it uses skeletons of directory structures and template files for generated configurations. For example, the `pickup` script template is the following:

```

#!/bin/sh
NAME=<APPNAME>
FPATH=/opt/web2pyapps/$NAME
cd $FPATH

```

98 Web2py defines `routes.py` configuration file, which allows choosing a strategy how incoming requests shall be routed. We mainly use it to match an incoming domain name with an application responsible for serving the domain.

```

tar -cvzf backup/$NAME-bkp-`date +%s`.tgz src
rm -r $FPATH/src/*
echo 'uncompressing...'
tar -xzf $1 src
echo 'compiling...'
cd /opt/web2py
sudo -u www-data python -c "import gluon.compileapp;
gluon.compileapp.compile_application('applications/$NAME')"

```

And the `newapp` script replaces the `<APPNAME>` using a `sed` command:

```

(
cat newapp_pickup_template | sed "s/<APPNAME>/$APP/"
) > $APP/pickup

```

The `newapp` script also sets the correct permissions for all the files and directories it generates. Web2py defines a folder structure for its applications. Subfolders containing *source files*, namely “controllers”, “languages”, “models”, “modules”, “private”, “static”, “views”, are symlinked to the target directory where the application is deployed, while other directories with *runtime generated content*, namely “compiled”, “credentials”, “databases”, “errors”, “sessions”, and “uploads” is directly copied from the skeleton.

Consistency of settings. The `sanitycheck` bash script written in Python allows checking at any time if the configuration of Web2py and Apache are in sync because with manual edits it is relatively easy to break something. Besides the macro `Web2PySSL` it supports also a variant `Web2PySSLwww` which defines an Apache configuration for a site which should be served from the 'www' subdomain of the second level domain. The script reveals if there is a 1:1 relation between sites defined in Apache to Web2py applications defined in Web2py routes. If a configuration is missing on either side, it gets reported.

```

#!/usr/bin/env python
variables = {}
execfile( "/opt/web2py/routes.py", variables )
web2py_routes = variables["routers"]["BASE"]["domains"]

from os import listdir
from os.path import isfile, join

confdir = join("/", "etc", "apache2", "sites-enabled")
print "using confdir %s" % confdir

apache_sites = dict()
for f in listdir("."):
    fil = join(confdir, f)
    if isfile(fil):
        with open(fil) as fl:
            first_line = fl.readline()[:-1].split(" ")
            if first_line[0] == "Use":
                app = len(first_line) > 3 and first_line[3] or None
                if first_line[1] == "Web2PySSL":
                    apache_sites[first_line[2]] = app
                elif first_line[1] == "Web2PySSLwww":
                    apache_sites["www.%s" % first_line[2]] = app
            else:
                print "skipping %s" % f

okays = []
errs = []

for wkey in web2py_routes.keys():
    if wkey in apache_sites.keys():
        if web2py_routes[wkey] == apache_sites[wkey]:
            okays.append("%s - OK" % wkey)
        else:
            errs.append("%s - DIFFER %s VS %s" % (wkey, web2py_routes[wkey], apache_sites[wkey]))
            del apache_sites[wkey]
    else:
        errs.append("%s - NOT IN APACHE" % wkey)

for akey in apache_sites.keys():
    errs.append("%s - NOT IN WEB2PY" % akey)

for a in okays:

```



```

    print a
if errs:
    print "-----ERRORS-----:"
    for a in errs:
        print a

import sys
sys.exit(66)

```

Pickup scripts. Further, we created a set of scripts which pack directories containing source files of a Web2py application into a Tar GNU Zip archive, securely uploads them to the server using the `scp` command based on SSH, and via `ssh` remotely calls the relevant application-specific `pickup` script on the server, generated by the `newapp` script. The `pickup` script unpacks the received archive, replaces with them the current sources, and compiles them.

Development environment scripts. We created a similar set of scripts which help to start the development of a new Web2py application on the side of the development device. First, the developer has to create a new PyDev project in the Eclipse environment. Then, he calls a script `mknew`, which populates the newly created project with our version of Web2py scaffolding application. The script also adjusts Web2py routes, generates configuration file `appconfig.ini` used by Web2py to define application parameters, adjusts `pydevproject_template` file, so the PyDev will include the relevant libraries in its environment, and generates `commitme` scripts which allow the developer to upload the application to the deployment server. The `mknew` script uses similar techniques described earlier, such as duplication of a skeleton directory structure and replacing variables in template files.

