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Master's Thesis

Impact of Implementing IoT-Based Smart Home Devices on Quality of Life among Senior Citizens

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DIPLOMA THESIS ASSIGNMENT

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Thesis title

The Impact of Implementing IoT-Based Smart Home Devices on Quality of Life among Senior Citizens

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Objectives of thesis

This thesis aims to contribute to the understanding of how IoT-based smart home devices can improve the quality of life among senior citizens.This study will provide useful insights and guidelines for the development and implementation of IoT-enabled smart home devices tailored to the needs of the elderly population by addressing the research objectives of research design, integration difficulties, moral and privacy issues, impact evaluation, and suggestions for improvement. IoT technology has the potential to positively tranform the lives of seniors by enabling them to age in place with greater comfort, independence, and well-being in general through smart design, ethical concerns, and user-centered methods.

Methodology

The methodology of the work consists of both quantitative and qualitative methods, whereby a mixed-methods research design will be employed to comprehensively investigate the impact of implementing IoT-based smart home devices.

The qualitative part will offer insights into the participants' subjective experiences and views, while the quantitative aspect will concentrate on evaluating the quality of life's objective indicators.

The outcomes of this study will be utilized to create a prototype gadget that can precisely track movement and send out alarms as necessary. Finally, a small group of elders will test the prototype to determine its effectiveness.

The proposed extent of the thesis

60-80

Keywords

Internet of Things (IoT), smart home devices, smart health, personal information, movement measurement, senior monitoring, home automation, home care assistance, wearable sensors, automated alerts, remote assistance, health-related quality of life

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Declaration

I declare that I have worked on my master’s thesis titled "Impact of Implementing IoT-Based Smart Home Devices on Quality of Life among Senior Citizens" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the master's thesis, I declare that the thesis does not break any copyrights.

In Prague on ______________________________

Acknowledgement

I would like to express my sincere gratitude to my supervisor for his guidance and continuous support throughout this research. Their expertise and insights have been instrumental in shaping the direction and scope of this thesis. I am also grateful to the participant who generously shared their time and experience, without whom this study would not have been possible. Finally, I would like to thank my family and friends for their unwavering support and encouragement throughout this journey.

Impact of Implementing IoT-Based Smart Home Devices on Quality of Life among Senior Citizens

Abstract

The thesis explores how IoT-based smart home devices can improve the quality of life for senior citizens. It covers various aspects such as the historical background, significance, security, sustainability, and power efficiency of smart home technologies (Jyothi et al., 2017). The objective of the thesis is to analyze the living conditions of elderly individuals and create a prototype that enhances their comfort, independence, and well-being.

It discusses the principle of IoT work, its evolution, and its potential to enhance industries such as healthcare, transportation, and agriculture. IoT devices can utilize AI to learn and improve data collection and processing, leading to more efficient systems. However, the use of IoT-based devices also poses security risks that need to be addressed.

Despite the security concerns, smart technologies can greatly benefit senior citizens. IoT devices can assist with daily tasks, monitor health and safety, and provide social connections. These devices can help seniors maintain their independence and improve their overall quality of life.

In conclusion, by highlighting ongoing research efforts that aim to address the limitations of IoT systems and contribute to the development of secure, efficient, and ethical IoT systems. The goal is to create IoT prototype that is not only beneficial but also safe and reliable for senior citizens.

Keywords: IoT (Internet of Things), Smart home, Senior citizens, Indoor air quality, Data analysis, Sensor technology, Real-time monitoring, Elderly care, Regression analysis, Correlation coefficient

Vliv Implementace Zařízení pro Chytré Domácnosti Založené na Internetu Věcí na Kvalitu Života Seniorů

Abstrakt

Práce zkoumá, jak mohou zařízení pro chytrou domácnost založená na internetu věcí zlepšit kvalitu života seniorů. Zahrnuje různé aspekty, jako je historické pozadí, význam, bezpečnost, udržitelnost a energetická účinnost technologií chytré domácnosti. Cílem práce je analyzovat životní podmínky starších jedinců a vytvořit prototyp, který zvyšuje jejich pohodlí, nezávislost a pohodu.

Pojednává o principu práce IoT, jeho vývoji a jeho potenciálu zlepšit průmyslová odvětví, jako je zdravotnictví, doprava a zemědělství. Zařízení internetu věcí mohou využívat AI k učení a zlepšování sběru a zpracování dat, což vede k efektivnějším systémům. Používání zařízení založených na internetu věcí však také přináší bezpečnostní rizika, která je třeba řešit.

Navzdory bezpečnostním obavám mohou chytré technologie výrazně prospět seniorům. Zařízení internetu věcí mohou pomáhat s každodenními úkoly, monitorovat zdraví a bezpečnost a poskytovat sociální spojení. Tato zařízení mohou pomoci seniorům udržet si nezávislost a zlepšit celkovou kvalitu života.

Na závěr zdůrazněním probíhajícího výzkumného úsilí, jehož cílem je řešit omezení systémů IoT a přispět k rozvoji bezpečných, efektivních a etických systémů IoT. Cílem je vytvořit prototyp IoT, který bude nejen přínosný, ale také bezpečný a spolehlivý pro seniory.

Klíčová slova: IoT (Internet of Things), Inteligentní domácnost, Senioři, Kvalita vzduchu v interiéru, Analýza dat, Technologie senzorů, Monitorování v reálném čase, Péče o seniory, Regresní analýza, Korelační koeficient

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1 Introduction

In the era characterized by a rapid technological progress and an aging population demographic, the confluence of these two contemporary phenomena offers both challenges and opportunities for society (Larson, 2003). With a growing number of seniors living solely, has made it more important than ever to protect their safety, health, and quality of life. Indoor air quality stands out as a crucial aspect in determining the general living conditions of elderly people, even with the multitude of factors that affect their health and comfort. The importance of indoor air quality for senior citizens cannot be overestimated (Bluyssen, 2013).

As older citizens spend a substantial amount of time indoors, especially in their homes, the physical health, cognitive function, and emotional stability are all directly impacted by the quality of the air they breathe (Bluyssen, 2013). However, there are particular difficulties in reducing the hazards connected to indoor air pollution, particularly for those who live alone or have limited social support.

Addressing this issue involves Innovative strategies with the use of cutting-edge technologies to monitor, assess, and optimize indoor environments. In this sense, integrating Internet of Things devices into smart home ecosystems presents viable methods to improve senior adults’ quality of life (Li et al., 2024). IoT-enabled devices can potentially identify and reduce indoor air pollution, offering healthier and more comfortable living conditions for senior citizens, by utilizing sensor technologies, data analytics, and real-time monitoring.

This thesis aims to examine the transformative potential of IoT-based smart home devices in enhancing the quality of life for senior adults with an emphasis on indoor air quality management (Bluyssen, 2013). By thorough investigation the correlations between important environmental factors like temperature, humidity, and carbon dioxide levels, this study intends to find insights that can guide both the creation and implementation of effective remediation methods.

By combining empirical research, data analysis, and statistical modelling, this thesis aims to add to the expanding body of knowledge on Internet of Things applications in elderly care and indoor air quality management (Li et al., 2024). Through highlighting the impact of IoT technology on the health of senior citizens, this research aims to contribute to the advancement of new technologies, caregiving strategies, and policies that will improve the quality of life for seniors in a world that is ever more digitally and interconnected.

This study essentially emphasizes how important it is to place the older population's health and comfort first by developing creative solutions that make use of IoT technologies. Adopting a comprehensive strategy for eldercare that incorporates smart home technologies can enable elders to age in place with dignity, autonomy, and comfort (Jyothi et al., 2017).

2 Objectives and Methodology

2.1 Objectives

This thesis aims to contribute to the understanding of how IoT-based smart home devices can enhance the quality of life among senior citizens. This thesis will give an overview of the useful insights and guidelines for the development and implementation of IoT-enabled smart home devices designed for the needs of the elderly population. The thesis aims to define the concept of the Internet of Things, provide a historical background of its emergence, the principle how the IoT works, technologies for making the appliances affordable, purpose of the IoT-based networks creation. Besides, this work covers the idea of the smart home technologies and gives an overview of its significance, security, sustainability and power efficiency, implementation of the IoT-based technologies in the healthcare sector, media and in a regular living condition (Jyothi et al., 2017).

The idea of this thesis is to attempt the integration of the smart technologies to the apartments where senior people live due to that fact that senior people who tend to stay home alone on a regular basis, pay less attention to potential risks around them. IoT technology has the potential to transform the lives of seniors in a positive way. It can provide a place with a greater comfort, independence, and well-being in general through smart design, ethical concerns, and user-centered methods.

The purpose is to analyze the living conditions of the old person: measure the level of carbon dioxide (CO_2), humidity level, and the temperature in the room where the old person spends most of their time. Simultaneously, gather the data on the regularity of the window being open throughout the day, and the weather conditions outside – temperature, humidity and the wind speed outside. The issue is that the higher the level of concentration of the CO_2 in the room, the more threat to the health of the person. A moderate concentration can cause breathing difficulties, however, at the higher levels – it might cause to death. This is why opening the window on time and ventilation are crucial. The selected data period is from October 1st, 2023 to January 31st, 2024. To address these issues, it is essential to state hypotheses:

- **H1**: The level of CO_2 is dependent on the temperature inside the room.
- **H2**: The level of CO_2 is independent from humidity level inside the room.
- **H3**: Given the window open, helps to decrease the level of carbon dioxide in the room.

In order to respond to these objectives, the research will be conducted, and a small experiment takes place. One of the sensors is installed in the bedroom of the old lady, which will show all the above mentioned data and how often the old lady opens the window daily. As a result of this experiment, the prototype will be drafted and created in order to improve the life quality of the elder people.

After addressing the research objectives, integration difficulties, privacy issues, impact evaluation, and suggestions for improvement will be discussed and summarized.

2.2 Methodology

The methodology of the work consists of both quantitative and qualitative methods, whereby a mixed-methods research design will be employed to comprehensively investigate the impact of implementing IoT-based smart home devices. The qualitative part will offer insights into the participant' subjective experiences and views, while the quantitative aspect will concentrate on evaluating the quality of life's objective indicators.

The thesis contains theoretical and practical parts. Theory implies a general information about the IoT-based technologies, particular research, and investigation of the systems. Whereas the practical part provides a deeper understanding by analyzing the collected data with the use of the statistical methods and regression analysis to find the correlation between the two variables, and dependence of each of the selected data points to each other. Another method which is used is informatics approach to create the flow chart of the potential prototype, which is intended for the integration to the senior people's rooms in order to ensure a better quality of life.

The outcomes of this study will be utilized to create a prototype gadget that can precisely track the air quality levels to mitigate the potential risks (Larson, 2003). It will also send the alarms to the respective providers or caregivers in case of emergencies. Finally, a small group of elders will test the prototype to determine its effectiveness.

3 Literature Review

3.1 Definition of IoT

Internet of things (IoT) is a technological advancement which became popular over the past decade. Nowadays it is possible to connect objects of everyday use – webcams, cars, thermostats, kitchen appliances, laptops, baby monitors, home security systems and other gadgets (OECD, 2023). In simple words, IoT is a network of the devices connected to each other through the wireless means, which allow to exchange the data in between. This connectivity allows for the collection and exchange of data, enabling objects to interact and perform tasks more efficiently (Yager & Espada, 2017). IoT devices are typically equipped with the special software or sensors and might contain the mechanic and digital machines and objects (Yacoub, 2017). Such devices can easily be controlled from one point – either remote controller or mobile app.

More and more industries and organizations tend to switch to IoT based technologies in order to operate in a more efficient way, provide an advanced customer experience, improve and speed up some of the processes, hence, enhance the value of business.

