Czech University of Life Sciences Prague

Faculty of Economics and Management

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Bachelor Thesis

Applications of Artificial intelligence

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BACHELOR THESIS ASSIGNMENT

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Thesis title

Applications of Artificial Intelligence

Objectives of thesis

The main goal of this bachelor thesis is to measure and compare performance of artificial intelligence and human players within gaming applications.

Partial goals include:
- Analyze possibilities for using AI in games
- Measure and compare performance of two practical scenarios, one with AI and one without
- Explore if utilization of artificial intelligence in gaming applications can be transferred for usage in other areas of life

Methodology

The thesis will have two parts: theoretical and practical. The theoretical part is based on the analysis of professional information sources about AI. Knowledge gained in the theoretical part will be used in practical part.

The methodology of the practical part consists of the analysis and comparison of human and AI performance in a gaming scenario.

The proposed extent of the thesis

35-50

Keywords

Artificial intelligence, algorithms, neuron, neural networks, games, neurocybernetics, black box cybernetics.

Recommended information sources

Bishop, Christopher M. Pattern Recognition and Machine Learning. United States: Springer , August 17, 2006. ISBN-10: 0387310738

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Declaration

I declare that I have worked on my bachelor thesis titled "Applications of Artificial intelligence" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break copyrights of any their person.

In Prague on 15 March 2021 _____

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I would like to thank my supervisor Ing. Jan Pavlik for his advice and support during my work on thesis and all members, who tested and answered the questionnaire of practical part of the thesis.

Applications of Artificial intelligence

Abstract

The purpose of the theoretical part of this work is to study the main aspects of artificial intelligence systems and neural networks and identify the direction of their application, consider the history of the development of AI, analyse possibilities for using AI in games. The practical task includes:

- Analyse the use of AI in games.
- Measure and compare performance of two practical scenarios, one with AI and one without.
- Explore if utilization of artificial intelligence in gaming applications can be transferred for usage in other areas of life.

Keywords: Artificial intelligence, algorithms, neuron, neural networks, games, neuro-cybernetics, black box cybernetics.

Aplikace umělé inteligence

Abstrakt

Účelem teoretické části této práce je studovat hlavní aspekty systémů umělé inteligence a neuronových sítí a určit směr jejich aplikace, zvážit historii vývoje AI, analyzovat možnosti využití AI ve hrách.

Praktický úkol zahrnuje:

- Analýzu využití AI ve hrách.
- Změření a porovnání výkonu dvou praktických scénářů, jednoho s AI a druhého bez.
- Prozkoumaní, zda lze využití umělé inteligence v herních aplikacích přenést na použití v jiných oblastech života.

Klíčová slova: Umělá inteligence, algoritmy, neuron, neuronové sítě, hry, neuro-kybernetika, kybernetika v černé skříňce.

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1 Introduction

In modern life technology is developing very fast and artificial intelligence is one of the most promising areas in software engineering. Artificial intelligence is now being actively studied and developed. The greatest efforts of mathematicians, engineers and cybernetics, linguists, philosophers, psychologists, are concentrated in this area.

The development of computer technology has led to the emergence of many different works, for example recognizing and synthesizing human speech, creation of vision systems that can recognize people's faces as well as humans, and teaching cars to drive without a driver and etc.

Moving forward, AI researchers are faced with confusing problems that transcend the boundaries of traditional computer science. First of all, it was necessary to understand the mechanisms of the learning process. Scientists have found that in order to simulate the work of the human brain, it is necessary to understand the mechanism of action of billions of interconnected neurons. The most difficult problem facing researchers of modern science is understanding the functionality of the human mind, and not just imitation of work.

Scientists cannot come to a consensus about the subject of their research - intelligence. For some, intelligence is the ability to solve complex problems; while others see it as the ability to learn, generalize, analyze; for third it is an opportunity to interact with the outside world through perception, communication and awareness of the perceived.

The relevance of the topic of this bachelor thesis is due to the importance of the development of artificial intelligence systems for various areas of human activity.

2 Objectives and methodology

2.1 Objectives

The main goal of this bachelor thesis is to measure and compare performance of artificial intelligence and human players within gaming applications.

Practical goals are:

- Measure and compare performance of two practical scenarios, one with AI and one without.
- Explore if utilization of artificial intelligence in gaming applications can be transferred for usage in other areas of life.

2.2 Methodology

The thesis will have two parts: theoretical and practical. The theoretical part is based on the analysis of professional information sources about AI. Knowledge gained in theoretical part will be used in practical part. The methodology of the practical part consists of the analysis and comparison of human and AI performance in a gaming scenario.

3 Literature review

3.1 Concept of artificial intelligence

Artificial intelligence (AI) is a system that explores ways to train a computer, robotic technology and analytical framework to think intelligently like a human being. It is a property of intelligent systems to perform creative functions that are traditionally considered as the prerogative of human. In software, logic, computation, and philosophy, the word 'artificial intelligence' represents several disciplines. In the early 1980s computer scientists Barr and Feigenbaum have proposed the following definition of artificial intelligence: “Artificial intelligence is a branch of computer science that develops intelligent computer systems with capabilities that we traditionally associate with the human mind - language understanding, learning, reasoning ability, problem solving, etc.” (Feigenbaum, 1981)

AI is not a format or a function but a process and an ability to think and analyze data. Many people use the term "artificial intelligence" to think off intelligent humanoid robots trying to conquer the world. Therefore, following question arises if AI is an attempt to imitate human intelligence? Such imitation occurs at some stage, but not always. On the one hand we understand how to build machines to solve problems by observing people and social behaviour, on the other hand AI research utilized algorithms that not observed in human and require far more computational skills. However, AI is not intended to replace people. Its aim is to expand and improve human skills and capabilities. Therefore, this technology is a valuable business advantage.

The scope of artificial intelligence is very extensive and has many incarnations and we face them every day, for example:

- Chatbots use AI to quickly evaluate customer queries and provide relevant responses
- Smart assistants use AI to collect thematic information from large datasets and simplify planning process
- Recommendation systems automatically choose similar programs for audience based on previously viewed ones.

- Different video games use AI
- Translation of texts in different languages
- Siri, Alexa and Google assistants
- Self-driving cars or autonomous vehicles
- Ridesharing apps like Uber and Lyft

3.2 History of Artificial Intelligence developing

3.2.1 The Turing Test

The study of artificial intelligence issues became possible only in the middle of 20th century. Opportunity to develop programs that perform complex intellectual tasks appeared after the creation of modern computers after the Second World War. In the 1950s, scientists from various fields started to explore the possibility of creating an artificial brain. Research in the field of neuroscience revealed that brain is a neural network and English mathematician Alan Tuning proposed that any kind of computation can be described in digital form and suggested that AI would be better explored by programming computers not by constructing machines. In 1950 in the "Mind" journal in the article "Computing Machinery and Intelligence" Alan Turing wondered if machines could think. He proposed to conduct an intellectual test that determines the level of similarity of machine actions with human consciousness, later this test was called the Turing test.

The "standard interpretation" the of Turing test as follows: "Person A interacts with person B and computer. Based on the answers to the questions, person A must determine who he is talking with him: a person B or a computer program. The task of a computer program is to mislead a person A. All test participants are unable to see each other. Person A might ask any questions that, in his opinion, could expose the nature of the interlocutor. If the person A cannot say for sure which of the interlocutors is a human, then computer is considered to have passed the test. In order to test machine's intellect not its ability to recognize speech, the conversation is conducted in a "text only" mode by using a keyboard and a screen. Conversation should be conducted at controlled intervals so that person A cannot make conclusions based on the speed of responses."

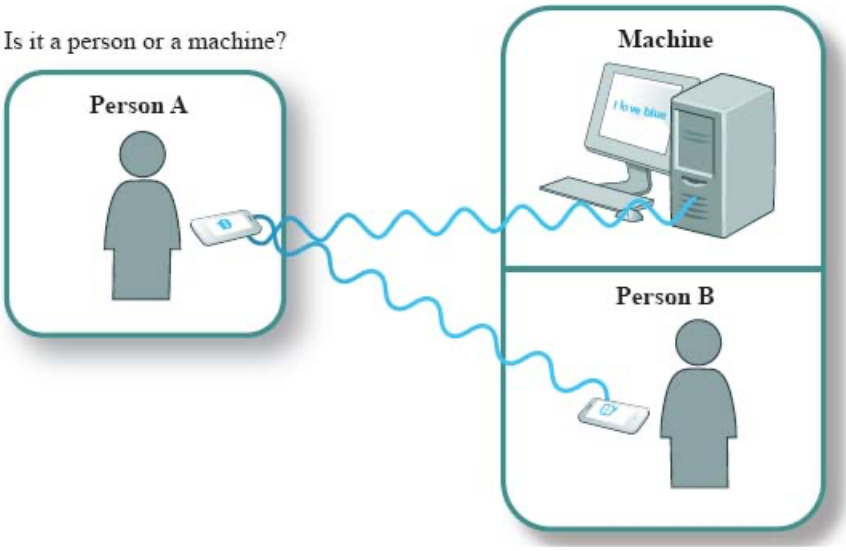

Figure 1: The Turing Test (www.sciencejrank.com)

The Turing test has a number of important advantages: it provides an objective and clear understanding of intelligence, excludes prejudgement in favour of humans. However, some researchers oppose this method of measuring intelligence, arguing mainly that machine intelligence can be different from human's and it would be a fundamental mistake to test it with human criteria. Nevertheless, the Turing test is an important component in the testing and certification of modern intelligent programs.