Straightforward deployment as a result. The set of the shell scripts described above makes deployment and upgrading of a Web2py application very easy. Only two steps are needed to start developing a new application. First, to create a new PyDev project in Eclipse and second, to run the `mknew` script. To set-up the deployment environment for the newly created application on the server, the `newapp` script will do the whole job. And to upload sources to the server, the `commitme` script is all that has to be invoked. Maybe it would not have been necessary to create the scripts just for the purpose of the usability trial. But because of the potential of the whole proposed system, we wanted to make it easy-to-replicate, so a burdensome deployment process won't hinder its future growth.

13.4 TESTING TABLETS

At the pre-development stage, when we also started planning for the usability testing, we had to think about a device on which participants of our trial would be testing the software. Because we were planning to involve primarily people with no or very limited previous experience with smart electronic devices, we knew, that we would be needing a device which we could provide them and based on the expected number of participants we have also decided, that we would be needing at least 5 pieces.

So, we performed *market research* to identify a suitable device. After surveying about parameters of mobile electronic devices at the time, we have decided for tablets with a good quality *display* of size about 10" (to increase chances that even users who are vision-impaired would be able to see well), reasonably fast (so users won't be bothered with poor response times), with a reasonable *storage* (mainly for caching of contents for offline mode), with sufficiently loud *speakers*, and with sufficient *connectivity* support. We wanted to have enough



Figure 58: Tablet for usability testing

options to connect the tablets to the Internet, so we put in the list of requirements both Wi-Fi 802.11 a/b/g/n, and FDD-LTE with support for the band B20⁹⁹. We have also decided to stick to devices with a recent version of the Android operating system, at least a version 6, or preferably 7. Newer versions of the system have better battery-management, which is also a very valuable feature because we wished to reduce hassles with charging. They also provide support for new technologies, such as Google services, which might be needed since a certain point of the development or testing.

Soon we found out, that devices which would meet our criteria are quite expensive on both Czech and a broader European market. Because funds for our research were limited, we surveyed further to find an affordable source. After checking prices worldwide, we focused directly on OEM manufacturers. Soon we found out, that unlike to the situation on the smartphone market, where it is easy to find phones with support for B20 FDD-LTE, tablet options are much more scarce. Among many, we revealed two Chinese candidate companies whose products seemed to meet all our technical criteria and able and willing to provide CE certificate required for import on the EU market. We have chosen the better out of the two, ordered five pieces, paid. The parcel has arrived, tablets were present. But the story was not over. Soon we have found out, that the tablets do not actually support B20 FLL-LTE band. After subsequent negotiations with the supplier, he admitted his fault and agreed to send another batch of tablets with a discount as a compensation for the troubles. The tablets from both batches look almost identically as shown in the Figure 58. Regarding their parameters, they have capacitive 10,1” 1920x1200 IPS screen, 64-bit 1.3 GHz octa-core CPU MT6753, 2GB RAM, 32GB internal storage, Android 7.0.

So, another five pieces have arrived. Testing with the MTK Engineering Mode (TheMonster, 2016) application confirmed that the tablets support B20 band, *but* they were still not able to connect to the local 4G network. Figure 59 demonstrates the problem. We used a mobile phone as a reference. As you can see in the first picture, the mobile phone connects to the LTE normally, whereas the tablet is connected to HSPA, which is a 3G technology. The second picture provides more technical details. It shows, that both devices declare support for band 20. The phone is connected to the LTE with EARFCN¹⁰⁰ 6300, which matches with B20. Neither the telecommunications operator's technical support nor the manufacturer was willing or able to provide assistance which would help us to identify where exactly lies the cause of the incompatibility.