Due to the emergence of the IoT, the data is easy to transform over the network, e.g. Bluetooth or Internet, with no human-to-human interaction and even minimal human interaction with computer. Physical things can gather and share the data with no human interaction as they record, analyze and adjust each interaction between embedded devices (OECD, 2023). The key concept in the IoT is the ability of objects to connect to the internet and communicate with each other. This is where the physical world meets digitalization, hence, cooperate with each other.

Such term "thing" can refer to a wide range of objects, including gadgets, transportation systems, animals, and even people. Cars and engines which are equipped with the special sensors are subjects of IoT (Al-Turjman & Lemayian, 2020). These sensors can provide a real-time information to the driver, such as tire pressure. Human and animals are subjects to become a part of the Internet of Thing only when there is a monitor or a chip which allows to support their vital activity. Examples of this include heart implants or biochip transponders.

All in all, the IoT can encompass a vast amount of objects and technologies which provides a connectivity and a data exchange (Yager & Espada, 2017). By integrating detectors and connectivity to various objects, the IoT has a potential to enhance numerous industries and domains, including healthcare, transportation, agriculture, and others.

3.2 Historical background

First, Internet of Things has been mentioned in 1999 at the presentation to the Procter & Gamble by the co-founder of the Auto-ID Center at the Massachusetts Institute of Technology, Kevin Ashton. He called his presentation as "Internet of Things" in order to make a reference to the new trend Internet itself (Karen et al., 2015). The idea of the presentation was to bring the radio frequency to the attention of the P&G management. Even though, he was the first who mentioned the term of IoT, the concept of interconnected devices has been discussed around since the 1970s, under the monikers pervasive computing and built-in internet (Karen et al., 2015). In 1999, one of the professors at the Massachusetts Institute of Technology, Neil Gershenfeld described the vision of the IoT in his book "When Things Start to Think" (Gershenfeld, 1999). Despite the fact that it was not an exact same term, the content exactly described the same idea.

The first internet-based appliance was a Coke machine at the Carnegie Mellon University in 1980s. The idea of it was an ability to check the status of the Coke machine online and determine the temperature of the Coke inside – whether there will be a cool enough (Karen et al., 2015).

Over the ages, the IoT evolved, the combination of the wireless technologies, micro- and electro- mechanical systems, services, and internet (Yacoub, 2017). The convergence allowed to merge the idea of the operational and information technologies, thus, enables the disorganized machine-generated data to be analyze with the purpose to bring the improvement. Therefore, IoT is now more about machine-to-machine (M2M) interaction with the limited human involvement (Karen et al., 2015). Now, IoT refers to the cloud connection and the device, which helps to collect and manage the data.

The next level of machine-to-machine communications enable the IoT using the sensor network of a huge amount of the smart devices and gadgets connecting not only applications and computer systems, but also people (Karen et al., 2015).

Besides, the Internet of things enhanced the supervisory control and data acquisition, namely SCADA, as well as the implementation of software applications helping to control the processes by gathering the real time data, and remotely monitor the conditions and control equipment. As mentioned, SCADA systems imply hardware and software. Since the SCADA system is widely used in the industrial processes, the hardware helps to collect data and transfers the data to the laptop in which the SCADA software is already installed (Karen et al., 2015). The software processes the collected data and represents the live results of the industrial machines. The latest generations of the SCADA have been developed into the first generation of the IoT systems.

The idea of the IoT system was not widely used until 2010, when it became a strategic priority of China on the governmental level. It became as a part of the five-year plan (Karen et al., 2015). Thus, between 2010 to 2019, the concept of the Internet of Things grew and found a broader consumer use (Keng et al., 2023). More and more people started to use devices which can connect to the internet. First of all, these were smartphones, then, smart TVs, and later on other smart technologies. All of them could connect to one network and communicate with each other.

The year of 2020 showed that the number of the IoT gadgets and devices started drastically increase along with the cellular communication (Karen et al., 2015). Internet of Things can use not only Wi-Fi, Bluetooth, and near-field communication (NFC) to connect and communicate, but also from 2G to 5G cellular internet, LoRaWAN, and LTE (Majumdar et al., 2023).

Today, there are billions of devices which gather, process, analyze and share the data for consumer and industrial use (Keng et al., 2023). IoT has become a crucial aspect in the emergence of the digital twins: the virtual representation of the real world. The physical representation between the “entity” and the twin can be sensors or a well-configured IoT maintenance is frequently a prerequisite for digital twins.

3.3 The principle of IoT work

IoT is an eco-system consisting of the interconnected smart devices which use inbuilt systems, which might include sensors, communication hardware, processors in order to collect, send and take an action based on the data which is acquired from the current surrounding environment.

Such devices use the Internet Protocol (IP) which identifies the devices globally and allows them to collect and share the data. Gadgets, home appliances, and wearables gather and share the data by connecting to the special network, i.e. IoT gateway, which is represented as the central hub where the data is stored (Aggarwal & Sindakis, 2023). Before the sharing, in order to reduce the bandwidth consumption, the data might be collected and processed by the edge device. The analysis of the data locally at the edge device decreases the volume of the data which is sent to the cloud.

The connectivity, networking and communication are highly dependent on the specific IoT applications. Based on their setup, the devices can communicate with each other and take an action based on the information and algorithm they are provided. Such devices can work with no human intervention, even though people can affect the data while interacting with the devices. People do the installation and setup, give the instructions, and able to access the data.

Moreover, with the development of the artificial intelligence (AI) and its incorporation to the IoT-based technologies, IoT devices can also learn and make the data collection and processing to become more efficient, easy and dynamic (Aggarwal & Sindakis, 2023). AI can help the IoT technology to analyze and interpret data more accurately and quickly. It allows to get a better well-informed decision, and hence, improve performance. For instance, AI-powered IoT devices learning day-to-day behavior from user, can adjust their settings or recommendations respectively, providing a more personalized experience.

Furthermore, AI is able to help to improve the security and privacy of IoT devices by detecting and responding to potential threats or breaches (Rehman et al., 2022). If there are any unusual patterns or anomalies in data, artificial intelligence can assist to identify and mitigate these risks, ensuring the safety and further integrity of IoT systems.

Likewise, the concept of the IoT is widely used in the healthcare, and it enhanced the use of the wearables and home sensors which can remotely affect the patient's health condition. The primary benefit of such technologies is that they are able to represent a real time data.

3.4 Types of IoT

IoT involves various types of continuously evolving technological advancements, aiding for plenty of connectivity options for embedded device producers. Each of those options has its benefits and drawbacks which must be viewed and weighted together. First and foremost, this is an aggregate connectivity of the wireless technology (Yacoub, 2017). Wireless means that all devices are interconnected via routers, sensors, platforms, applications and further systems. Each of the mentioned options has trade-offs between energy consumption, range, and bandwidth. The highest level is represented by the standard wireless options such as cellular and Wi-Fi. The rest are long-range ones represented by LoRaWAN and LPWAN (Majumdar et al., 2023).

Embedded device companies must know the fundamentals of the top IoT-based technologies in order to determine superior non-wire technology option based on business' needs.

There are six major types of wireless technologies used in IoT based systems:

1) Cellular

This is one of the well-known and widely used types of the wireless technology. It is best-known in the consumer mobile market (Keng et al., 2023). The cellular technology provides one of the most reliable broadband access and communication. It supports multi-purpose use – from streaming applications to ordinary voice calls. Due to the fact that cellular is well-established, it has a good coverage and high bandwidth.

Cellular options also work in low-energy environments. Carriers provide Category M1 (Cat M1) and Narrowband Internet of things (NB-IoT), which are also cellular options contending with Low-power WAN (LPWAN) technologies (Majumdar et al., 2023).

This type of wireless technology operates well in low-energy environments, e.g. Cat-M1 (Yacoub, 2017). On contrary, for non-mobile applications where the power is not taken into consideration, cellular type is also a great choice. Implementing the 5G ultra-low latency, wireless connection can effectively maintain the needs of all, such as time-sensitive tasks and real-time status of important activities (Majumdar et al., 2023). For example, industrial automation, public safety, medical data track and delivery.

2) Bluetooth

This is another wide-spread type of connection in wireless technology. Unlikely the cellular one, Bluetooth is a short-range technology used for communication with optimization of energy consumption aimed at supporting small-scale consumer IoT apps (Keng et al., 2023).

Bluetooth as the IoT-based technology is widely used in wearables, security systems, fitness watches, medical devices – all of them can be connected to application in smartphone and communicated. It is a very efficient way of connection, however, only in a limited distance range.

3) Wi-Fi

With the development of the internet connection, there was a need to connect more devices and appliances to one network. Thus, the implementation of it was found in Wi-Fi. Wi-Fi is a wireless provider of the highest throughput data transfer in a certain area (Yacoub, 2017). It can be anywhere home, park, public place, or enterprise. This is another very effective way of communication, even though, again, it has limited scale of coverage as well as higher power consumption in comparison to other means of connection.

The newest firm security practices suggest the primary used IoT devices (laptops, phones, and others) to be added to separate Wi-Fi networks as otherwise, using one IoT system might jeopardize firm’s security (Yacoub, 2017).

The main disadvantage of such system is a constant connection to the power. Due to the high energy requirements, Wi-Fi frequently results as a poor solution for the bigger networks with accumulator-operated sensors, e.g. smart industries and smart office buildings. It requires more energy for the smart building coverage, hence, cannot afford to connect more devices to the same Wi-Fi in order not to overload the network.

Wi-Fi connection is more effective in use of the smart home appliances. The latest version of the Wi-Fi offers a higher speed and improved bandwidth, although still not powerful and secure enough to be used as one single connection. It carries a number of security risks which other options are less vulnerable.

4) LPWAN

LPWAN, low power-wide area networks, is a longer-range way of IoT communication which utilizes smaller and less costly accumulators (Majumdar et al., 2023). In comparison to previous ways of connectivity, LPWAN is an ideal way to support bigger areas for IoT-based networks where a significant coverage is important. A disadvantage of this communication is that due to the low-power consumption, it can send only smaller blocks of information.

This connection perfectly suits for cases which do not need high coverage and time sensitivity, e.g. water meter. It is effective for utilization in asset tracking in production, facility management, and monitoring environment (Yacoub, 2017). The crucial part of this type is standardization. It is significant to ensure the security, inter-operability, and reliability of the selected network. The newest version of the LPWAN gains more popularity nowadays.

5) LoRaWAN

This is a powerful technology similar to Bluetooth. It has a wider range and small data transfer with the low energy consumption. The frequency, data rate and power for all aggregate devices is managed by LoRaWAN. Its detectors communicate through the cellular gateway to forward the data to the cloud with the backhaul report.

The features of the utilization of LoRaWAN are quite similar to those for LPWAN – it has the small-scale coverage and time sensitivity is not important for such data. However, it is a point-to-point non-wire embedding which has no direct internet connection, whilst LPWAN has a direct connection to the internet (Majumdar et al., 2023). The LoRaWAN technology requires a gateway to send the data to the final destination, which is the cloud. Frequently, this connection is LoRa to cellular (Soy, 2023).

In comparison to LPWAN, LoRaWAN sensors or detectors can be deployed over the bigger area. Sensors are simplified and designed in order to forward the smaller data packs with smaller frequency. For instance, it is used in irrigation management, asset management, detection of leaks, logistics management, transportation, and equipment tracking. This type of communication also continues to evolve.

The practical part implies the implementation of the LoRaWAN sensors to the prototype.