3.2.2 Heuristic programming

The 60s in the history of artificial intelligence were characterized by attempts to find general methods for solving wide variety of problems, simulating the complex process of thinking. The development of universal programs was too complicated and pointless. It has been discovered that wider is the class of problems that AI can solve, the weaker are its ability in solving a specific problem. The birth of heuristic programming has begun during this period.

Heuristic programming is based on program-solving algorithms, using a functional approach that is not guaranteed to be correct or optimal but sufficient to solve the problem. This form of algorithms allows to user to speed up the solution of the problem in cases where the exact solution cannot be found.
Heuristics is not completely mathematically oriented but practically useful algorithm. According to Judas Pearl, American-Israel computer scientist, heuristic methods are based

on intelligent search of strategies for solving a computer problem using several alternative approaches.

It is necessary to understand that heuristics, in comparison to the correct algorithm, has the following characteristics:

- It doesn't guarantee that the best solution is found
- It doesn't guarantee that solution will be found even if it exists
- In some situations, heuristics can offer wrong solution

Various heuristic algorithms are now used in antivirus applications, computer games, pattern recognition and so on.

There have been many different areas of research in the field of AI but heuristic programming can be defined as the first attempt in creation a truly general theory of artificial intelligence.

3.2.3 Expert systems

A major advance in the practical applications of artificial intelligence occurred in the late 60s and early 70s, when the quest of universal algorithm was replaced by the idea of modelling the unique knowledge of expert specialists. Expert systems "MYCIN" and "DENDRAL" for medicine and chemistry were developed in USA. Both of these systems were diagnostic, in "MYCIN" diseases were determined by number of symptoms and in "DENDRAL" chemical compound was determined by number of properties.

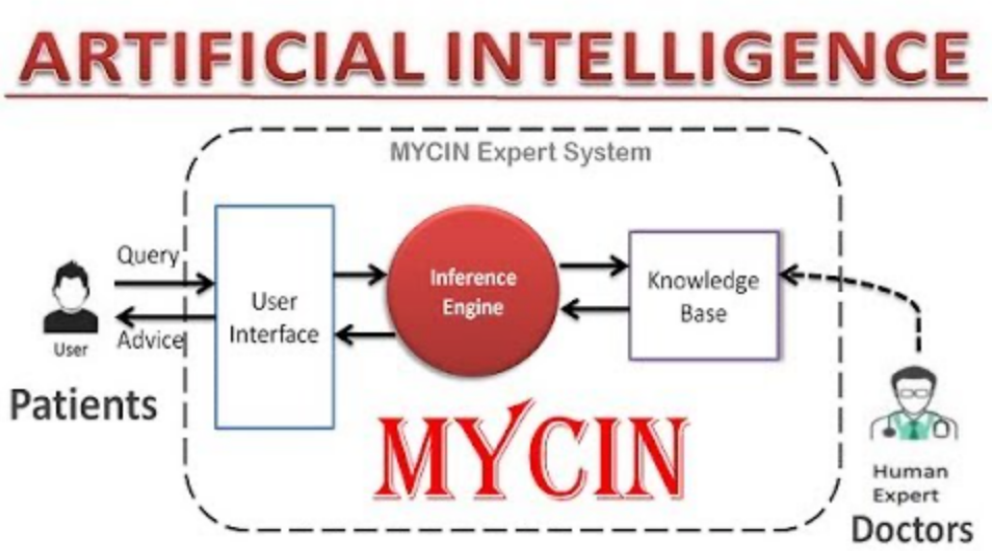

Figure 2:MYCIN (Exam Aasaan Hai)

Expert systems are currently used for forecasting, planning, tracking and managing at nuclear power stations. There are also expert systems such as HASP and SIAP that determine the location and types of ships in the Pacific Ocean based on data from acoustic tracking systems.

The next important era in the history of artificial intelligence is the 80s. First of all, a family of programming languages that were not focused on solving purely computational problems were appeared. The most popular of these languages were LISP and PROLOG. During this time the field of machine learning began to develop. Until then transferring the knowledge of a specialist expert into a computer program was a tedious and time-consuming procedure. The key challenge encountered during the production of MYCIN and subsequent expert systems was "extracting" knowledge from the experience of human experts to form a rule basis.

In addition to programming languages, multiple intelligent systems support instruments have begun to be actively developed, offering programmers the opportunity to automate their activities.

Today artificial intelligence is evolving very rapidly, because of the huge flow of knowledge that people get every day. In addition, people have easy access to the Internet and any source of information. Every year different high-quality technologies are developed, which definitely have an effect on the production of AI.

3.3 Artificial neural network (ANN)

A neural network is one of the ways to implement artificial intelligence. It is a sequence of neurons connected by synapses. The structure of the neural network came to the programming from biology. Thanks to this structure the machine acquires the ability to analyze and even memorize various information.

Neural networks are used to solve complex problems that require analytical calculations similar to human brain. The most common uses of neural networks are:

- **Classification** - data distribution by parameters. For a set of people given as the input data is necessary to decide whom to give a loan and whom not. This work can be done through a neural network, analyzing information such as age, solvency, credit history, etc.

- **Prediction** - the ability to predict the next move. For example, the rise or fall of securities prices on the basis of stock market situation.
- **Recognition**- actually is the widest use of neural networks. Used by Google to detect the location of person's face on photo.

Neurons are units which receive and transmit information. They do not play an important role on their own but neurons matter in the sequence built from them.

The artificial neural network is composed of the following components:

1. Input nodes
2. Hidden nodes
3. Output node

The neural network simulates the function of the human nervous system, a feature of which is the ability to a self-learn on the basis of previous experience. It helps to the system make less mistakes each time. The data arriving at the input of the neural network are processed sequentially on each node of the network. In addition, each neuron has certain parameters that can differ based on the obtained results - this is the way how network is trained.

Suppose the purpose of a neural network is to differentiate cats from dogs. A large array of signed images of cats and dogs is sent to tune the neural network. The neural network analyzes the features including lines, shapes, their size and color in these images and constructs a recognition model that minimizes the percentage of errors in relation to the reference results.

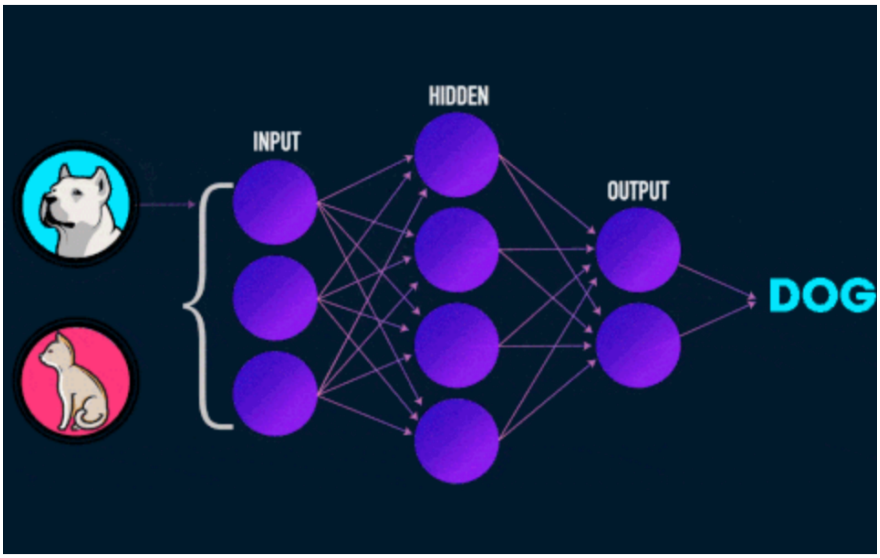

Figure 3: ANN Nodes (Neurohive)

Synapse is a connection between two neurons. Synapses have a parameter - weight. Thanks to weight the input information changes when it is transmitted from one neuron to another.