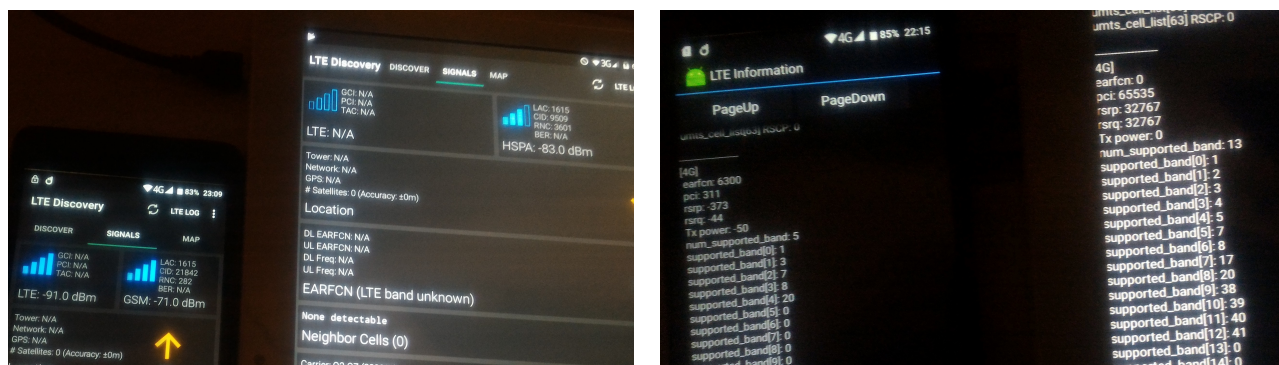


Figure 59: Tablet not able to connect to the LTE network

To not get stuck with a technical problem which was not directly related to the topic of our research, though we wanted to perform our trial on devices with 4G support, we have decided to just move on with the 10 tablets we have got.

Preparation and installation steps. According to Kazimi from Breezie quoted by Sherwood “*When you take a tablet out of the box, there are 43 different settings you need to do to make it senior-friendly. These include the timeout on the screen, brightness, touch sensitivity, predictive text on the keyboard. There’s a ton of simplification that can be done.*” (Sherwood, 2015) Though we did not do it to the same level of perfection

⁹⁹ FDD-LTE band B20 operating on frequency around 800 MHz is used by the telecommunications operators in the Czech Republic and in many other EU countries to provide a 4G Internet connection.

¹⁰⁰ EARFCN stands for E-UTRA Absolute Radio Frequency Channel Number. Refer to (RF Wireless World, n.d.) for further details.

which is necessary for a real product, we also performed several steps before giving a tablet to a user for testing. We summarise the steps below:

1. *Unboxing.* The device has to be removed from its package, charged if the battery level is too low.
2. *SIM installation.* If there is no Wi-Fi Internet connection at the place where the person who will be using the tablet is living, it is necessary to install a SIM card with a proper data-enabled plan.
3. *Screen protector.* The devices arrived with an unprotected screen; we had to attach the provided supplementary screen protector. It is a relatively tricky process, especially if we do not have access to a dust-free environment.
4. *Screen lock.* As a default, Android devices are secured with a screen lock. We had to disable it in Settings → Security → Screen lock → None.
5. *Display settings.* We also had to adjust the default display settings, namely: Display → Sleep → 10 minutes, Display → Press power button twice for camera → Disable, and Display → Screen saver → Disable.
6. *Localization.* In Date & Time we had to pick the correct time zone and 24-hour format. In Languages & input-Languages we had to install the desired language.
7. *Notifications and interruptions.* We wanted to disable as many distractions, as possible. So, we adjusted Notifications → Configure Notifications → On the lock screen → Don't show notifications at all, and Interruptions → Don't disturb. Note – it might be better to disable notifications altogether, perhaps, at the system level.
8. *Internet.* We had to configure the device to connect to our local Wi-Fi network to perform the following steps. It involved choosing the correct network SSID and filling-up the appropriate password.
9. *Google account.* For each user involved in our trial, we created a new Google account. It was necessary to access Google Play store to install certain required applications, namely Chrome, to keep the device updated, to enable automatic back-up of the device settings, back-up of credentials needed to access our system for the first time, to use Google services¹⁰¹, and in general, to benefit from Android system fully. Accounts → Add account → Register new Google account. To be able to provide the correct information we had to know the full name and birth date of the user in advance.
10. *Install applications.* Then, we accessed Google play and installed Chrome browser and AutoStart - No Root (Guro Labs, n.d.) applications.
11. *Autoplay policy.* Then, to allow automatic playback of embedded videos from our YouTube Content Provider, we launched Chrome, navigated to `chrome://flags/#autoplay-policy`, and set it to “No user gesture is required”.
12. *Back-end account.* Next step was to access the back-end management interface and create a new user account. It requires us to know the name, and an e-mail (the one we created for the Google account in one of the previous steps). As soon as a new account is created, still in the management interface, we have chosen and assigned content providers to the account. This step does not have to be performed on the tablet, but any device may be used. The credentials created in this step will be needed later.
13. *Install the viewer.* Back on the tablet, we navigated with Chrome to the viewer default page. The browser automatically offers “Add to Home Screen” as a pop-up dialogue. So, we accepted the offer. Alternatively, in the case the dialogue won't appear, it should be at least possible to click “Add to home screen” from the Chrome menu. The application should be available from the home screen from now on. Chrome may be closed now.