6) RFID-IoT

Radio Frequency Identification (RFID) is a kind of communication which utilizes radio frequency signals in order to monitor and track the assets and objects in efficient and accurate ways (Evdokimov, 2010). RFID is a smart system which us equipped with unique identifiers attached to objects in a form of tags, credential badges, wearables, cards, labels, etc. This way of communication allows to exchange the data without wires too, but with no direct internet connection. Instead, it requires a gateway and a connection to cellular to forward the data to the cloud.

One of the areas where the RFID is widely used is supply chain management. IoT plays a crucial role there as it allows to track the status of products online, decrease manual labor and rationalizing logistic operations (Evdokimov, 2010). With the help of RFID tags on goods firms can monitor the volumes and inventory levels, determine bottlenecks and procure the flow of the supply chain with no effort.

Applications of RFID are utilized in healthcare for patient tracking, management of medication, and medical equipment monitoring (Majumder et al., 2017). Hospitals often use equipment based on this technology. Also, some departments provide with RFID wristbands to identify the patients and see their location in order to ensure their safety and well-being. Medications also can be labelled with RFID tags in order to automate the inventory management processes, prevent mistakes, and improve the patient care.

3.5 Technologies making IoT affordable

While the concept of IoT existed for quite long, a constant technological development and emergence of cheaper alternatives for advanced technologies, put that into practice only in the last decade (Ciuffoletti, 2018). The following reasons made it possible to people to access the IoT:

- Access to low-cost technologies and low-energy consumption sensors and detectors made it more affordable for manufacturers to produce the IoT-based technologies (Ciuffoletti, 2018). Hence, the final price of the smart device is lower for customers, making it affordable for more and more people.

- Development of connectivity, as a development of host of network protocols for the internet, the hub, allows to easily connect sensors to each other and cloud for more rational and efficient data transfer.

- An enhancement of cloud computing platforms enables people and businesses to access infrastructure they have to scale up with no actual intervention into its management.

- Ability of machine to learn and analyze the data made it also popular and possible to people to access IoT-based technologies. Due to machine learning and ability to analyze sided with the various data gathered and stored in the cloud, people can collect insights faster and take decisions easier (Ciuffoletti, 2018). The emergence of the advanced interconnected technologies keeps pushing the boundaries of IoT-based and data produced by the Internet of Things also feeds these devices.

- Emergence of the artificial intelligence (AI) enhanced the learning and analyzing processes in IoT-based technologies (Aggarwal & Sindakis, 2023). AI is an advancement based on the neural networking, which brought natural-language processing (NLP) integrated into the IoT appliances. Such devices include a virtual fast-learning assistant as Alexa, Siri, Alisa, etc. AI-based devices are now affordable and appealing for most people, and viable for home use (Aggarwal & Sindakis, 2023). Moreover, it cannot be only as a separate device, but also as a mobile application, which makes it convenient to manage the home-based technologies remotely. The neural network advancement made it also possible the AI in IoT-based system to communicate.

3.6 Purpose of IoT-based technologies

As it was mentioned above, the purpose of the IoT technologies is to embed the objects and devices to the internet allowing them to collect, analyze, share, and store the information and data from the overall or internal environment with ability to manage and monitor it remotely (Jyothi, 2017).

The idea of the IoT technologies is connectivity of all devices, gadgets and appliances in one place. It makes a network of devices, involving integration of remote applications or systems which can be used to control, record, automate, monitor tasks and activities, aiding to increase efficiency and improve the decision making. Therefore, improve the quality of life in the various sectors. IoT-based technologies can potentially transform industries, increase productivity, and provide new opportunities for innovation.

The characteristics of such technologies imply:

3.6.1 Automation and efficiency

IoT facilitates the automation of some processes eliminating human intervention to day-to-day activities. People use IoT-based devices with the purpose to optimize the systems which technically might not need human interaction. Automation is intended to enhance the efficiency and productivity (David, 2023). By connecting objects and devices, the data can be collected, analyze, and utilized to optimize the operational work.

On the one hand, businesses and wide manufacturers which more and more tend to use advanced technologies and robots controlled through the integrated system in order to lower the labor costs. Factories usually automate processes aiming produce more at lower costs. In addition to that, devices are able to monitor and control machinery, analyzing, decreasing the downtime and enhancing the efficiency overall. However, such implementations are long-term investments, requiring less labor but extra investment for service maintenance.

On the other hand, people also tend to automate daily routines. For instance, smart home systems help people spend less time on daily tasks (Jyothi et al., 2017). It is easy to connect regular home appliances and regulate them in one application. It might be and not limited to regulating temperature in house, turning on and off the lights, monitor humidity at home, turn on the vacuum robot, make coffee, etc. remotely.

All in all, automation makes the users to feel safer and comfortable once the IoT system is in charge of their appliances and belongings.

3.6.2 Data collection and analytics

As it was discussed above, the IoT appliances gather the data from such sources as sensors, reles, etc. The collected data can be analyzed in order to get the insights and make better and clearer decisions based on the collected information (David, 2023). For example, the agricultural sector widely uses the IoT sensors to gather the data about the moisture of the soil, temperature of it as well as the climate around, crop health, which helps the farmers to understand and sustain the irrigation and fertilization of the crops.

Analytics is what allows the smart technology to step in on the next level. Analysis is performed based on the data collected by sensors or detectors in various places which makes possible to draw an analysis of various aspects. An example of smart home devices implies such gadgets which allow to measure temperature, humidity, moisture, quality of air, energy and water consumption, etc.

IoT system aggregates the data from all devices and makes an analysis in order to give an instruction to other devices to run or stop. For instance, if the temperature at home falls below 18 degrees, smart application automatically gives instruction to heating system to turn on until the temperature reaches 20 degrees. People gain lots of insights for taking decisions based on analysis performed through IoT systems in order to make human lives feel better.

3.6.3 Monitoring and control

One of the most crucial and interesting aspects of the IoT-based systems is an ability to learn and understand how tasks and processes are working out. The IoT-based technologies enabled monitoring and control of all devices and systems online. It is very useful and helpful in such public sectors as healthcare, traffic controls, control of the weather and environment conditions such as air quality, and energy consumption.

One of the examples of such feature is the principle how the delivery works. People can track location and the current status of the package. Logistics firm has more advanced access to the real time status: except location, logistics company can trace the routes of the trucks and the road conditions to estimate the delivery time. Such companies usually cannot afford to waste time and prolong delivery terms; therefore, they are in constant control on delivery timeframes promised to clients.

In the healthcare, IoT-based appliances can monitor and inform about the current patients' health state, his vital signs and send necessary data and even alerts to the healthcare providers in case of emergencies.

3.6.4 Improved decision making

As a part of the advancement by the IoT-based technologies, the data, which is collected can be showed in the real-time, hence, the analytics performed. It helps the businesses and individuals to take well-informed decisions. As an example, in retail sales, the devices are able to track the levels of the inventory, based on the search, analyze the behavior of the customers and provide the personalized recommendations. All stated above allow to improved customer experience, increased satisfaction, and inclining sales.

3.6.5 Safety and security

Another benefit of the IoT-based technologies is that there is no need to have the manual controls of the fire or gas leaks (Mitton, 2017). IoT devices are intended to improve the safety and security as they monitor the leaks and send respective alerts either to the owners or emergency services. In the industrial sector, the sensors are able to detect hazardous conditions efficiently and trigger the safety protocols respectively in order to prevent the accidents (Mitton, 2017).

3.6.6 Improved quality of life

IoT-based technologies have a good background and shows a promising potential to improve the quality of life for the individuals. As it was mentioned above, the IoT devices are more and more used in the healthcare sector to track the patient’s vital signs remotely (Majumder et al., 2017). It helps to monitor the health of the patients receiving the care from the comfort of their homes.

Another side of it is application of the IoT-based devices in the smart homes, which enables automation of such regular tasks as adjustment of the lightning in the room, temperature, ventilation, providing comfort.

3.6.7 Environmental sustainability

The modern technologies tend to support the environmental sustainability by optimizing the usage of resources and waste decrease. As a part of the energy management, the IoT-based technologies are able to monitor and control the consumption of energy in order to make the use of resources more efficient. Another example of agricultural sector shows that sensors can optimize not only a fertilization and irrigation practices, but also decrease the water use ensuring sustainability of the framing practices.

3.7 Smart home technology

3.7.1 Significance

Lightning, security, kitchen appliances, thermostats, cleaning appliances and other systems can be a part of the smart home technology. These are all IoT-based technologies which can be connected to one wireless network to be manipulated with through the means of mobile application (Yacoub, 2017). All of them can collect, send, respond to the data shared in the central hub with no human intervention into the smart home management system. The pre-installed instructions by the user can eliminate the person's manual adjustments.

3.7.2 Security of Smart Home

One of the biggest concerns of all devices nowadays is security. Smart home technology is not an exception since it is also connected to one of the wireless networks which cannot ensure a complete protection. Nevertheless, IoT-powered smart locks promise to provide a secure and very convenient access control to lock and unlock the windows and doors in the property via smartphone or using a voice control detector.

Even though, 'smart home' is associated with the comfort and easiness of use, one of the main ideologies of a smart home is to ensure the engineering safety of the home and the personal safety of the owners (Mitton, 2017). In order to maintain the safety and security in a smart home, there are IoT sensors, sensors, timers and electrical reles providing:

- protection against leaks – the system shuts off the water supply, if the leak sensors are triggered;
- protection against short circuits in the electrical network by automatically turning off sockets or lamps as part of smart home safety measures;
- fire protection using smoke detectors and an automatic smart home fire safety and fire extinguishing system;
- triggering an alarm to call service.

The system, using smart video cameras, will monitor the perimeter of the house (open doors and windows, garage doors) and the site (gates, gates, fences). Simulating the presence of owners in the premises and the ability to call private security also work to protect against unwanted or illegal intrusion.

Automatic lighting of the area, closing external blinds when the perimeter of the site is violated - this also ensures the safety of the owners in a smart home (Mitton, 2017). The IoT-based technology enables the owners of property (homes, houses, etc.) to monitor the status remotely, receiving a real-time notifications or alerts in case of any issues, as well as control access to their property. Due to the advanced equipment, smart sensors and cameras can detect any suspicious actions and alert the owner sending a notification to a smartphone.

3.7.3 Power efficiency and sustainability

Internet of Things was invented and specializes in optimizing energy consumption. It also promotes sustainability in the smart homes. One of the most frequently used mobile-controlled technology is thermostat (Giusto et al., 2019). It is equipped with the ability not only following the instructions, but also learn user’s preferences, adjusting temperature based on the current environment and conditions, and enabling sufficient savings on energy.

In the similar way, IoT-based lightning can adjust levels of brightness, give a command to the system to close and open blinds or curtains. It happens on automatic basis depending on the levels of natural lights and occupancy. Furthermore, power monitoring technologies give a real time status of the energy consumption, helping owners to take the data into consideration in order to optimize the energy use in efficient manner.

3.7.4 Home automation and convenience of use

Another underlying concern is automation of some home processes. IoT technology assumes home automation as a primary benefit in implementation of smart homes. By connection of different gadgets and appliances, the owner can automate house routines and take a full control over them via the centralized application in the phone.

IoT-based technologies have important implications in the automation of the home: smart technologies now able to learn the preferences of the homeowners and build a strategy of efficient energy use. From the security perspective, it can connect the cameras, locks, doorbells, which can be also controlled via smartphone app.

For instance, Apple has a default application integrated into all Apple devices, SmartHome, allowing to connect and manage various devices around the house. A person can turn on and off all IoT-enabled devices from anywhere. These can imply sensors, thermostats, lightning, locks, TV, etc. (Giusto et al., 2019). Some of them have integrated IoT assistants to help to apply or execute functions via voice commands, which enhances the easiness of use. With the help of automation, such thing as smart lighting can be integrated with smart thermostats to create a more energy-efficient home; or smart security systems can be integrated with smart cameras and doorbells to provide a more comprehensive security solution.