“Let's say there are 3 neurons that transmit information to the next one. Then we have 3 weights corresponding to each of these neurons. For the neuron with the greater weight, that information will be dominant in the next neuron (for example, color mixing: green + red = brown). In fact, the set of weights of a neural network or a matrix of weights is a kind of brain of the entire system. It is thanks to these weights that the input information is processed and converted into a result.” (Arnis, 2016)

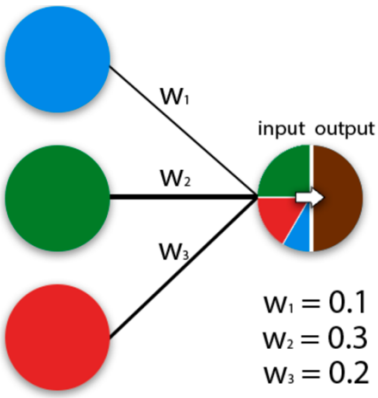

Figure 4: Synapse weight (Habr)

The architecture of neural networks is complicated process. Only large corporations can afford to develop their own neural systems. Usually, smaller companies use pre-designed environments with neural network algorithms.

Example of such environments are:

- MATLAB (an abbreviation of “matrix laboratory”) is technical programming environment and language designed to solve a wide range of engineering and scientific problems of any complexity.
- NeuroShell Trader is an environment developed to forecast and execute successful trading strategies in financial market.

Active use of neural networks is due to wide opportunities. Effective simulation techniques implemented by neural networks are used to reproduce complex dependencies. And applications based on neural algorithms are easy to use. Neural networks are capable of learning by example. An individual using a neural network selects the appreciate data and then has an opportunity to launch a learning algorithm that will automatically detect the data.

3.4 Robotics

Robotics is area of direct practical interest and clearly demonstrates the potential of artificial intelligence. Robotics is scientific and technological basis for designing, manufacturing and using of robots. This field of research tries to take computers out of cloud services into real life. Modern computers are substantially different from the comparative effective machines of industrial revolution. Robot (from Czech word "robota") is programable mechanical device able to perform tasks and communicate with outside world without human assistance. Over the last 100 years the robots have not only progressed they have become the part of our everyday lives. The term "robot" came to use after Karel Capek's story published in 1920 about artificial people.

Modern robots differ from each other in forms, functionalities and purposes. Therefore, robots can be divided into 3 generations:

1. Software robots
2. Adaptive robots
3. Intelligent robots

3.4.1 Software robots

The robots of "first generation" are programmed robots or software robots. They are specifically designed to execute a pre-programmed sequence of operations determined by a specific technical process. Robotic Process Automation (RPA) is a method of automation business processes by using software robots. Software robots imitate human behaviour such as pressing buttons, copying and pasting symbols or entering data into spreadsheets. Such actions can be automated by documenting and coding the particular steps of human employee. RPA software is commonly applied in finance, insurance, health and accounting. In customer service RPA technology is mainly used in collaboration with chatbots that replace operators. While a chatbot interacts with a client, programmed robots search for requested information in connected multiple intern applications and databases. Software robot has big disadvantage that requires attention during the work. It doesn't make any decisions, only provides steps for which was trained. Unlike to advanced AI systems software robot doesn't try to improve itself but strictly follows instructions set out in it.

Nevertheless, according to NASCIO, non-profit organisation representing state chief information officers in USA, software robots will save to companies about 40-70% of labour cost. In order to minimize the need for manpower RPA technology offers several business benefits, such as acceleration of processes, reducing of the number of mistakes almost to zero, simplicity, increasing the amount of completed tasks. According to Reuters, international news organization, demand in this technological area is rising at 29% annually, which means that by the end of 2021 more than 4 million robots will work in enterprises.

3.4.2 Adaptive robots

"Second generation" of robots are adaptive robots or industrial, a function of such robots is formed by a human, but the robot has the ability to automatically reprogram or adapt during the technological process, because of the not properly determined conditions at the stage of forming the task. It should be noted that external recognition factors are important to adaptive robots. Such robots have instruments for understanding external world (e.g. cameras and microphones).

Adaptive systems have sensors that allow to receive information from external environment and based on this information execute certain movements. Except to main program adaptive robots are equipped with subroutines that allow to robots to navigate in the environment and change the operating mode using feedback. Thanks to adaptability of robots a single robotic complex can be used to manufacture thousands of different products. It leads to the fact that use of robots in production becomes profitable and efficient for many firms which hadn't possibility to automate their processes. As a result, the cost of using robots is lower than using manual labour.

"The largest driver of the year-to-date growth of industrial robots was an 83% increase in units ordered by automotive OEMs (see fig. 5), according to the RIA (Robotic Industries Association). Other industries that saw increases include:

- Semiconductor and electronics (12%)
- Life sciences (8%)
- Food and consumer goods (3%)" (Crowe, 2019)

Figure 5: Industrial robots (www.therobotreport.com)

Industrial automation is currently an incontestable reality, but it must be viewed on both sides. The use of industrial robots in manufacturing increases productivity but it has a disadvantage such as limiting of human's role in controlling robots. The bellow table is considered on main pros and cons of industrial automation.

Advantage	**Disadvantage**
Safety Automation protects workers from dangerous working conditions (e.g. poor air conditions, harmful materials)	Loss of jobs Industrial workers of all levels are worried about their employment status as robots may replace them
Quality The possibility of human mistake that employees might face during manufacturing process will be eliminated	Expensive In the long term, robots are cheaper than humans, they pay off over time, but they have a high initial cost and expensive repair services
Efficiency The cost of having a human being to handle manufacturing operations is more costly than robots. Robots would reduce production cost by eliminating worker wages	Difficult learning It's very easy to teach a person to move object from point A to B. However, the training of robots for such things involves skilled and certificated specialists

Productivity	Non-adaptive
Industrial robots don't get tired, they are stronger, faster and more efficient than people. Machine can work without breaks what increase a productivity	Robots are bad adaptive at dealing with changes that don't comply with their programmed rules. If something changes, they torn off.
Prestige	Limitation
Robots are great as marketing tool to improve the reputation of company and mostly are used for PR	Absolutely not all functions are integrated into robots, so success or failure of industrial robots depends on how smart is coded its system

Table 1: Pros and Cons of Industrial robots

Macro effects are another general problem associated with job losses. People who think about "big picture" wonder how the displacement of manufacturing jobs could impact the national and global economy. How can this huge unemployment be compensated for and how can the perceived success of robotics be limited from being absorbed in other industries? (2020)

For these questions CNN gives extremely effective analogy saying that "horse vs car" is the same as comparing "people vs robots". The population of horses peaked about a century ago as they were a main form of transport. But these numbers had decreased since cars became a mainstream. As a result, new professions have appeared for people, such as drivers, highway builders for cars, road traffic controllers, mechanical engineers and etc. Over time, whole new vehicle industries have been developed which we still using today, of course this development influenced on creation of large number of new jobs.

As a conclusion, work that doesn't require analytical and critical thinking is more fragile, therefor it is easier for machine to process it. In the meantime, other jobs will appear in the world which will be more feasible for people.

3.4.3 Intelligent robots

Intelligent robots are the thirds generation of robots which are designed not only to implement physical and motor functions but also to solve intellectual problems. For execution of human missions an intelligent robot has the ability to plan its actions in unpredictable and rapidly changing environment. Such robot is characterized by advanced

information processing of microprocesses, rich arsenal of logical operations, system of solution recognition and inclusion of elements of self-programming. It radically varies in complexity of functions and the perfection of the control system which incorporates some elements of artificial intelligence from robots of second generation. The ability to learn from experience and adapt in the process of solving problems is characteristic feature of intelligent robot. Intelligent robots are not so much programmed to simulate human physical behaviour as to automate human intellectual activity. There are numerous types of intelligent robots, such as android robots, gaming and household robots, military, medical and space robots.

Intelligent robotic systems have found applications in the field of passenger transportation. An experimental "Google driverless car" series of autonomous vehicles for urban environment has been successfully tested in USA. The intelligent control system of such vehicles allowed the traffic situation to be adequately assessed and travel in autonomous mode for long distance. Subsequently, major car manufacturers have already announced their mass production of driverless vehicles.

The impact of robotic systems in medicine is very significant and especially great advances were made in surgery. As an example, robotic surgical system "Da Vinci" created by American company "Intuitive surgical" has carried out over 200 000 operations around the world. Furthermore, research have close to integrating the means of interacting with technology directly into the human brain over the past 10 years. Bionic prostheses and artificial vision systems controlled by means of neurocomputer interfaces have already become a reality. (Orenstein, 2012)

Significant progress has been made in the space sector too. Nowadays space robotics gaining popularity rapidly. Space robots are robots that are designed for use in space, in the orbit of the Earth and other planets, on surface of different space bodies for purpose of space and galaxy research. Use of robots outside the Earth's atmosphere is obviously good robot's application. There are a lot of reasons to use them as a getting out into space, being there and coming back is very dangerous process for human. In addition, at the moment it's completely difficult to move people to another planets. But it's possible for space intelligent robots. For such purposes Mars rovers were created. "Perseverance", previously

known as MARS 2020, is a NASA rower launched on 30th of July 2020 with expected land on Mars in February 2021. One of the key tasks of this rover is identifying potential signs of life and collecting materials with their possibility to return on Earth. Furthermore, scientists are planning to use the rover as a tool to research the conditions for constructing a sustainable base on the Mars surface. (NASA, 2020)

Intelligent robots would support the development of uninhabited territories of the Earth and space at a new technological level. At the same time human's position in this new automated world needs to be continuously supervised. People need to try to ensure that infinitive possibilities of robotic systems are not wasted but used for individual's growth and solving universal problems.