¹⁰¹ Currently, our system does not depend on Google services. But in the future, some of the planned functions will need access to, e.g. a localisation service.

14. *Log-in.* Now, the application has to be launched from the home screen. A log-in dialogue appears. We fill up the user's credentials created in the “Back-end account” step. The browser offers to save the password; we did so. An initial welcome screen defined by the system provider appears. It means everything went well so far. We may close the application.
15. *Autostart.* We wanted the application to start automatically if the device boots up. So, we had to launch the AutoStart application installed earlier, and add our progressive web application in the list of applications set for an automatic start. To make the settings effective, “auto startup” switch has to be turned to ON.
16. *Clean-up.* As the last step, we organised the icons, so only our application would be present on the main home screen. From the main home screen, we removed even the default icons for calls, contacts or camera, so they won't bother the user if he somewhat accidentally accesses the home screen.

In addition to the steps summarised above, if we planned to connect the device via an available Wi-Fi at user's place, we had to set-up the Wi-Fi details on the tablet.

13.5 DEPLOYMENT FOR PRODUCTION USE

Server deployment. For the production deployment, it would be better to use dedicated devices, as shown in the following deployment diagram in Figure 60. The example illustrates that for front end and back end we could deploy a load-balancing machine, which would be responsible for dispatching of incoming requests to servers running as a farm. For the storage, we might involve load-balancing dispatcher for the database requests, a master database for write queries from which the changes would be replicated to slave databases used for reading queries. Another alternative would be to use cloud technologies.

Client devices. The tablets we used during the trial do not have fully functional support for 4G *connectivity*, which is unacceptable for production. They use the standard *micro USB* connector for charging. It might pose a problem for some users who do not see well or whose tactile skills have worsened. What makes micro USB connector even less practical for seniors is the fact that it is not symmetrical. It would be nice to have a charging stand instead. The stand should be stable. It may be relatively massive. Another option would be to choose tablet which supports wireless charging. As the trial has revealed, the tiny power-on/off and volume control *buttons* on the edge of the tablets are difficult to operate for some.

Device management. Though, none of the steps which have to be performed to prepare an Android device for the use of the application is difficult, though, for production, most of them should be automated. Automating some of the steps would be relatively easy. Other steps would require close coordination with the device manufacturer. For some of the desired adjustments, the manufacturer would need an appropriate service agreement with Google. A complicated step not just technically, but also from the legal point-of-view, is the creation of Google user accounts. On one hand our system does not directly require a valid Google account on the device from which it is being operated, or at least not at its current state, but on the other hand not having the device set-up with a proper Google account variety of complications would arise. For example, it would require more work on our part to keep the system up-to-date with security patches applied. Breezie, described in 4.2.4.2, may serve as an inspiration.

Scalability. To increase scalability, we might consider also distributed deployment. Good source of inspiration is the concept of loosely-connected and locally-managed so-called 'pods' serving as a backbone of the diaspora* project (The Diaspora Foundation, n.d.).