As a bonus, IoT-based technologies can also personalize the home entertainment experience. Smart speakers, streaming devices – can be also controlled remotely via application or voice commands.

3.7.5 Healthcare implementation

Expect business and personal use, Internet of Things technologies can be used in healthcare. There is a huge potential of IoT-based devices to be monitored via smartphone application as a part of the smart homes.

Health is already tracked by the wearable devices with IoT capabilities. If the patient receives the treatment at home, an application can show the data obtained from the fitness trackers, smartwatches, and even collect a data on health state, activity levels, patients' vital signs, medication adherence to provide the real-time data to the healthcare providers, i.e. doctors (Majumder et al., 2017). It assists to monitor people at risk to detect health issues in order to provide a timely solution or intervention. Moreover, there are also IoT-powered medical devices enabling smart dispensers or pumps to activate on time to help people manage the state of the health, monitor conditions in efficient and independent fashion. IoT also supports the tele-medicine and tele-health services, which allows the patients to get the medical consultations, treatment, diagnoses remotely, based on the collected data from the remote examination tools.

IoT-based technologies improve emergency response and disaster management in healthcare settings. IoT devices, such as wearable sensors or location tracking systems, can help locate and monitor patients during emergencies. These devices can also provide real-time data to emergency responders, enabling timely and effective interventions.

The hospitals are more and more equipped with the IoT technologies, which transform healthcare facilities and hospitals into smart environments. Nowadays, the IoT healthcare devices imply medical equipment, smart beds, asset tracking systems (Majumder et al., 2017). It allows to improve operational efficiency, patient safety, and resource management. These devices can automate workflows, monitor equipment performance, and ensure timely maintenance and restocking of supplies.

Another feature which can be provided by the IoT technologies is data analytics. The system can analyze the data using advanced techniques, such as machine learning and predictive analytics. These analytics can identify patterns, trends, and anomalies in patient data, enabling early detection of diseases, personalized treatment plans, and population health management.

3.7.6 Media and entertainment

The IoT also covered the entertainment and media part. Smartphones can connect to different devices, e.g. smart TV and streamline by sharing screen. The smart sharing allows users to manage their entertainment via the smartphone applications and even voice commands (Hallur et al., 2021). IoT-based speakers make music streaming easier and enables media playback controlled by voice only.

Another entertainment regularly met at home are smart theatre systems. IoT basis creates immersive audio-visual experience due to the smooth coordination of lightning, video and audio effects. Taking into consideration the use of the TV, there is also a concept of the Smart TV (Hallur et al., 2021). Such TVs and streaming devices are IoT-enabled devices, allowing users to access a wide range of content from various sources. These devices can also collect data on habits, preferences, and behaviors, enabling personalized recommendations and targeted advertising.

In order to make the media experience better, there are also smart speakers based on the IoT technology to allow users to access media content through voice commands. These devices can also integrate with other IoT devices, such as smart TVs or streaming devices, to provide a seamless media experience.

Virtual reality (or VR) is also one of the modern IoT-based multimedia transformation of the way media content is created and consumed (Hallur et al., 2021). Such technologies are mainly used as the source of entertainment to get 360-degree immersive experiences. It is a new level of engagement and interactivity for people.

Almost all IoT-based devices can collect and analyze the data of the users use regularly, hence, allows the system to generate personalized content, recommendations, advertising, procure the content creation and distribution strategies. Smart advertising is another component of the IoT-based technological advancements. Each user based on their preferences belongs to the specific target audience (Hallur et al., 2021). Target audience is defined by users' location, preferences, behaviors. By this, advertising improves the effectiveness of advertising campaigns and provide more relevant and engaging experience. Content delivery in the real time is another step of the advertisement – delivering the content to the users right at the moment (Hallur et al., 2021).

In addition to that, IoT technologies open new forms of the content creation. People can have new interactive media experiences. These technologies allow to automate the content creation enabling the video and picture edits, content curation on the automatic basis.

3.7.7 Smart appliances and living

The evolution of IoT lead to the development of smarter appliances. People use such technologies for cooking and cleaning – the daily routine which constantly repeats from one day to another. For instance, the robot cleaner can be set and controlled via application and follow the routes configured by the user (Aheleroff et al., 2020). Thus, individuals can skip swiping and even washing the floor for the day. Similarly, smart coffee machine can make coffee based on your preference. Smart device turns on based on the time set, or even and learn when the regular time is for having coffee to heat the water to have coffee prepared on time. Also, one of the interesting inventions is a refrigerator which is able to keep a track of the food inventory, make a list and order the missing positions online, and suggest recipes based on existing ingredients (Aheleroff et al., 2020). Furthermore, washing machines can be a part of the IoT-based network too. IoT helps the washing machine and dryer to measure load size, analyze the fabric type, hence, optimize laundry cycles by saving water and power. Such concepts lay beyond of the ordinary home appliances, and nowadays they are more and more incorporated into the daily aspects of life – transportation, shopping and healthcare.

3.8 Security and privacy issues

Nowadays security and privacy concerns arise more frequently than it was pre-IoT. The Internet of Things has its drawbacks, and the data is vulnerable (Rehman et al., 2022). First of all, the data security. The IoT devices collect and transmit a vast amount of data which implies personal and very sensitive information. The data can be vulnerable to hacking and unauthorized access. It is important to ensure respective security measures such as data encryption, authentication protocols.

Secondly, device vulnerabilities are also a huge concern as IoT services can be susceptible to security vulnerabilities. One of such is a weak password, outdated firmware, or lack of security patches (Alladi et al., 2020). These systems can be exploited by hackers gaining unauthorized access to the devices or the network they are connected to. Regular updates and security audits are crucial in order to address these vulnerabilities and ensure the security of devices.

Thirdly, network security is another concern. IoT devices use Wi-Fi or other cellular networks in order to transmit the data. Despite the fact that there are lots of programs and ways to secure the data, connection to the network cannot ensure a hundred percent security and privacy (Alladi et al., 2020). These networks are very vulnerable to the attacks. Such preventive methods as data encryption and multiple factor authentication can aid to protect the data transferred from the IoT devices to the network.

Fourthly, IoT devices collect and process the personal data, which implies information about location, health data, and behavioral patterns. It is important to understand clear privacy policies and understand which data you give the consent to (Rehman et al., 2022). The personal data should be collected and used in the transparent and lawful manner. The data privacy and anonymization techniques can help to protect the data of the individuals.

Fifthly, the breach of the data or an authorized access to the sensitive information can be easily expose or misused. It leads to the identity theft, malicious activities, and frauds (Alladi et al., 2020). It is crucial to mitigate and respond to the data breach effectively.

Sixth reason is the lack of standardized security protocols and further practices across the different devices and platforms based on the Internet of Things. It can drive challenges. Inconsistent measures to prevent the vulnerabilities can make it tough to manage and secure the IoT-based systems in an efficient way (Alladi et al., 2020). Establishment of the industry-wide security standards and the best practices possible can assist to address these issues.

The last but not the least, lack of the user awareness can be also a potential risk to security. It is an essential part to be educated as most of the security and privacy risks are associated not only with devices used, but also the way the risks can be addressed in order to have them mitigated at all means possible within the shortest period of time (Rehman et al., 2022). The importance of the knowledge of the best practices how to respond to security threats is essential. This can help to protect from the potential attacks, secure devices, take necessary precautions to protect their privacy and security and make informed decisions.

Addressing all these issues requires an advanced approach to involve producers, service providers, users, and policy-makers (Alladi et al., 2020). It implies the implementation of the robust security arrangements, ensuring the compliance, encouraging user education, and fostering collaboration in order to establish industrial standards and best practices.

3.9 Senior people and smart technology

Senior people can benefit from the implementation of the IoT-based technologies. The main challenge is that the older the person gets, it is tough to keep with the technological development pace and adjust to the modern devices.

However, smart technologies can help to make the lives of the senior people much easier in some way. For instance, a simple assistance in the daily routine and tasks (Seven & Dirik, 2023). Old people usually take lots of medication, smart technologies can help reminding them to take a pill on time. Another benefit is turning on and off the lights and adjustment of the thermostat in the room. Old people usually forget to turn off the lights after them, especially when they live alone or spend most of the time alone. This useless energy consumption affects the utility bills. Taking into consideration the utility payments, adjustment of the thermostat also plays a vital role in improving the quality of life (Giusto et al., 2019). Moreover, some smart technologies are able to identify potential risks to the people such as intrusions, fire and gas leaks, sending the alerts and notifications to the caregivers or respective providers to prevent the hazardous situations. For the senior people, it is very crucial due to the fact that elderly usually tend to forget to turn off the gas after cooking, or do not pay attention to potential dangers – such as unsafe sockets, exposed wires and cables, which are signs of the potential hazards.

For the people with disabilities, with serious diseases and on a regular medication, smart technologies enable remote monitoring the safety and health of seniors (Seven & Dirik, 2023). It allows the caregivers and social services to track and quickly respond to the emergency situations. A simple wearable device can send an alert to the healthcare provider to prevent the abnormal situations (Majumder et al., 2017). Smart technology also can make the homes more accessible to the people with mobility or sensory impairments. As an example, the voice controllers and smart assistants can be controlled without the physical intervention.

A very essential to the caregivers and the families who are leaving the senior people alone on a regular basis, smart technologies allow the senior people to stay connected with everyone, even if they are not able to leave their homes (Seven & Dirik, 2023). Such advancements as video conferences and social media platforms can help to communicate with other people and decrease the feeling of the isolation and loneliness.

3.9.1 Implementations and appliances for senior people

There are various implementations and appliances specifically designed for senior people to enhance their daily lives and address their unique needs. As it was mentioned earlier smart home devices as voice articulated assistants, some automized daily tasks can make it easier for seniors to manage their living environment independently (Jyothi et al., 2017). Wearable devices, medications management systems, emergency response systems, smart safety and security systems, and online monitoring of the health state of the seniors – all help the caregivers to respond to the emergencies in a timely manner.

Remote monitoring and GPS tracking are also important for the older people who have such disorders which might lead to the partial memory loss (Pandian et al., 2020). Hence, the person can easily be lost. These devices are usually worn on a daily basis, or attached to the personal belongings, so as providing the peace to the caregivers and families that the senior person is safe. These implementations and appliances are designed to improve the safety, health, and overall well-being of senior people, enabling them to live independently and comfortably (Pandian et al., 2020).