3.5 Cybernetics

Cybernetics is a study of general control laws in machines and living organisms. Such term was suggested by Norbert Wiener in 1948. This science was emerged at the intersection of mathematics, logic, semiotics, physiology, genetics and sociology. Cybernetics involves researching feedback, black boxes, control and communication in living organisms, computers and organizations.

The appearance of cybernetics is mainly due to the need of creation of complex automatic control systems. Unlike other sciences which are also associated with creation of such systems cybernetics is not engaged in the analysis and development of unique technical issues but studies characteristics of all control processes regardless of their physical existence. Cybernetics structures are considered abstractly regardless of their material nature.

The main goal of cybernetics is to establish a single control process theory. All controlled systems are the objects of cybernetics and systems that can't be controlled can't be an object of cybernetics study. Example of cybernetics systems are automatic controllers in technology, computers, the human brain, biological populations and human society. "Each of these systems is a collection of interconnected objects or system elements capable of perceiving, memorizing, processing and exchanging information. Cybernetics establishes general concepts for developing control systems and systems for the automation of mental work." (ai-news.ru, 2019)

The most significant ideas brought together by cybernetics are following:

1. Artificial intelligence and Robotics
2. Theory of algorithms
3. Recognition of pattern
4. Learning systems theory
5. Automata theory
6. Theory of signal transmission
7. Optimal control theory
8. Decision theory
9. Control theory

To synthesize solutions, cybernetics use informatics and different directions of mathematics:

- Mathematical programming
- Computer science
- Mathematical analysis
- Linear algebra
- Convex geometry
- Theory of probability
- Mathematical statistics and econometrics and etc.

For artificial intelligence are important not only technical but also general, cybernetical principles which perform regulatory role in scientific research. A deeper analysis of the ways of self-organization of matter was made possible by cybernetics. This science is used in machines and living organisms to transfer, process and store fundamental knowledge and information.

3.6 Theory of game

Artificial intelligence is truly influencer of the development of a range of industries and games are at the forefront of AI evolution. This is demonstrated by the fact that gaming environments becoming a popular training tool in reinforcement and imitation learning. Video games are one of the most dynamic and technologically advanced sectors of global economy based on intersection of different fields such as programming, designing, mathematics, marketing and etc. Additionally, this sphere is especially important because of the high level of young people's interest. Earlier, we studied the term artificial

intelligence and its use in different areas of our lives. The practical part of this bachelor thesis is concentrated on AI in games therefore, it is necessary to study the term game as an independent discipline.

Game is a mathematical implementation of the interaction of multiple participant or players. Mathematical method which studies optimal strategies in games is called theory of games. The main task of game theory is solving conflicts between players. Conflict can apply to various fields of human interests, for example economics, sociology, politics, even military relations. Conflicts is any circumstance in which are affected interests of two and more participants. There is a basic set of tactics that can be applied to each player. Overlapping of multiple players strategies generates a certain scenario in which each participant gets certain results. Results can be either positive or negative. While choosing strategy it is important to consider not only making benefits for yourself but also possible actions of opponent which will effect on whole game situation.
The foundation of game theory was stated in 18th century but only in 1944 the first mathematical elements of the theory were discussed by American scientists John von Neumann and Oskar Morgenstern. Since a sharp jump in the US economy after the Second World War and after the huge support of science by government Game theory started to be used in economics, biology, cybernetics and other directions. During and after the Second World War the army became seriously interested in theory of games as it was a powerful tool for strategic military decisions. In early 1950's John Nash, American mathematician, introduces methods of analysis in which all participants either win or fail. These compounds of game were called "Nash equilibrium". Nash's work made a major contribution to the advancement of game theory and the mathematical methods of economic modelling have been revised.

3.6.1 Nash equilibrium

Nash equilibrium is a solution concept where series of strategies for two and more players will not increase their winning possibility by changing strategy if other players don't change it too. According to Nash theory players should use the optimal strategy to create a stable equilibrium. It is beneficial to maintain this balance as any changes would make their situation worse. John Nash suggested that A. Smith's classical approach to game where every player is for himself is not optimal. More optimal methods are when players

want to do better for themselves and for others at the same time. Nash's equilibrium is better to understand by following example of Prisoners' dilemma.

Dilemma:

"Two criminals A and B were caught at related crimes at the same time. There is reason to believe that they acted in collusion and police isolates them from each other and offers the same deal: if criminal A testifies against to other and criminal B remains silent, then criminal A is released for helping the investigation and criminal B gets the maximum sentence imprisonment for 5 years. If both are keeping silent their act is subject to an easier article and they are sentenced for 1 year. If both testify against each other they receive a minimum sentence for 3 years for each. Each prisoner chooses to remain silent or testify against the other. However, neither of them knows exactly what the other will do." (Guran, 2012)

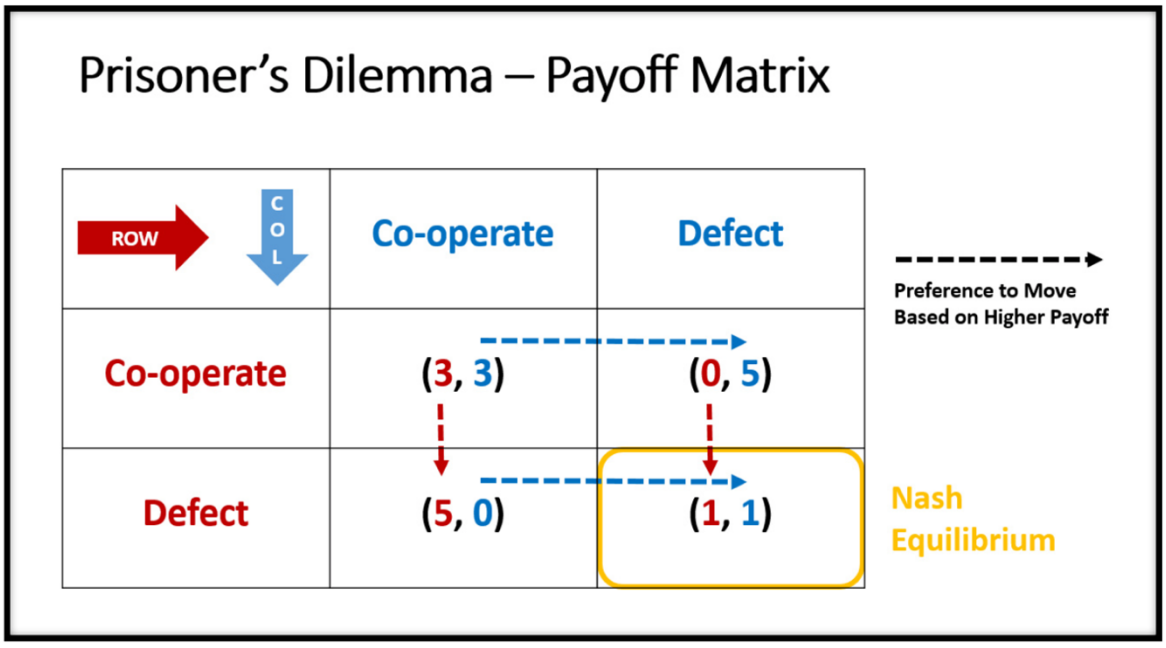

Figure 6: Prisoner's Dilemma (www.studycas.com)

Decision:

If criminal B is silent for criminal A it is better to turn him in and be released. If criminal B speaks then it is also better to tell everything and get only 3 years instead of 5. So, if each player chooses the best position for himself both will hand over each other and get 3 years, which is not ideal situation for both. If two criminals think about common good, they would receive only 1 year as you can see in Payoff Matrix.

As a conclusion, from this example it is clear how Nash's equilibrium works in game theory thereby proving the Nash's theory.

3.6.2 Types of games

Game theory always has been focused on modelling the most common interaction patterns that we can find in AI systems. Important element in designing of successful gamed AI systems is understanding of various types of game. Different types of games are helping to analyse problems and possible scenarios which might be raised during the game. These types were formed based on the number of involved players, collaboration between them and on symmetry of games.

There are five types of games that are mostly used in AI environment:

1. Corporative and non-corporative games
2. Normal form and Extensive form games
3. Simultaneous move games and Sequential move games
4. Zero sum and Non-zero sum games
5. Symmetric and Asymmetric games

Corporative and non-corporative games

Corporative game is a conflict in which players can communicate with each other and join in groups in order to achieve the best results. Good example of such game is intellectual card game Bridge, which is comparable in complexity with chess and Go. In Bridge points of each player are counted individually but the pair with highest amount of points is winner. Contract agreement is also modelled on corporative games. War between 2 participants is a perfect example of non-corporative games, where players can't join to each other. In comparison of two types non-corporative games explain scenario in more details and show more accurate results. Corporative ones consider a process of game as a whole.