Besides the matters related to the system itself, more has to be secured to deploy such a complex product successfully. Keystone Technologies share their experience with deployment of computers system in elderly-care environments (Keystone Technologies, 2018). They consider the following areas as critical determinants of success. We picked three out of four recommended, and adjusted them to fit our system better:

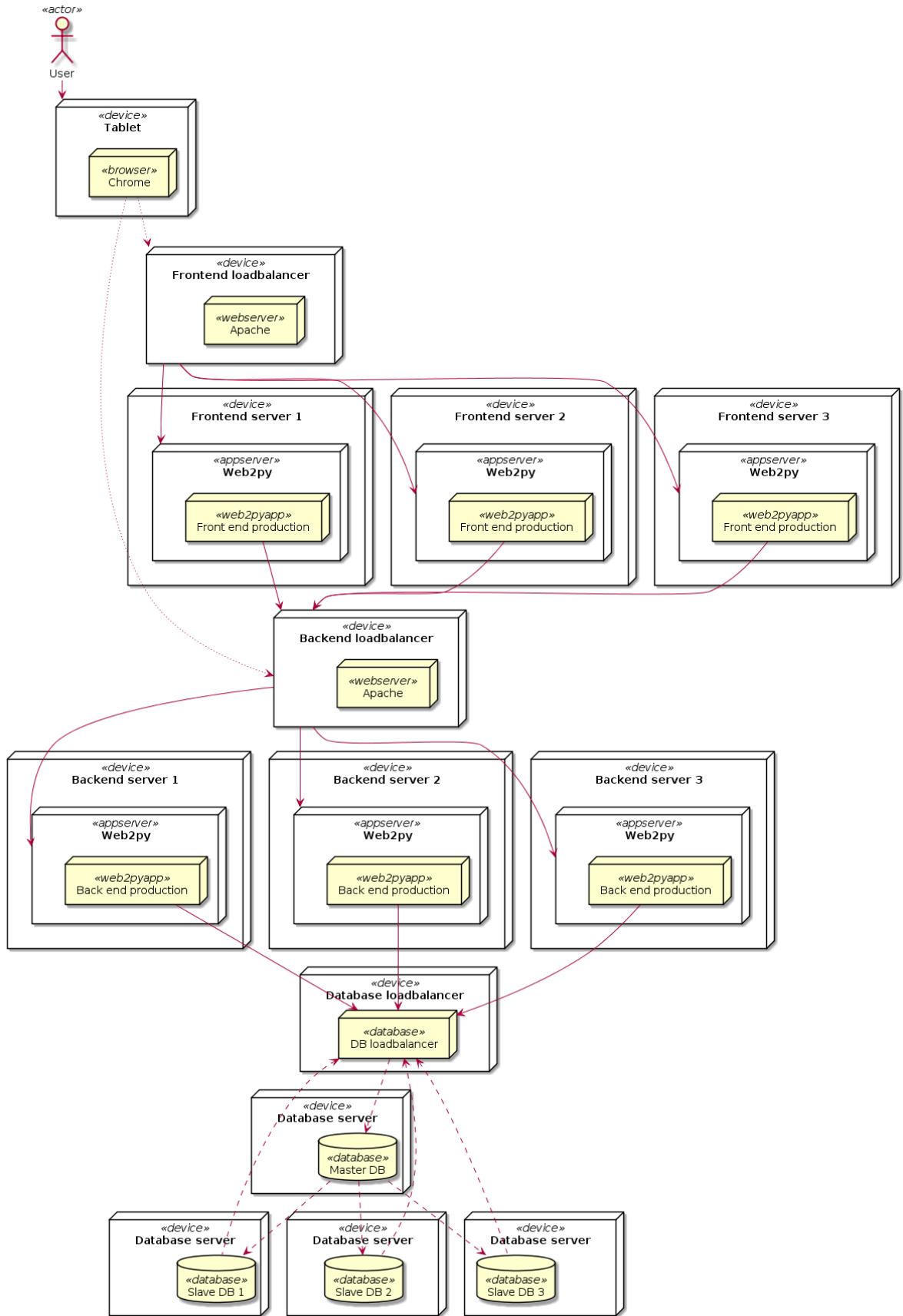


Figure 60: Deployment example for the production use

Education. Users must be educated about the system its benefits and how to use its functions successfully. It requires the elderly-care provider to make a conscious effort to offer on-site lectures or hands-on practice sessions for beginners. It may include either the technical aspects, such as how to operate the device and the software, and also soft skills, such as how to stay safe online, how to use the technology to build and keep valuable relations, or about risks of digital addiction. It may also include training for more advanced user about topics such as how to create their own content. Instructional groups may have an additional positive effect in improving feelings of connectedness.