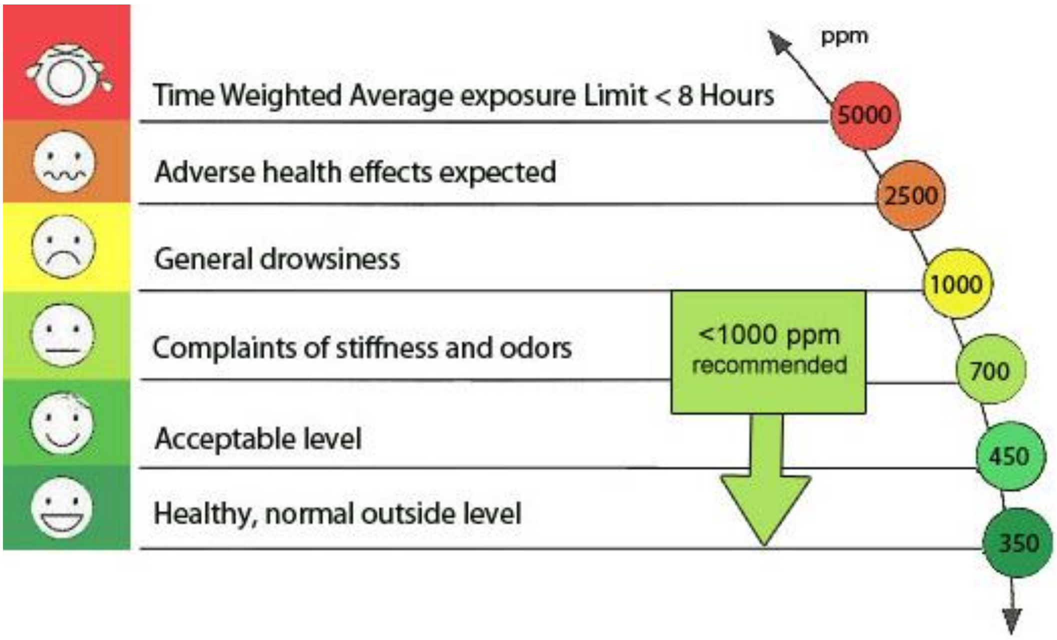
4 Practical Part

4.1 Problematics

The number of senior people in the Czech Republic has been increasing over the years (O'Neill, 2024). In 2022, the percentage of senior people was 20.6%, and it increased to 20.8% in 2023. The average annual growth rate of senior people since 1974 is 0.99% (O'Neill, 2024).

Due to the fact that there are more and more senior people living alone or spend most of the time alone at home, a number of social services take care of them. They typically tend to visit the old people one or two times a week to provide wit food, and necessary assistance and support. Since senior people tend to neglect some of the risks to their health, they do not have a habit to open the windows regularly. One of the reasons why older people do not open the windows regularly is because they are afraid of catching a cold. Any kind of small wind can bring the cold. And the problem is one or two times a week visit is not enough for a senior person to ventilate the room. This can lead to a higher level of carbon dioxide (CO_2) in the room, which can result in serious health problems, and in the worst case, even death.

Picture 1. CO_2 levels explained



Source: Arnovick, 2023.

The level of the CO_2 is measured in ppm (parts per million). If the window is not open for a longer time, the concentration of CO_2 increases and reaches a dangerous level.

To address this issue, a possible solution can be to install detectors to measure the air quality level, especially carbon dioxide level in the room, where the senior person sleeps or spends most of their time. These sensors can monitor the levels and notify the social services and caregivers in case of reaching the dangerous levels. This way, immediate action can be taken to ensure the old people's safety and well-being. By implementing this solution, social services can proactively address any potential health risks and provide timely assistance to senior individuals in need.

The purpose of this thesis is to understand how the IoT-based smart home devices can improve the quality of life of the senior citizens. In order to understand that it was important to gather the respective data. An elder person took a part in the experiment. The old lady lived in the apartment of 34 square meters in total. The room in which she spends most of her time is 12 square meters. The study was conducted from October 1st, 2023 till January 31st, 2024. Due to old lady's health issues, she rarely goes out. As an old person, she occasionally opens the window to ventilate the room she lives in. She opens the window, generally once a day for 5-7 minutes. The apartment has a separate kitchen, and she tends to cook twice a week.

During the study, the thermostat was installed which measured the level of the carbon dioxide in the room, temperature in the room, and its humidity level. The data from the thermostat was sent to the mobile application and tracked from there. Another data was derived from the official database of the weather forecast archives. Then, the data was combined and analyzed in order to determine correlation between the indoor and outdoor environment.

The outcome of this study is intended to be used to create a prototype gadget which can track the environment in the room and outside of it, gather the data, perform the necessary actions, and send out alarms, if necessary.

4.2 Data collection principle

The indoor data was collected by the means of the special sensor installed in the room where the lady spends most of the time, as a part of experiment. This was a bedroom where she sleeps, watches TV, reads books – thus, spends 80% of the time at home. The chosen sensor is Milesight AM103 (Milesight-IoT, 2024). The data was collected and stored in the mobile application. Since installation it gathered the data for four months. The data used for the analysis are: humidity, temperature and level of the carbon dioxide in the room.

The outdoor data has been retrieved from the official weather forecast website Weather Underground, where the data of the temperature, wind speed, and humidity were gathered correspondingly for the selected dates – from October 1st, 2023 to January 31st, 2024 (Weather Portal, 2024).

The main objective of this study is to prove or reject the following hypotheses:

- **H1**: The level of CO_2 is dependent on the temperature inside the room.
- **H2**: The level of CO_2 is independent from humidity level inside the room.
- **H3**: Given the window open, helps to decrease the level of carbon dioxide in the room.

To examine the hypotheses, the potential relationships should be calculated and described:

- CO_2 level inside vs. Temperature inside
- CO_2 level inside vs. Humidity inside
- CO_2 level inside vs. wind speed outside

To accomplish this, a arrange is to utilize a factual strategy known as direct relapse investigation, moreover, known as Ordinary Least Squares Method (OLSM) or basic regression analysis.

Linear regression analysis is a measurable procedure utilized to decide the relationship between two or more factors. In this case, the point is to evaluate whether there is a relationship between the chosen factors. The OLSM is a commonly utilized approach in regression analysis that gauges the relationship between factors by fitting a direct condition to the watched information points.

By applying regression analysis, it would offer assistance to assess the quality and course of the relationship between the chosen estimations. The investigation will give bits of knowledge into whether changes in ones have a critical effect on the others and the nature of this affect (positive or negative).

It is critical to note that direct regression analysis accept a straight relationship between the factors beneath examination. There is a require guaranteeing that the suspicions of direct regression, such as linearity, autonomy, homoscedasticity, and ordinariness, are met for the examination to be substantial.

4.3 Analysis of the collected data

While examining the data, the old lady frequently complained about headaches and general dizziness. According to the data obtained from the detector, the level of the carbon dioxide in the room was at the maximum level of 2,897.82 ppm, the minimum level of 447.22 ppm and average level of 1,555.41 ppm for the whole period from October 2023 to January 2024.

Relying on the *Picture 1* above, the average level of the concentration of the carbon dioxide is in the yellow section, which means that might be one of the reasons of frequent headaches and general health issues. The old lady confirmed that she opens the window for five to seven minutes a day, however, it is not enough to significantly decrease the CO_2 level in the room. What is more, the level of the carbon dioxide is primarily high in the room – there are only two days within the four-month period when the level was more or less acceptable (below 700 ppm).

The minimum temperature in the room for the four-month period was 19.20 ^{o}C, indicating the lowest temperature observed. The maximum temperature that is recorded was 24.97 ^{o}C, and the average temperature is 22.08 ^{o}C. In general, this is a comfortable and acceptable indoor temperature.

The humidity level also stays within the acceptable level at the minimum of 45%, maximum of 67% and average of 57%. Upon the investigation, there is no mold in the apartment, thus, majority of the time, the level of humidity does not exceed unacceptable levels.

Therefore, the biggest concern is the level of CO_2 in the room, which is hazardous.

4.4 Formulas

4.4.1 Regression analysis

The basis of this method is an existence of the dependent and independent variables. The formula is as follows:

$$\boldsymbol{y = bx + a + \varepsilon} \qquad \text{(Formula 1)}$$

where

y is a dependent variable to be predicted; ***x*** is an independent variable, which is the the factor affecting ***y***; ***a*** is a Y-intercept; ***b*** is a slope of the regression line; ***ε*** is a random error term.

4.4.2 Correlation coefficient

The correlation coefficient of the regression model gives an understanding on how well the variables correlate each other. The formula is as follows:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \qquad \text{(Formula 2)}$$

where

r is a correlation coefficient; ***y*** is a dependent variable; ***x*** is an independent variable; ***n*** is a number of observations.

In the Excel, it is enough to use **= *CORREL(x; y)*** formula in order to get the respective result.

4.4.3 R-squared

The coefficient of determination, also known as R-squared, is the square of the correlation coefficient. It demonstrates how the dependent variable is explained and whether it fits the model. The formula is as follows:

$$R^2 = 1 - \frac{SS_{RES}}{SS_{TOT}} = 1 - \frac{\sum_i (y_i - \hat{y}_i)^2}{\sum_i (y_i - \overline{y})^2} \qquad \text{(Formula 3)}$$

where

R-squared is a coefficient of determination; ***SS res*** is a residual sum of squared errors; ***SS tot*** is a total sum of squared errors; ***y*** is a dependent variable.

The higher the result of the R-squared, the more the model fits.

4.4.4 Interpretation

The strength of the relationship is determined according to the Rule of Thumb scale:

Table 1. Rule of Thumb

Range	Relationship
0.8 – 0.9	Very strong
0.6 – 0.79	Strong
0.4 – 0.59	Moderate
0.2 – 0.39	Weak
0 – 0.19	Very weak

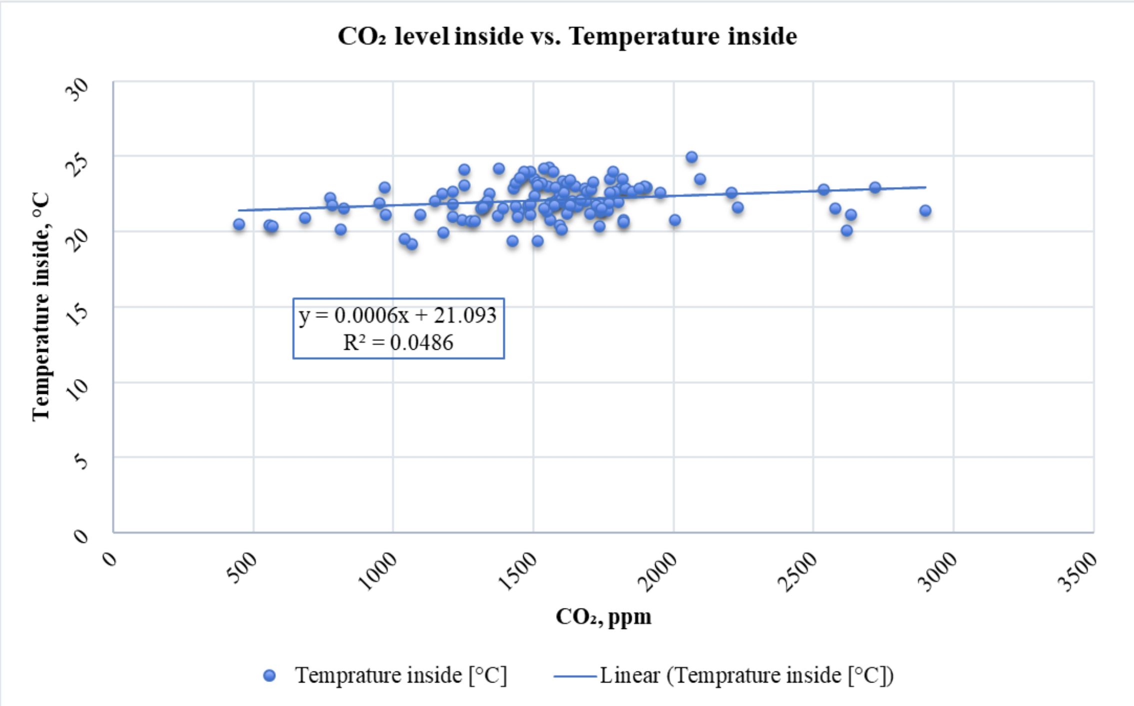
Source: Mukaka, 2012.

4.5 Calculations

4.5.1 CO_2 level inside vs. Temperature inside

Based on the data collected on the level of the carbon dioxide in the room for the period from October 2023 to January 2024 as well as temperature data inside the room for the same period of time, the R and R^2 were calculated, and a respective chart has been constructed for representation purposes.