Normal form and Extensive form games

A further essential classification of games is based on the type of available information. In extensive form of games players can see and follow steps of opponent. Chess is example of extensive game. But nowadays the great amount of games is based on normal form, where all steps of opponent are hidden. Perfect example of game with normal received information is poker.

Simultaneous move games and Sequential move games

Sequential move game is played in environment where both players take turns and each player has information about previous steps of opponent. Such as example of sequential move games can be board games. In simultaneous move games both players can make acts simultaneously. Securities trading is example of such parallel games.

Zero sum and Non-zero sum games

Games where the win of one player is equal to loss of another are called zero-sum games. As example of zero-sum game could be dispute situations when player win some amount of money and his opponent would lose this amount. In the game with non-zero sum the total price of game can change and benefits of one player don't take away possibilities of winning other one. Example of non-zero sum games is chess, where by turning a pawn into a queen first player increases the total sum of his pieces but not take anything from second player. So, in non-zero sum games the loss of one player is not sufficient conditions to lose whole game, although such scenario might happen.

Symmetric and Asymmetric games

Symmetry of game is one of the easiest game classifications. Symmetrical game is based on environment where all players have same goal and result can be depend on the strategies which will choose a player. Chess is classical example of such games. In real life we are facing more with asymmetric games as each player has his own goal and sometimes, they are conflictive. Business negotiations are example of asymmetric games, in which each company has its own goal, analyses the outcome from different point of view.

There should be mentioned that Nash's theory of equilibrium is not suitable for many asymmetric game types. Nash's theory assumes that players have limitless computing power, which happens rarely in actual game environment. In addition, many Nash's equilibrium models don't take into account the notion of risks that are present in these game types. As a conclusion there are many asymmetric game conditions that are challenging to use Nash's equilibrium.

3.6.3 Game AI

Game artificial intelligence is a group of software programs used in video games to build illusion of intelligence in behaviour of computer-controlled characters. In other words, it is possible to describe artificial intelligence as a set of techniques used to construct the actions of "non-player characters" (NPCs) or non-player controlled characters.

In game scenarios, AI can be introduced in various ways. The most common use case for artificial intelligence in video games is route finding. These are the paths in which the opponent moves from one destination to another, taking into account the topography of the terrain, obstacles or dangers in the form of enemies, NPCs can move in different environments in a coordinated way preventing collisions between them, and working together to find solutions.

Artificial intelligence in video games is also used to balance complexity. In other words, non-human opponents can adapt their strategy to the skills demonstrated by the player. (Avilez, 2020). Thanks to the ability of AI to learn in games were appeared so-called hunting abilities. Enemies used only two tactics in older games: attack and protection. But thanks to the advancement of artificial intelligence, now they can evaluate their capabilities in a battle. For example, the opponent may be more aggressive if the player is unprotected, planning joint tactics to surround the player, and attack from different distances. It is also essential to note that enemies may know the number of remaining lives of players in certain modern games and based on this, trigger certain behavior. Furthermore, in order to evaluate the possibilities of victory in the conflict, the NPC may know the number of remaining bullets or weapons of the player.

4 Practical part

Because AI is constantly evolving in various sectors of our lives it was fascinating to compare what capabilities AI would demonstrate in comparison with humans at the moment, and on the basis of this, I would like to check in which intellectual capabilities weaker AI and stronger humans. Based on the results and analyses obtained, I would like to demonstrate what skills should be taught in the future to AI and how it can be used in different sectors of life and what business ideas this can serve for start-ups.

In the practical part of this bachelor thesis the comparison of abilities of human intelligence with artificial intelligence were measured within gaming applications: Chess, Semantris, StarCraft.

4.1 Chess

Chess is undoubtedly intellectual but at the same time clearly formalized, simple in structure and compact task, that's why it is a convenient object of practical research in artificial intelligence. Computer chess is a term from the field of artificial intelligence research, meaning the creation of software and special computers for playing chess. One of the first human-computer competitions in chess game was in 1978. David Levy, an international master in chess, played against the Chess 4.7 program. In these competitions, Levy was able to win the program. The next major game after that was Garry Kasparov's game against Deep Blue. Deep Blue is an IBM built chess computer. Garry Kasparov is Soviet and Russian chess player, 13th world chess champion, International grandmaster.

4.1.1 Garry Kasparov vs Deep Blue

Game 1: In the first game Kasparov played white. Kasparov opens the game with Reti's opening and puts bishops on both flanks, such move is called double fianchetto. This strategy means an immediate exit from well-analyzed opening highways. And it presupposes non-standard maneuvering on his half of the board, game with a long accumulation of non-obvious positional advantages that are understandable to the masters of the game, but hardly realized by a machine evaluating a position with a given stereotype. The peculiarity of the first game was that none of Kasparov's pieces had ever

been on the opponent's half of the board. And nevertheless, it was the atypical maneuvering which was deserved victory. Score is 1:0.

Game 2: Kasparov played black. Seeing a simple perpetual check is not so easy for a computer. The black queen can check from a sufficiently large number of squares, while the white king can evade an attack in various directions. These attacks and withdrawals can be combined in different ways. A person can understand the whole situation at once, and the computer going through all the moves will suddenly come across a huge tree of options. And to see the end of the cycle, the computer would have to look deep into 30 moves, and it would take more than an hour to iterate over all the branches that arise. Score is 0:1.

Game 3: Kasparov played white. In terms of defense, the machine had a difficult position, and made movements that were actually perfect. Not finding a win, the world champion agreed to a draw. Score is ½: ½.

Game 4: Kasparov played black. He chooses the Pirc Defence. In general, Garry managed to outplay the Deep Blue, but the computer used every opportunity and found more and more resources to hold the position. Score is ½: ½.

Game 5: Kasparov opens the game with Reti's opening and the computer exchanged the bishop for the knight on the 4th move. At the end of game Deep Blue coordinated the forces in the final attack, which was led by the black king. Score is ½: ½.

Game 6: Kasparov played black. This time he used the Caro-Kann defence. This opening allows black to build a strong but passive position. During the game, the computer gives up the knight. And on the next move Garry makes a decisive mistake. Instead of immediately taking the knight with a pawn, he makes an intermediate move with the queen, after such a move it is difficult to win. Score is 0:1.

Bellow table shows the final results of competition between human and computer. As visible form table Deep Blue is a winner in chess game.

Game	White	Black	Result	Note
1	Kasparov	Deep Blue	1-0	Kasparov won
2	Deep Blue	Kasparov	1-0	Deep blue won
3	Kasparov	Deep Blue	½: ½	Draw
4	Deep Blue	Kasparov	½: ½.	Draw
5	Kasparov	Deep Blue	½: ½.	Draw
6	Deep Blue	Kasparov	1-0	Deep blue won
Total Result: Deep Blue 3½ - Kasparov 2½.				

Table 2: Deep Blue vs Kasparov (www.jamesaltucher.com)

4.1.2 Chess engine vs Human

Chess engine is a computer program designed to calculate variants of chess moves. The chess engines Komodo and Stockfish were marked as the strongest engines for nowadays. Bellow table shows the best chess engines characteristics.

Rating list	Moves per minute	Updated	Bit extension	Total number of games	Engine name	Rating
CCRL	40/40	7 Nov 2020	x64	1 189 229	Stockfish Komodo	3516 **3419**
SSDF	40/120	11 Jul 2020	x64	152 481	Stockfish Komodo	3354 **3471**

Table 3: Chess engine rating (SSDF) (CCRL)

CCRL - Computer Chess Rating Lists.

SSDF- Swedish Chess Computer Association.

One of the last Human and AI chess competitions was between Nakamura and Komodo. Hikaru Nakamura is American grandmaster in chess game, five-time US champion and one of the world's leading chess players.

Since people can no longer compete with the computer on equal terms, the grandmaster got a head start in each of 4 games:

In the first game - the computer played with black and without the f7 pawn.

In the second - the computer played white without a pawn f2.

In the third - the computer is white without the rook a1, the man is without the knight b8 and with the rook a8 in his place.

In the fourth - the person plays white and instead of the first move makes 4 any moves without crossing the middle of the board.

Game 1: Nakamura starts with an advantage in every game, so it's enough for him not to make mistakes. However, when he is facing an opponent with a rating over 3400 (Hikaru's rating at the time of the game was 2595), it is not easy to play. Until the 35th pass, the grandmaster retained the advantage of one pawn, but was afraid of a harmless rook penetration on the d8 square. This was a crucial mistake because of the return of equality by the neural network. The score is

½: ½.

Game 2 and Game 3: In a similar scenario, the second and third games took place - Nakamura played well but still did mistakes. Bellow graph demonstrates an accuracy of grandmaster of 95.8 in the third game when his opponent played with an accuracy of 97.4. The score is 1½: 1½.