Staff. Assuming that the recreation staff at the provider will automatically adopt a new technology is not realistic. Ideally, there should be a well-trained support staff member available to lead training and offer individual support to residents. This dedicated person will assure that residents are educated, confident, and accessing online content throughout their time. Even better, the person is available and willing to ask any technology questions which may arise from residents, other staff, or family members.

Connectivity. The computer network must be able to support the additional online traffic that residents may induce. Additional infrastructure may be needed to provide sufficient Wi-Fi coverage. Other systems which require stable bandwidth must not be affected. Relevant regulations have to be considered as well, such as HIPAA¹⁰² in the US, or GDPR¹⁰³ in the EU.

102 The Health Insurance Portability and Accountability Act of 1996 (HIPAA), Public Law 104-191, was enacted on August 21, 1996. Sections 261 through 264 of HIPAA require the Secretary of HHS to publicise standards for the electronic exchange, privacy and security of health information.

103 The General Data Protection Regulation (EU) 2016/679 is a regulation in EU law on data protection and privacy for all

14 APPENDIX D – PRINTED TOOLS FOR THE IN-DEPTH USABILITY TEST

The plan for the introductory meeting with the usability trial participants and the sheet used for the assessment meeting are attached below. The materials were very simple, because the meetings were conducted by the author himself.

Úvodní setkání (předpokládaný čas: 45 minut)

Délka setkání a jednotlivých bodů je stanovena orientačně, není nutné striktně ji dodržet.

Je možné pořizovat poznámky, ale pouze v takové míře, jaká nenaruší plynulost rozhovoru.

Po návštěvě bez odkladu podrobně poznamenej veškeré poznatky.

- *Neformální seznámení* (cca 15 minut)

Pokládej přátelské otázky, snaž se navázat vztah, získej celkovou představu o potřebách, zájmech a omezeních.

- *Semi-strukturovaný rozhovor* (cca 15 minut)

Shromáždí demografická data – věk, rodinný status, bývalé zaměstnání.

Dále se ptej se konkrétně na (1) zdraví, (2) rodinu, (3) digitální technologie.

Možné otázky pokud jde o digitální technologie:

- Používáte mobilní telefon? Jaké jeho funkce?
- Jak přijímáte informace - sledujete televizi, čtete noviny, posloucháte rádio?
- Co vám říkají názvy jako Google, Facebook, Twitter, nebo Instagram?
- Jak hodnotíte svoji schopnost zacházet s počítači, chytrými mobilními telefony a podobnými věcmi?

Možné doplňující otázky:

- Co si o tom myslíte?
- Co se vám na tom líbí a co ne?
- Jak se v souvislosti s tím cítíte?
- Co byste v souvislosti s tím rád(a) změnil(a)?
- Proč? (i opakovaně)

- *Představení prototypu* (cca 3 minuty)

Stručně popiš účel aplikace a předveď. Zeptej se na první dojmy.

- *Instrukce* (cca 4 minuty)

Předej zařízení účastníkovi, umožni mu zkusit ovládání.

Poskytni instrukce ohledně nabíjení, zapnutí a vypnutí displeje a zapnutí a vypnutí celého tabletu.

Je-li to praktické, hlavní instrukce společně napište na list papíru.

- *Zkoušení* (cca 5 minut)

Nech účastníka, ať zkusí program používat a ať se ptá, je-li cokoliv nejasné. Ujisti ho, že nemusí nic platit a naopak, že jeho spolupráce je velmi cenná.

- *Další kontakt* (cca 3 minuty)

Vyměň kontakty. Předej pokyny, kam se obrátit o pomoc. Domluv závěrečné setkání.

Závěrečné setkání (předpokládaný čas: 30 minut)

	Funkce	Obsah
Líbí		
Nelíbí		
Pocity		
Návrhy		