Figure 1. Correlation of CO_2 level inside and Temperature inside, October-January



Source: Own proceedings

According to the *Figure 1*, the data and the values are very grouped, which is a sign that a relationship should be traced.

A regression analysis shows an equation: y = 0.0006x + 21.093, where R^2 = 0.0486.

Based on the linear regression analysis represented in *Figure 2*, the coefficient of correlation is equal to 0.2204 and $R^2 = (0.22042)^2 = 0.0486$. It shows that these two variables have a weak relationship.

The statistical analysis performed includes regression statistics, ANOVA table, and coefficients for the variables in the regression model. As a result of the regression analysis, it shows a weak positive correlation between the independent variable (CO_2 level) and the dependent variable (temperature inside the room), with only 4.86% of the variance. The ANOVA table indicates that the regression model is statistically significant, the p-value of 0.0143. The coefficients table demonstrates that the temperature inside has a statistically significant effect on the CO_2 level in the tested room, with an estimated coefficient of 76.9036. Even though, the model has a low R-squared value, indicating that the temperature as independent variable explains only a small portion of the CO_2 level as the dependent variable.

Figure 2. Linear regression analysis of CO_2 level inside and Temperature inside, October-January

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.220446276
R Square	0.048596561
Adjusted R Square	0.040733722
Standard Error	403.2182268
Observations	123

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	1004862.176	1004862.176	6.180536683	0.014280657
Residual	121	19672777.55	162584.9384		
Total	122	20677639.72			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-142.3305864	683.8704643	-0.208125067	0.835481229	-1496.23255	1211.571377	-1496.23255	1211.57137
Temprature inside [°C]	76.90357279	30.93381063	2.486068519	0.014280657	15.66193547	138.1452101	15.66193547	138.145210

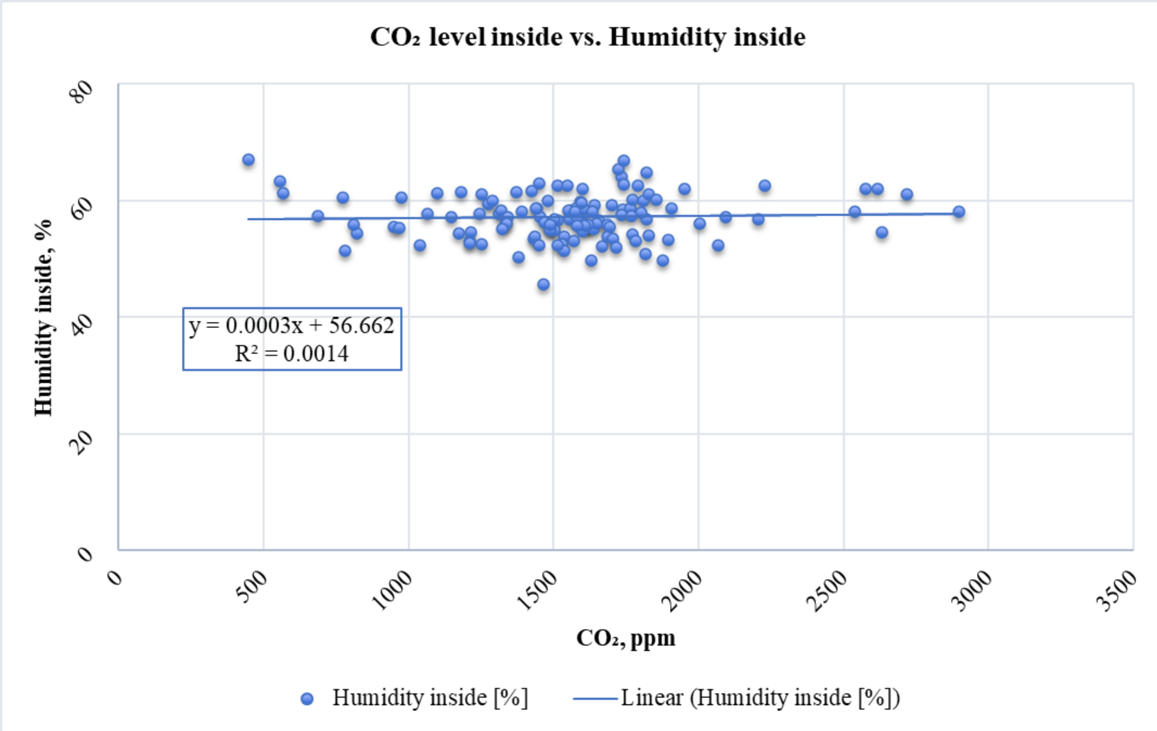
Source: Own proceedings

4.5.2 CO_2 level inside vs. Humidity inside

Similarly, the data on the level of the carbon dioxide in the room for the period from October 2023 to January 2024 was opposed to the humidity data inside the room for the same period of time. The R and R^2 were calculated in the same way, and a chart represents the correlation below. The *Figure 3* shows the values are less grouped, an assumption that the relationship is weaker than in the previous analysis.

A regression analysis shows an equation: $y = 0.0003x + 56.662$, where $R^2 = 0.0014$.

Figure 3. Correlation of CO_2 level inside and Humidity inside, October-January



Source: Own proceedings

Based on the linear regression analysis represented in *Figure 4*, the coefficient of correlation is equal to 0.0376 and $R^2 = (0.0376)^2 = 0.0014$. It shows that these two variables have a very weak relationship.

The output gives the information about a regression analysis performed on a dataset. As the result, the regression statistics represents a very weak positive correlation between the independent variable (CO_2 level) and the dependent variable (humidity inside the room), with only 0.14% of the variance. The ANOVA table indicates that the regression model is not statistically significant with a p-value of 0.6795. The coefficients table shows that the CO_2 concentration does not have a statistically significant effect on the humidity level in the room with an estimated coefficient of 0.0003. The overall model has an extremely low R-squared value, indicating that the humidity level explains only an insignificant part the CO_2 level as the dependent variable.

Figure 4. Linear regression analysis of CO_2 level inside and Humidity inside, October-January

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.037626392
R Square	0.001415745
Adjusted R Square	-0.006837017
Standard Error	3.81480968
Observations	123

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	2.496499943	2.496499943	0.171548059	0.679472937
Residual	121	1760.88552	14.55277289		
Total	122	1763.38202			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	56.66199472	1.349447967	41.98901782	5.481E-74	53.99040654	59.33358291	53.99040654	59.33358291
CO_2 [ppm]	0.000347468	0.000838924	0.414183605	0.679472937	-0.001313402	0.002008339	-0.001313402	0.002008339

Source: Own proceedings

4.5.3 CO_2 level inside vs. wind speed outside

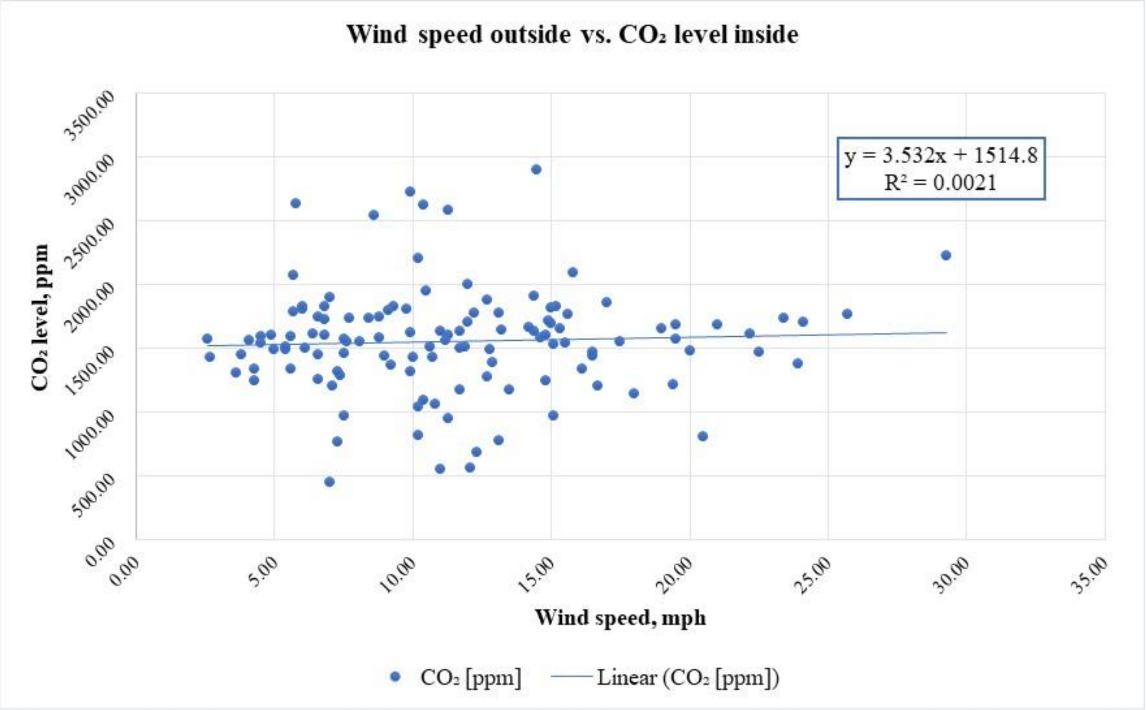
The last but not the least important is the data analysis of the carbon dioxide level versus wind speed outside for the period from October 2023 to January 2024. The R and R^2 are represented in the *Figures 5 and 6* below. The *Figure 5* shows the values are chaotic, there is a little grouping, hence, an assumption that the relationship is extremely weak in comparison to the previous analyses.

A regression analysis shows an equation: $y = 0.0006x + 10.551$, where $R^2 = 0.0021$.

Based on the linear regression analysis represented in *Figure 6*, the coefficient of correlation is equal to 0.0461 and $R^2 = (0.0461)^2 = 0.0021$. It shows that these two variables have a very weak relationship too.

The Table above provides an output of the regression analysis performed. The regression statistics demonstrates a very weak positive correlation between the independent variable (wind speed) and the dependent variable (CO_2 level inside), with only 0.21% of the variance. The ANOVA table indicates that the regression model is not statistically significant with a p-value of 0.6123.

Figure 5. Correlation of Wind speed outside and CO_2 level inside, October-January



Source: Own proceedings

Figure 6. Linear regression analysis of CO_2 level inside and Wind speed, October-January

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.04614806
R Square	0.002129643
Adjusted R Square	-0.006117219
Standard Error	5.395427072
Observations	123

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	7.517436942	7.517436942	0.258236805	0.612259271
Residual	121	3522.386628	29.11063329		
Total	122	3529.904065			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	10.55077433	1.908574399	5.528091718	1.89466E-07	6.772247896	14.32930076	6.772247896	14.32930076
CO_2 [ppm]	0.000602954	0.001186521	0.508170056	0.612259271	-0.001746076	0.002951985	-0.001746076	0.002951985

Source: Own proceedings

The coefficients table shows that the CO_2 concentration does not have a statistically significant effect on the CO_2 level in the room, with an estimated coefficient of 0.0006. The overall model has a low R-squared value, indicating that the wind speed has a small effect on the CO_2 concentration in the room in this case.