Figure 7: Accuracy of AI and human (SamCoperland)

Game 4: Nakamura makes another mistake after which he gets into time trouble. The opponent wins because the chess player had to spend much more time thinking about moves.

The score is 2½: 1½.

The chess player managed to prove in this match that the superiority of the best programs over the best people at the moment is between 1 and 2 handicap pawns. Of course, this estimation is quite uncertain, but for a reliable estimate, several thousand games between individuals and programs need to be played.

The games were played with 45 "+15 'controls, that is, 45 minutes per game and 15 seconds of adding each move. Usually, shorter controls give an additional advantage to the computer, while longer controls slightly increase a person's chances. Computer in a second will manage to remove losing moves, while due to the exponential growth of the tree of variations, each subsequent improvement in the analysis takes more and more time.

4.1.3 AlphaZero vs Stockfish

AlphaZero is a DeepMind neural network program that can play Go, Shogi, and Chess. It is a more generalized version of the AlphaGo Zero (AGZ) algorithm.

In 2017, DeepMind released the AlphaZero software, which beat the world champion in chess programs, the Stockfish, after just 24 hours of training.
Although traditional programs evaluate positions in a game based on grandmaster experience, AlphaZero evaluates positions using deep neural networks, which takes more time per position. In chess, AlphaZero analyzes 80,000 positions per second, while Stockfish analyzes 70 million. AlphaZero uses Monte Carlo quest to compensate for the low number of estimates per second, allowing it to concentrate more selectively on the most promising choices.
In the chess games of AlphaZero against Stockfish, each program had one minute of time per move. In contrast to Stockfish, AlphaZero had the best computer hardware. AlphaZero won 25 games with white, 3 games with black, and drew the remaining 72 games from a normal starting position. As a result, AlphaZero's artificial intelligence is currently the most powerful of all chess, shogi, and go programs.

4.2 Semantris

Semantris is a game focused on machine learning technology and natural language comprehension, with a series of word associations. The AI goes through all the words in the game each time the player enters a clue and selects the ones it feels are most related. As the AI has been trained to work with spoken text covering a wide range of topics, associations of several kinds can be made. It is important to note that if the player gets the highest number of points in the game Semantris, then the AI did a good job with clues from player to search for associations
The collaboration with a team composed of different individuals, with different analytical abilities, skills, preferences and age was proceed, to incorporate this part of the practice. It is also essential to mention that the team consisted of members with an average academic performance and there were no professional players and analysts in the team. This team received a task in the form of a testing and playing Semantris game that was implemented by using AI. At the end of the game, all team members were asked bellow questions about the outcome of the game, and each player was given the opportunity to share their impressions of losing or winning AI.

Question 1

What was your result in Semantris game?

The following graph shows the score of the players in the game. As it is visible, most of the players received an average score of 2000-3000, but there were also those who were able to get the highest results and also the lowest.

Number of players who were able to receive the highest score is 12,5%. The lowest score was achieved by 12,5 % players.

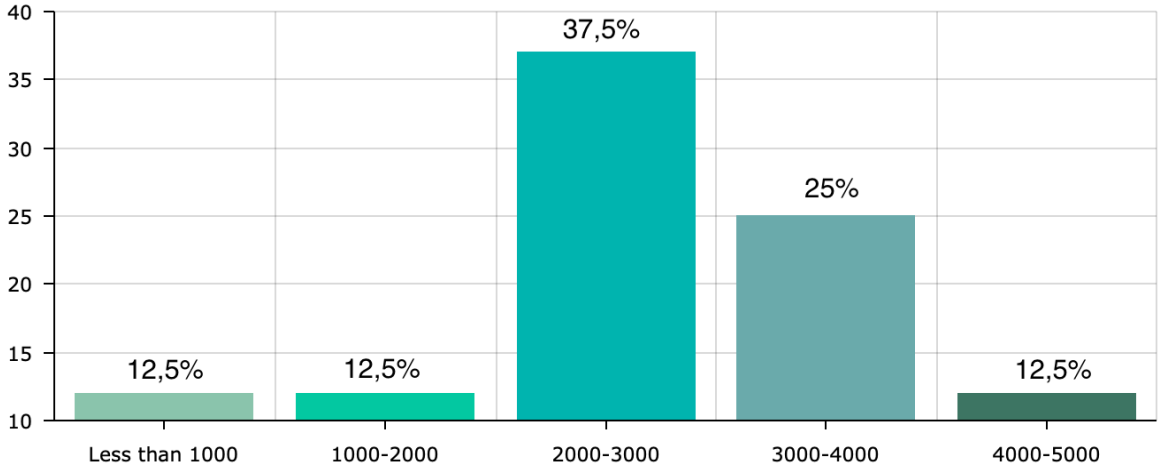

Figure 8: What was your result in Semantris game? (own source)

Question 2

Have you faced a scenario during the game when the AI was unable to find an association for the word you entered?

71,4 % of the players were faced with the fact that the AI could not match the associations to the word gamer texted and the remaining 28,6 % did not have such situations.

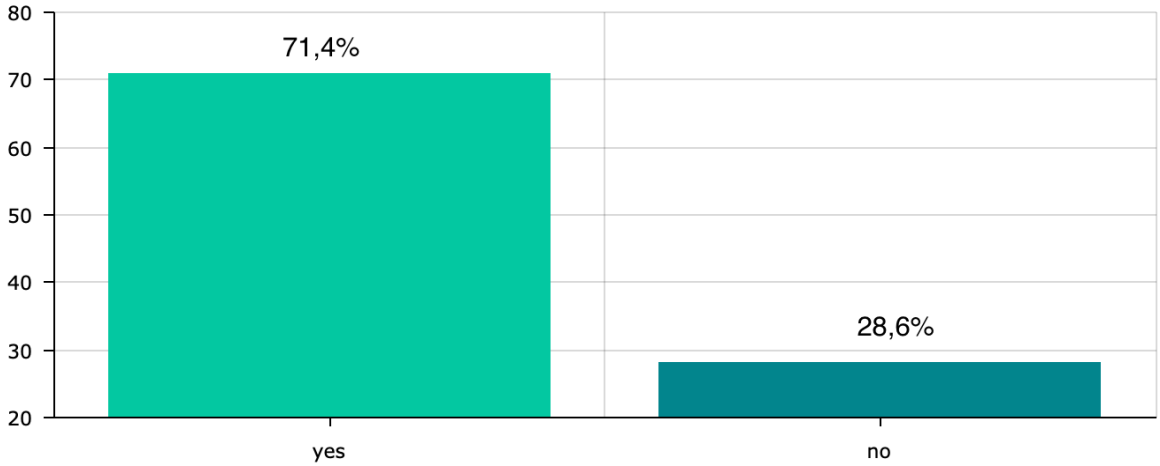

Figure 9: AI was unable to find an association. (own source)

Question 3

Was the AI able to find multiple associations for your given word?

The team players were also asked whether the AI could identify several associations, thereby connecting them logically, the results show that not all players noticed such AI capabilities, only 28.6% were able to notice such AI behavior.

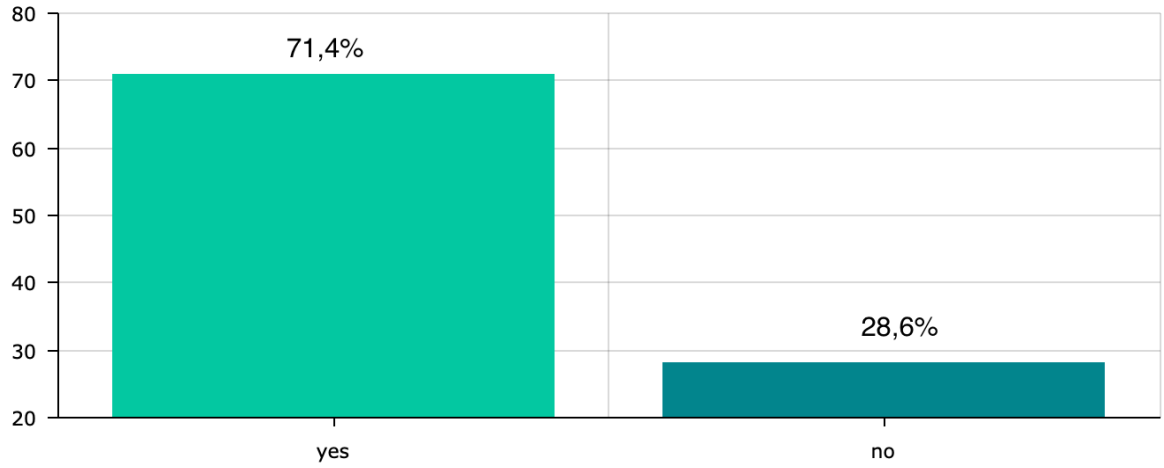

Figure 10: Was the AI able to find multiple associations for your given word? (own source)

Question 4

Which of the below options AI could recognize less?