4.6 Sensor to detect the indoor environment

The AM103 is a LoRaWAN sensor from Milesight that is outlined to collect and transmit remote information by means of implies of LoRaWAN convention (Milesight-IoT, 2024). It bolsters numerous sensor inputs, counting computerized, analog, and temperature and mugginess sensors, permitting you to interface different sensors and gadgets to screen and control different parameters. The sensor is battery-powered, giving adaptability in establishment and diminishing a need for a consistent control supply. It has a compact plan that makes simple to introduce anyplace, guaranteeing assurance against tidy and water entrance. Another advantage is that it is moreover appropriate for the open air utilize. The AM103 has a communication of a more extensive extend, coming to a few kilometers. It depends on the environment and the LoRaWAN capabilities (Milesight-IoT, 2024). It can transmit information at normal interims or based on pre-defined limits, which permits to screen and send cautions in the real-time. The operation level comes to the wide temperature run, ordinarily from 0°C to 60°C, guaranteeing reasonableness for different situations (Milesight-IoT, 2024). The sensor has a compact dimension making it easy to install and integrate into existing systems.

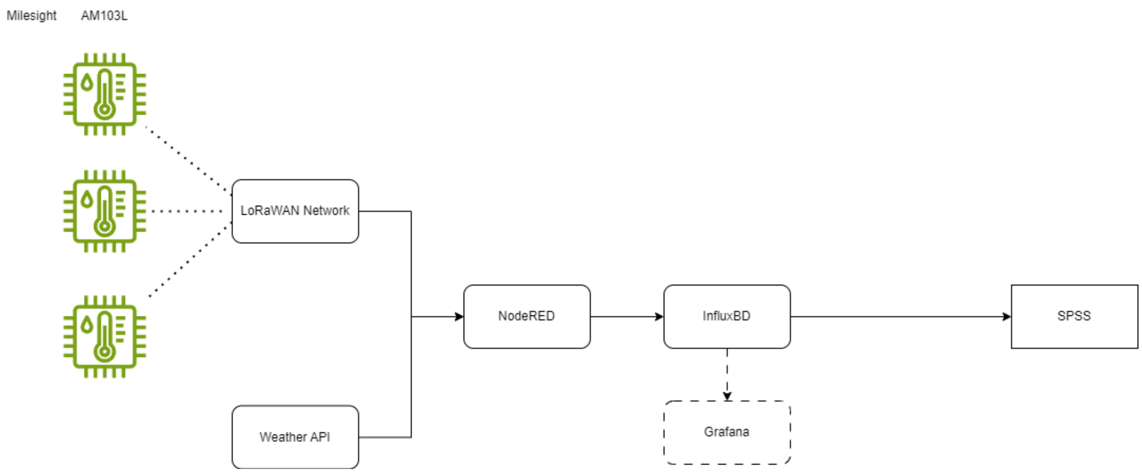
The preference fell to this thermostat is due to the fact that it provides the necessary statistics for the data analysis and driving conclusions respectively.

4.7 Principle of work

The principle of work is represented in the data flow diagram in *Figure 7*.

The Milesight sensor is an IoT-based device which collects the data of the particular room and transfers the data via the LoRaWAN gateway to connect and exchange the data (Yager & Espada, 2017). The mentioned network server manages the communication between Milesight device and application.

Figure 7. Data flow diagram



Source: Own proceedings

At the same time, the system gets the data from the weather API in order to understand the pattern of opening the window for which period of time (Weather Portal, 2024).

Then, the data from the LoRaWAN and weather API is transferred to the Node-RED. The Node-RED is a powerful and flexible tool for building IoT applications task automation (NodeRed, 2024). It is an open-source programming tool to connect hardware devices, APIs, and online services together. It provides a visual interface which allows the users to create flows by connecting 'nodes' representing various functions or devices.

Then, the data is transmitted to the InfluxData, which is a comprehensive platform for collecting, storing, analyzing, and visualizing time-series data used for different industries (Delquié et al., 2024). It is interconnected to an open-source platform called Grafana. This is a platform intended for data visualization and monitoring. It allows users to create dashboards to visualize data from various sources, including time-series databases like InfluxDB (Grafana, 2024).

Afterwards, all the data is transferred to the SPSS (Statistical Package for the Social Sciences). It is a software package utilized for statistics. It provides a range of tools for data analysis, diverse types of statistics, data visualization, and its management.

All the data will be interpreted via decoder to ensure the accuracy of the data.

5 Results and Discussion

The aim of the thesis was to test the following hypotheses:

- H1: The level of CO_2 is dependent on the temperature inside the room.
- H2: The level of CO_2 is independent from humidity level inside the room.
- H3: Given the window open, helps to decrease the level of carbon dioxide in the room.

Hypothesis 1 – The level of CO2 is dependent on the temperature inside the room.

Hypothesis is proved.

Even though the relationship is quite weak, there is a small dependence between the CO_2 level and temperature inside the room.

It is not accurate to rely that the CO_2 level is entirely dependent on the relationship with the temperature inside the apartments.

The carbon dioxide (CO_2) levels and temperature, have an indirect dependency as the CO_2 is primarily affected by the amount of people present in the room or other objects which emit the CO_2 , lack of ventilation, and inability of handling with the amount of CO_2 in the apartments.

The human breathing is the way how people release the carbon dioxide into the air. A concentration of CO_2 might raise because of the amount of people present or in case if the ventilation is not enough to let an adequate amount of fresh air. The more people in the selected room, the higher the CO_2 levels.

Temperature has an impact on human respiration. The higher the tempt, people tend to breathe faster, which gain affects as an induced CO_2 emission. Even though, the temperature alone does not determine the concentration of the carbon dioxide in the room.

Thus, ventilation plays an important role in life as it helps to reduce the CO_2 levels within an acceptable range and brings the fresh air.

An essential note that higher levels of carbon dioxide have negative effects on human health. Different concentrations of the CO_2 cause headaches, reduced productivity, and even death. Thus, it is recommended to ensure a proper ventilation and monitor the indoor weather.

Hypothesis 2 – The level of CO2 is independent from humidity level inside the room.

Hypothesis is rejected.

It is not accurate either. It has also an indirect relationship as there are plenty of other factors such as human presence and ventilation are important too.

Humidity is the of moisture present in the air. The higher the humidity level, the air is able to keep moisture and it can have an effect on the behavior of CO_2 molecules. The more moisture in the air, the CO_2 molecules are dispersed meaning that they are less likely to gather in one area. So the CO_2 is likely to have lower concentrations in the air than when the air is dry.

Hypothesis 3 – Given the window open, helps to decrease the level of carbon dioxide in the room.

The hypothesis is neither proved nor rejected.

Due to the fact that the old lady who tested the sensor did not open the window on a regular basis, it is tough to say based on the research and data that open windows can help significantly decrease the level of carbon dioxide in a room.

But letting the fresh air in through the open window, it allows better ventilation.

Ventilation, in other terms, the provision of the fresh air into a room plays a vital role in maintaining air quality as it aids to eliminate the CO2 concentrations. A poorly ventilated apartment, CO_2 amount raises (Larson, 2003).

It is essential in spaces with a regular high occupancy or constraint ventilation systems as circulation of the air is important.

It is crucial to take on to account also an external environment while opening a window. If the outdoor air quality is poor, usually it is typical to the areas with higher pollution levels, there is a necessity to utilize air filters or ensure to have a good ventilation system to maintain indoor air quality and ensure proper CO_2 removal.

In summary, opening a window can be an effective in terms of reducing the level of carbon dioxide in a room by promoting ventilation and the exchange of indoor and outdoor air. However, it is important to consider the external environment and ensure proper air quality when utilizing this method.

5.1 Limitations of study

The study of IoT-based technologies has the limitations.

First of all, the technological progress has its imprint too. IoT is a rapidly evolving sector. There are lots of new technologies, devices, and applications developing every year. It is challenging to keep up with the latest advancements and perform the analysis encompassing all aspects of IoT.

Secondly, IoT is a complex ecosystem of interconnected devices, networks, and applications. It requires an expertise from different disciplines, including computer science, engineering, telecommunications, and data analytics. In order to perform a detailed analysis and do the studies, it is often implies cooperation of experts from different fields of studies, which can be very challenging to coordinate.

Thirdly, as it was mentioned in security and privacy section, the lack of standardized protocols in IoT makes it challenging to conduct comprehensive studies (Rehman et al., 2022). Again, this is a continuously evolving field, it is tough to take into consideration all the aspects to standardize the application of protocol. Various IoT devices and platforms have different capabilities, operational background, privacy and security measures (Rehman et al., 2022).

Fourthly, IoT technologies are associated with the collection and processing of large amount of data, including personal information (Rehman et al., 2022). This definitely raises ethical and privacy concerns of the data privacy, ownership, consent, and potential misuse of confidential data shared. Such doubts limit the scope of studies, and it is needed to address and navigate a combination of the legal and ethical frameworks.

Fifthly, the IoT studies usually have small-scale deployments which might not fully capture the challenges and complexities of larger scale IoT-based implementations. In the real world, the deployment of IoT technologies implies taking into consideration the scale, network infrastructure, and integration with already existing systems. Therefore, the research cannot fully cover all the points.

Sixth point is that in the long term, the IoT is limited as the internet of things is a relatively new sector and there is no understanding what the long-term effects of IoT on the different aspects are. Privacy, security, and social dynamics demand lots of research and observation.

Finally, the IoT-based technology is in need of important resources, financial support, infrastructure, and relevant expertise.

6 Conclusion

To conclude, this thesis explores how IoT-based smart home devices can improve the quality of life for senior citizens, with a focus on indoor air quality management. The study utilizes both quantitative and qualitative methods for investigation of the impact from implementing IoT-based smart home devices (Jyothi et al., 2017). The outcomes of the study will be used to create a prototype gadget that can precisely track the air quality levels in order to mitigate potential risks and send information to the caregivers in case of emergencies.

IoT technology is intended to enhance the decision making, safety and security, quality of life, and environmental sustainability. Although there are security and privacy concerns with IoT devices, it is important to address this issue. The risks associated with IoT-based systems include data breaches, lack of standardized security protocols, and lack of user awareness.

The study, which was conducted, on the correlation between CO_2 levels and temperature, humidity, and wind speed inside and outside a room. The results show a weak positive correlation between CO_2 levels and temperature, no significant correlation between CO_2 levels and humidity, and a very weak correlation between CO_2 levels and wind speed.

All in all, there are limitations of IoT-based technologies. There is a necessity for the expertise from various angles, ethical and privacy concerns, and the significance for resources and infrastructure (Rehman et al., 2022). Overall, the study highlights the potential benefits of the IoT-based smart home technologies for seniors and emphasizes the importance of referring the security and privacy concerns, and the importance of the interdisciplinary collaboration and infrastructure.