Most often, the AI faced difficulties in finding associations when entering antonyms and homonyms, as the following graph shows, and it was able to easily find associations to synonyms, but it was harder to cope in the remaining two cases.

Difficulties with antonyms was 38,5% and with homonyms was 46,2%.

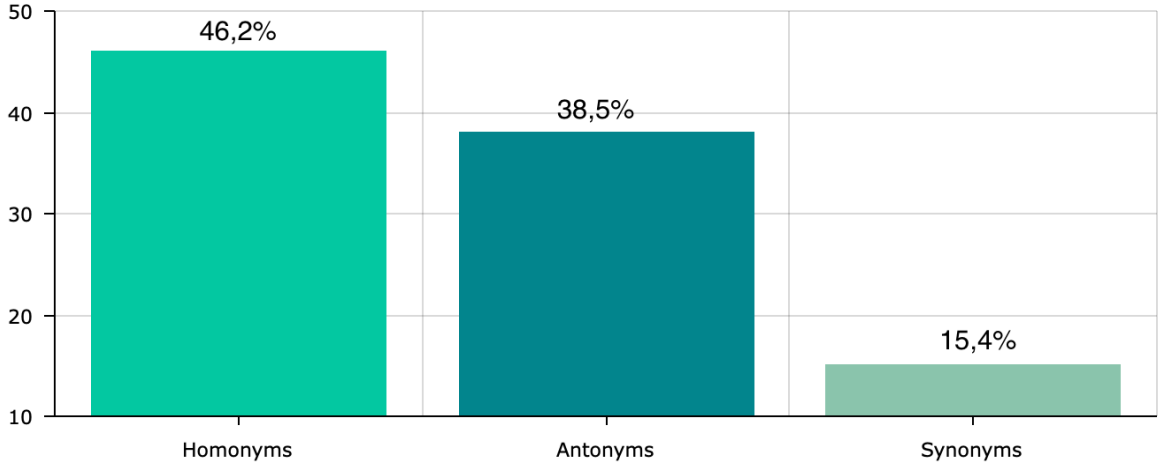

Figure 11: Which of the below options AI could recognize less? (own source)

Logical reasoning is the ability to understand and logically work through concepts expressed in words. It tests the ability to extract and work with meaning, information of the

main part of the text. An individual seeing the words “sun”, “water” and “plant”, for instance, can logically associate them with “photosynthesis”, but during the game AI could not make such association and destroy words “sun”, “water” and “plant”.
Every day people are faced with many tasks, the solution of which requires them to be able to think logically. Human is more capable of logical thinking than AI.

Natural language processing is the analysis of natural language in all of its forms, meanings and contexts. Sometimes the same word can mean different things in different contexts. During the game, seeing the words “music” and “tape” the player tried to enter the word “band” (“band” has 2 meanings: music band and tape or ribbon) to check how AI recognizes the homonym, according to the results, the scores were defended only with the association to the word “music” and for the word “tape” AI could not recognize any associations.
Understanding the correct form, meaning, and context of language is one of the characteristics of intelligence. AI is much weaker at recognizing words and the meaning of text than humans.

4.3 StarCraft II

StarCraft II is a real-time strategy computer game developed by Blizzard Entertainment in 1998. Compared to board games (chess, go), complex real-time computer games have an important feature: events in them develop in the same way as in the real world, constantly changing. In this sense, the ability of an AI to play StarCraft II successfully has serious applied value. The following table shows the relative difficulty of the board game Go and StarCraft II.

Criteria of Complexity	Go	StarCraft
Availability of information	Extensive form of game (full information)	Normal form of game (incomplete information)
Number of actions	361 actions	10^{26} actions
Number of moves per game	>100	>1000

Table 4: Complexity criteria of Go and StarCraft (The AlphaStar Team, 2019)

The player must select one of three different alien races - zerg, protoss, or terrans - according to the rules of the game. They all have distinctive features and skills (professional players usually play as for one race). Each player starts with a certain number of working units, which collect the initial resources of the game world to turn them into

structures, technologies, and other entities that ensure success. To win, the player must carefully balance the management of his "economy" and the management of game units. It is important to establish short-term and long-term strategies, to be able to respond to unexpected situations.
In StarCraft II, important knowledge is hidden from the player and can only be identified by the "scout" unit, unlike chess or Go, where the players see every move of opponent. Real-time action must continuously be carried out by players. It is important to control hundreds of different objects at the same time, which leads to many variations of the game that, unlike chess, do not lend themselves to brute computational power.

AlphaStar is a software developed by DeepMind, which plays StarCraft II and was the first AI reached the level of the best players in the eSports discipline without special restrictions. AlphaStar was created using deep learning techniques - with reinforcement and with a supervisor. Supervised learning is one of the methods of machine learning, during which the system under test (agent) is forced to learn using examples of "input-output".
Reinforcement learning is one of the methods of machine learning, during which the system under test (agent) learns by interacting with some environment, it doesn't need labels of input-output pairs.

4.3.1 Learning

There is no best strategy in StarCraft II, so the AI must constantly explore and push the boundaries of "knowledge." For AlphaStar's training, a scalable, distributed program that supports multiple agents training in many thousands of concurrent instances of StarCraft II was created. Each player selects one of three races in StarCraft - Terran, Protoss or Zerg, each with its own characteristic. Three main agents (one for each race) and six League Exploiters (two for each race) were created during training. Each agent was trained over 44 days using 32 third generation tensor processing units (TPU23) and was evaluated during training at three different stages: after supervised learning (AlphaStar Supervised), after 27 training days (AlphaStar Mid) and after 44 training days (AlphaStar Final). Tensor processors belong to the neutron processor class and are intended for machine learning purposes. Its performance is estimated at 420 teraflops (operations per second). Maps and opponents were chosen in the process of matching players. The matches were played

blindly: the identity of the opponent was not revealed by AlphaStar and was played under an anonymous account.

4.3.2 Results of learning

"For all three races, AlphaStar Final won 6275 MMR (Match Making Rating is an approximate indicator of a player's skill) for Protoss, 6048 MMR for Terrans, and 5835 MMR for Zerg, making it above 99.8 % of human players for all three races. An average rating of 3699 was achieved by AlphaStar Supervised, which is above 84% of players and demonstrates the efficacy of learning with a supervisor. "(Oriol Vinyals, 2019) On the next matrix is visible the results of the AlphaStar game against human opponents in each of the races.

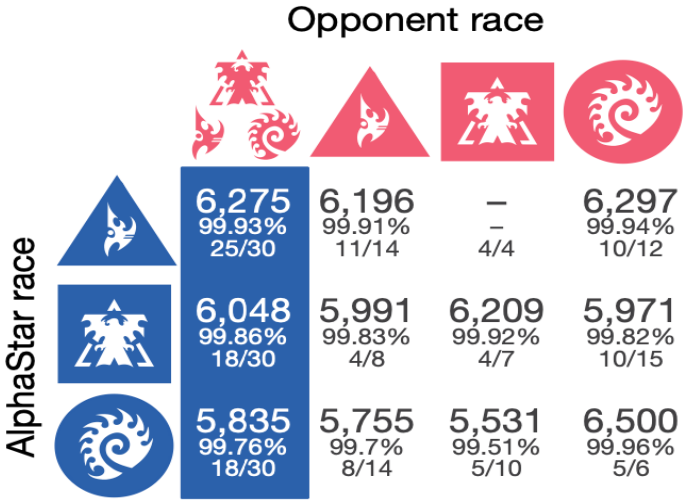

Figure 12: Training results 1 (Oriol Vinyals, 2019)

Below graph shows MMR indicators for each skill level. As it is visible from the graph, in geometric progression AlphaStar improves its abilities and techniques and reaches the level of Grandmaster achieved the result over 6000 MRM.