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8 List of pictures, tables, graphs and abbreviations

8.1 List of figures

8.2 List of tables

8.3 List of pictures

8.4 List of abbreviations

CO_2	Carbon dioxide
IoT	Internet of Things

Appendices

Appendix 1 – the level of carbon dioxide in the room, October – January

October	***CO_2 [ppm]***	***November***	***CO_2 [ppm]***	***December***	***CO_2 [ppm]***	***January***	***CO_2 [ppm]***
1	447.22	1	1320.83	1	1334.64	1	1632.45
2	771.92	2	1448.76	2	1618.46	2	1488.78
3	555.65	3	1515.40	3	2897.82	3	1468.43
4	568.69	4	2576.23	4	1503.34	4	1213.08
5	685.29	5	1210.49	5	1603.34	5	1725.27
6	822.00	6	1340.99	6	1336.71	6	1743.43
7	810.92	7	1504.25	7	1321.43	7	1852.58
8	947.80	8	1390.68	8	1486.93	8	1773.44
9	1066.73	9	2537.84	9	1802.94	9	1488.93
10	1372.34	10	1821.97	10	1904.95	10	1538.08
11	973.93	11	2617.99	11	1537.67	11	1514.01
12	1096.73	12	1558.49	12	2205.33	12	1896.53
13	1810.43	13	1735.72	13	1594.36	13	2092.75
14	782.06	14	1821.65	14	1826.31	14	1617.71
15	1173.87	15	1443.90	15	1741.24	15	1687.39
16	1210.48	16	1429.75	16	1636.47	16	1691.71
17	1310.79	17	1514.81	17	1579.60	17	1609.05
18	1245.72	18	1576.51	18	1600.55	18	1579.88
19	1592.00	19	2004.23	19	1657.77	19	1631.35
20	1601.62	20	1553.03	20	1574.22	20	1816.96
21	967.72	21	2719.77	21	2227.75	21	1783.20
22	1605.37	22	1437.17	22	1649.66	22	1706.10
23	1251.73	23	1739.05	23	1773.12	23	1714.46
24	1558.08	24	1146.35	24	1765.26	24	1377.41
25	1555.73	25	1641.19	25	1701.11	25	1465.38
26	1179.52	26	1953.07	26	1684.71	26	1666.76
27	1424.54	27	1792.45	27	1733.81	27	1878.04
28	1275.10	28	1547.09	28	1529.87	28	2066.01
29	1289.41	29	1040.09	29	1481.90	29	1569.50
30	1455.12	30	2634.41	30	1767.90	30	1434.31
31	1250.95			31	1829.70	31	1450.43

Source: Milesight, 2024

Appendix 2 – temperature inside the room, October – January

October	***Temperature inside [°C]***	***November***	***Temperature inside [°C]***	***December***	***Temperature inside [°C]***	***January***	***Temperature inside [°C]***
1	20.53	1	21.79	1	21.91	1	21.78
2	22.24	2	21.34	2	21.22	2	21.83
3	20.41	3	19.37	3	21.41	3	23.84
4	20.37	4	21.58	4	22.39	4	21.85
5	20.90	5	20.99	5	21.98	5	21.78
6	21.56	6	22.54	6	22.03	6	21.57
7	20.16	7	23.49	7	21.63	7	22.67
8	21.92	8	21.52	8	21.10	8	22.57
9	19.20	9	22.77	9	21.95	9	23.97
10	21.09	10	20.78	10	22.96	10	24.19
11	21.16	11	20.09	11	21.54	11	23.10
12	21.12	12	20.78	12	22.62	12	23.02
13	22.84	13	20.38	13	22.44	13	23.53
14	21.74	14	20.64	14	22.86	14	23.20
15	22.55	15	21.02	15	21.47	15	22.05
16	22.69	16	22.91	16	22.03	16	22.64
17	21.57	17	23.26	17	21.92	17	22.58
18	20.81	18	22.05	18	22.19	18	22.93
19	20.43	19	20.76	19	21.69	19	23.40
20	20.17	20	23.02	20	21.74	20	23.52
21	22.96	21	22.93	21	21.65	21	24.02
22	23.38	22	21.68	22	23.03	22	22.81
23	24.09	23	21.36	23	23.50	23	23.29
24	21.90	24	22.01	24	21.39	24	24.19
25	24.30	25	21.95	25	21.23	25	24.01
26	19.94	26	22.57	26	22.85	26	22.09
27	19.41	27	22.68	27	21.91	27	22.88
28	20.70	28	21.32	28	23.22	28	24.97
29	20.75	29	19.53	29	21.79	29	24.01
30	23.54	30	21.13	30	21.92	30	23.24
31	23.11			31	22.89	31	23.59

Source: Milesight, 2024

Appendix 3 – Humidity inside the room, October – January

October	*Humidity inside [%]*	*November*	*Humidity inside [%]*	*December*	*Humidity inside [%]*	*January*	*Humidity inside [%]*
1	67.00	1	58.26	1	55.95	1	58.08
2	60.44	2	62.85	2	55.43	2	54.97
3	63.35	3	62.63	3	58.12	3	56.29
4	61.15	4	61.91	4	56.78	4	54.63
5	57.33	5	52.61	5	58.46	5	65.39
6	54.42	6	57.22	6	56.04	6	66.87
7	55.85	7	54.83	7	55.16	7	60.09
8	55.43	8	58.17	8	55.28	8	60.05
9	57.72	9	58.13	9	57.94	9	55.82
10	61.37	10	56.79	10	58.60	10	51.45
11	60.49	11	62.01	11	53.72	11	52.27
12	61.33	12	58.27	12	56.76	12	53.16
13	59.97	13	64.08	13	59.59	13	57.10
14	51.47	14	64.73	14	61.02	14	55.89
15	54.36	15	58.58	15	62.69	15	53.72
16	53.03	16	53.36	16	55.13	16	55.51
17	57.77	17	56.59	17	56.95	17	55.68
18	57.64	18	58.66	18	54.81	18	55.74
19	59.78	19	56.12	19	56.59	19	49.77
20	61.93	20	58.28	20	58.06	20	50.78
21	55.38	21	61.00	21	62.54	21	53.05
22	56.04	22	58.71	22	56.13	22	53.51
23	52.51	23	58.50	23	54.21	23	51.99
24	57.51	24	57.18	24	58.65	24	50.27
25	56.71	25	59.18	25	59.28	25	45.54
26	61.49	26	62.07	26	55.94	26	52.18
27	61.65	27	62.59	27	57.61	27	49.80
28	59.38	28	62.46	28	52.56	28	52.41
29	59.93	29	52.39	29	59.90	29	53.01
30	57.18	30	54.62	30	57.43	30	53.77
31	61.13			31	53.97	31	52.27

Source: Milesight, 2024

Appendix 4 – Temperature outside the room, October – January

October	***Temperature outside [°C]***	***November***	***Temperature outside [°C]***	***December***	***Temperature outside [°C]***	***January***	***Temperature outside [°C]***
1	14.33	1	10.39	1	-2.44	1	4.89
2	17.78	2	8.33	2	-3.94	2	4.67
3	18.33	3	7.22	3	-4.33	3	8.00
4	12.17	4	7.22	4	-7.11	4	6.56
5	11.06	5	9.67	5	-3.94	5	3.39
6	12.28	6	9.33	6	-1.39	6	2.72
7	15.06	7	8.06	7	0.22	7	-3.22
8	11.83	8	6.11	8	-2.22	8	-7.61
9	11.94	9	6.89	9	0.72	9	-9.33
10	15.39	10	6.28	10	3.06	10	-7.78
11	18.44	11	3.50	11	6.39	11	-5.44
12	16.44	12	3.78	12	6.17	12	-2.22
13	17.78	13	5.06	13	5.94	13	-1.50
14	15.39	14	9.06	14	4.33	14	-1.00
15	6.61	15	8.22	15	2.72	15	-1.50
16	4.94	16	6.00	16	3.78	16	-1.67
17	4.72	17	3.56	17	4.33	17	-3.78
18	3.83	18	2.94	18	5.44	18	-2.06
19	6.94	19	6.00	19	6.17	19	-4.28
20	10.83	20	8.61	20	3.78	20	-3.72
21	14.56	21	5.72	21	5.17	21	-5.17
22	12.11	22	-0.72	22	1.94	22	2.22
23	10.33	23	2.72	23	1.00	23	3.78
24	10.11	24	3.22	24	7.39	24	7.44
25	11.00	25	0.11	25	9.28	25	5.78
26	11.00	26	-0.78	26	7.94	26	4.50
27	9.44	27	1.39	27	3.94	27	2.89
28	10.00	28	-1.06	28	5.94	28	0.44
29	12.11	29	-2.39	29	8.22	29	-3.22
30	12.22	30	-0.94	30	6.72	30	-3.00
31	10.61			31	2.67	31	1.17

Source: Weather Portal, 2024

Appendix 5 – Humidity outside the room, October – January

October	***Humidity outside [%]***	***November***	***Humidity outside [%]***	***December***	***Humidity outside [%]***	***January***	***Humidity outside [%]***
1	63.50	1	79.60	1	95.80	1	78.60
2	58.70	2	87.30	2	95.50	2	87.30
3	64.20	3	89.10	3	86.10	3	79.50
4	73.60	4	76.80	4	90.40	4	83.20
5	74.60	5	71.80	5	91.50	5	90.70
6	71.70	6	71.10	6	95.20	6	98.10
7	64.90	7	79.60	7	92.00	7	84.10
8	78.60	8	80.30	8	90.20	8	77.20
9	88.90	9	68.90	9	93.90	9	77.00
10	83.90	10	78.00	10	88.70	10	79.60
11	60.70	11	90.50	11	82.10	11	81.90
12	71.80	12	82.00	12	83.50	12	84.60
13	70.50	13	91.50	13	93.70	13	81.00
14	66.60	14	78.60	14	93.60	14	81.60
15	76.50	15	82.00	15	83.20	15	77.50
16	75.60	16	85.70	16	81.80	16	77.80
17	74.80	17	78.90	17	80.40	17	88.20
18	82.40	18	78.20	18	65.70	18	96.20
19	88.20	19	89.00	19	57.40	19	84.80
20	97.50	20	83.00	20	83.00	20	78.60
21	74.60	21	89.80	21	83.00	21	79.70
22	81.80	22	89.60	22	84.00	22	69.00
23	77.80	23	81.00	23	93.00	23	79.60
24	91.20	24	84.30	24	85.00	24	75.80
25	83.80	25	88.00	25	80.20	25	64.70
26	83.20	26	83.80	26	78.00	26	84.30
27	91.20	27	91.40	27	82.20	27	72.20
28	83.40	28	98.10	28	73.50	28	85.30
29	72.60	29	86.70	29	73.80	29	96.10
30	80.10	30	90.50	30	77.10	30	96.30
31	84.10			31	89.80	31	96.00

Source: Weather Portal, 2024

Appendix 6 – Wind speed outside, October – January

October	***Wind speed [mph]***	***November***	***Wind speed [mph]***	***December***	***Wind speed [mph]***	***January***	***Wind speed [mph]***
1	7.00	1	9.90	1	4.30	1	14.40
2	7.30	2	6.60	2	9.90	2	12.80
3	11.00	3	10.60	3	14.50	3	22.50
4	12.10	4	11.30	4	6.10	4	19.40
5	12.30	5	16.70	5	4.90	5	6.80
6	10.20	6	16.10	6	5.60	6	6.60
7	20.50	7	11.70	7	7.30	7	17.00
8	11.30	8	12.90	8	5.40	8	12.20
9	10.80	9	8.60	9	6.00	9	5.00
10	9.20	10	9.30	10	14.40	10	4.50
11	15.10	11	10.40	11	15.50	11	5.40
12	10.40	12	11.20	12	10.20	12	7.00
13	9.80	13	8.40	13	5.60	13	15.80
14	13.10	14	15.20	14	6.00	14	22.20
15	11.70	15	16.50	15	8.80	15	21.00
16	7.10	16	10.70	16	11.70	16	15.00
17	3.60	17	11.90	17	14.60	17	6.40
18	4.30	18	7.50	18	14.80	18	8.80
19	4.50	19	12.00	19	15.30	19	11.00
20	6.80	20	17.50	20	19.50	20	15.00
21	7.50	21	9.90	21	29.30	21	5.70
22	11.30	22	9.00	22	19.00	22	12.00
23	6.60	23	23.40	23	13.10	23	14.90
24	4.10	24	18.00	24	25.70	24	23.90
25	7.60	25	13.20	25	24.10	25	16.50
26	13.50	26	10.50	26	19.50	26	14.20
27	10.00	27	9.10	27	7.70	27	12.70
28	12.70	28	8.10	28	15.10	28	5.70
29	7.40	29	10.20	29	20.00	29	2.60
30	7.50	30	5.80	30	15.60	30	2.70
31	14.80			31	6.80	31	3.80

Source: Weather Portal, 2024