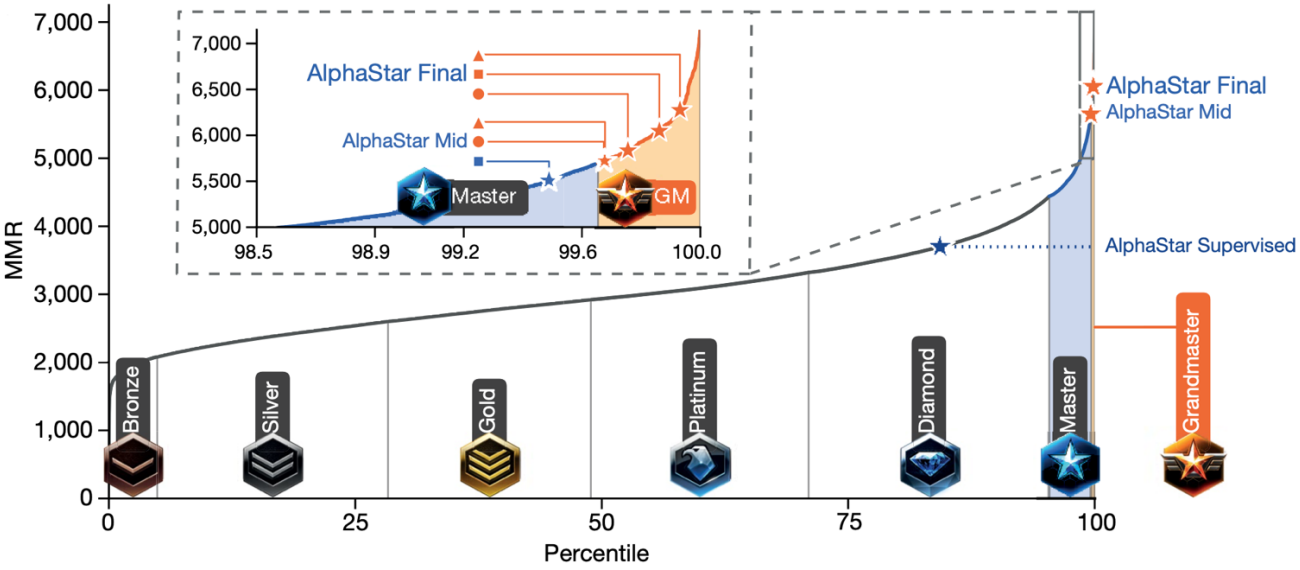

Figure 13: Grandmaster's MMR (Oriol Vinyals, 2019)

4.3.3 A competition between AlphaStar and the Grandmasters

A competition between AlphaStar and the best players, the Grandmasters, was the next step in evaluating the abilities of AI and humans.

Mana (Grzegorz Komincz) and TLO (Dario Wünsch), some of the best StarCraft players, took part in these competitions.

TLO is a member of the German national team and plays for the top team Liquid. Statistics indicate that he has 135 wins (50.75%), 129 defeats (48.50%) and 2 draws (0.75%).

Mana has won a dozen medals at major European and World eSport Championships. Player statistics indicate that 177 battles were won by Mana and 146 battles were lost, 3 draws.

For this competition AlphaStar was trained during14 days. It is approximately 200 years in real-time conditions. (The AlphaStar Team, 2019) The neural network was initially educated by watching the games of the best players in esports. AlphaStar learned to reproduce traditional strategies and to combine different tactics. By analogy with chess, this was an analysis of the games previously played by grandmasters.

Then the AlphaStar League was formed. Neural network agents were forced to play with each other during AlphaStar Training League. Gaining their own experience, agents began to develop in different ways. The main goal was to find a winner not among humans, but among differently trained neural networks. Then, an artificial selection began among the agents: agents with the best private skills were identified, then these skills were transferred

to other, more perfect instances of the neural network. The next graph shows that the neural network has surpassed humans in terms of the complexity of the game skills.

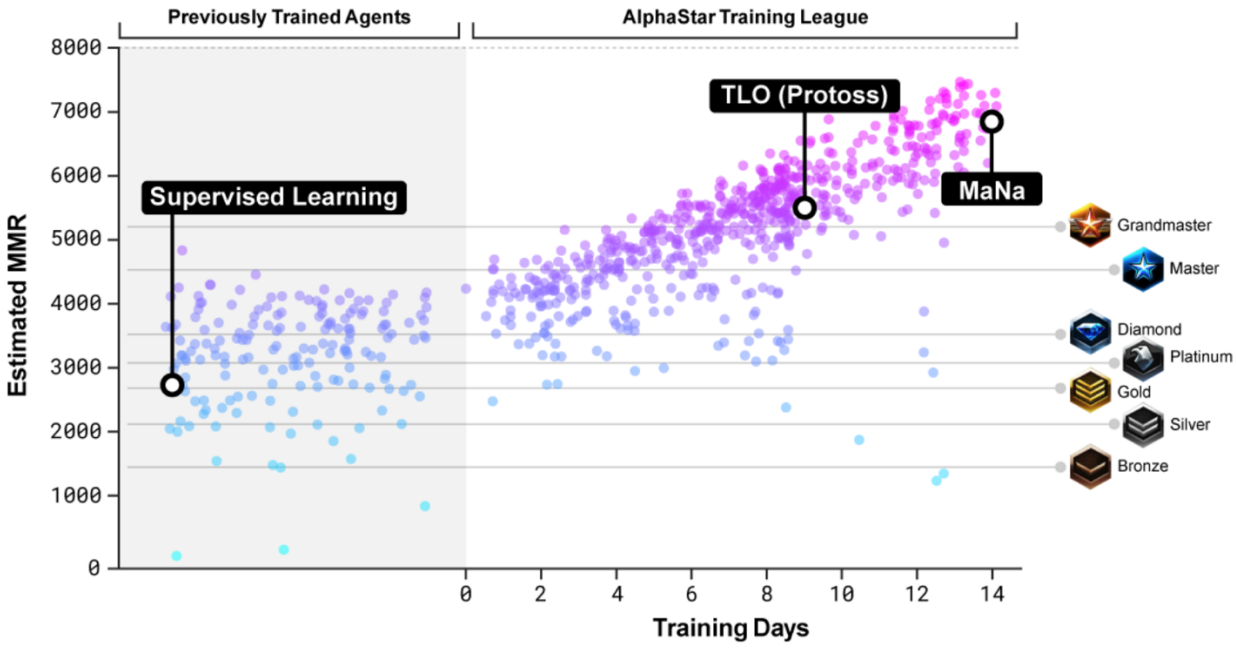

Figure 14: 14 days training (The AlphaStar Team, 2019)

In eSports, a competition is played most often as a series of five heads-up games. At the competition, the Protoss race was played by the neural network and by esports players. TLO was the first one who played against AlphaStar.

Results of first competition

Game 1: During the game protection was ignored by AlphaStar. It makes small errors in the course of the game, which it corrects due to more detailed tactical control of the situation. The score is 1: 0, AlphaStar is winner.

Game 2: Protection is again ignored by AlphaStar. The AI game focuses on having an edge in the economy. At the beginning of the game the military advantage was in human beings, but the AI did not allow them to be used because of better control of battlefield units and evasion from a decisive battle before closing the unit gap. The score is 2:0.

Game 3: AI constantly attacks the player's base in small groups and gradually gains an advantage in the game. All attempts by TLO to attack are unsuccessful, the AI is constantly taking over the initiative. The score is 3: 0.

Game 4: TLO successfully repels the first attacks of the AI. AlphaStar uses small forces to separate the player's defence. By concentrating on defence, he does not attack and loses the economic race. The score is 4: 0.
Game 5: AlphaStar performs weak reconnaissance in the area of its base and is not ready for sabotage in its own rear. TLO utilizes this technique, but suddenly discovers that the AI is behaving the same way, but more powerful and aggressive. The score is 5: 0.

The next player who played against AI was Mana.

Results of second competition

Game 1: AlphaStar ignores protections. This is used by the player to obtain an advantage. AlphaStar breaks into the player's base and leaves him no chance. The score is 1:0
Game 2: At the same time, AlphaStar takes easy, but multiple acts that could have been parried by Mana, but not simultaneously - he loses focus and the initiative. The player tries to counterattack but loses due to insufficient effective management of his units on the battlefield. The score is 2: 0.
Game 3: For the first time, AlphaStar is attempting to close the entrance to its base - standard defensive move. Mana uses a similar tactic. But after the exchange of blows, with equal opportunities, the AI wins. The score is 3: 0.
Game 4: The competitors have joined the economic race and they are accumulating strength and do not attack. The AI monitors what kind of combat units Mana produces, and in return produces cheaper killers of these combat units. He has the advantage over AI after a series of fights. AI, controlling three small squads, separates the more powerful Mana's squad and makes him make mistakes over and over again. This is a new tactic that was not previously known. Mana loses the advantage and loses. Score 4: 0
Game 5: AlphaStar repeatedly attempts to conduct a clever operation at the enemy base to capture the mine, but Mana manages to fend off the threat, then goes into reconnaissance, but he is unable to determine which approach the AI has chosen. Meanwhile, AlphaStar unexpectedly creates a military base and prevents the player from developing, constantly increasing their capabilities. The score is 5: 0.

4.3.4 Reaction time

AlphaStar performed about 277 actions per minute in games against cybersports men, which is slightly lower than the average amount of actions for professional players (390 for Mana and 678 for TLO). APM (Actions Per Minute) counts every action performed. The peak values of the number of acts per time in AI also differ considerably. The peak APM of Mana is about 750 and half of them are spam clicks, while AlphaStar's is above 1500 and the acts of AlphaStar were more effective. EPM (Effective Actions Per Minute) counts every effective action. The peak value of TLO is 2000, a trick called "rapid fire" made this possible. TLO doesn't click very fast. He just holds a button - and the game registers that as 2000 APM, but again it is not counted as effective.

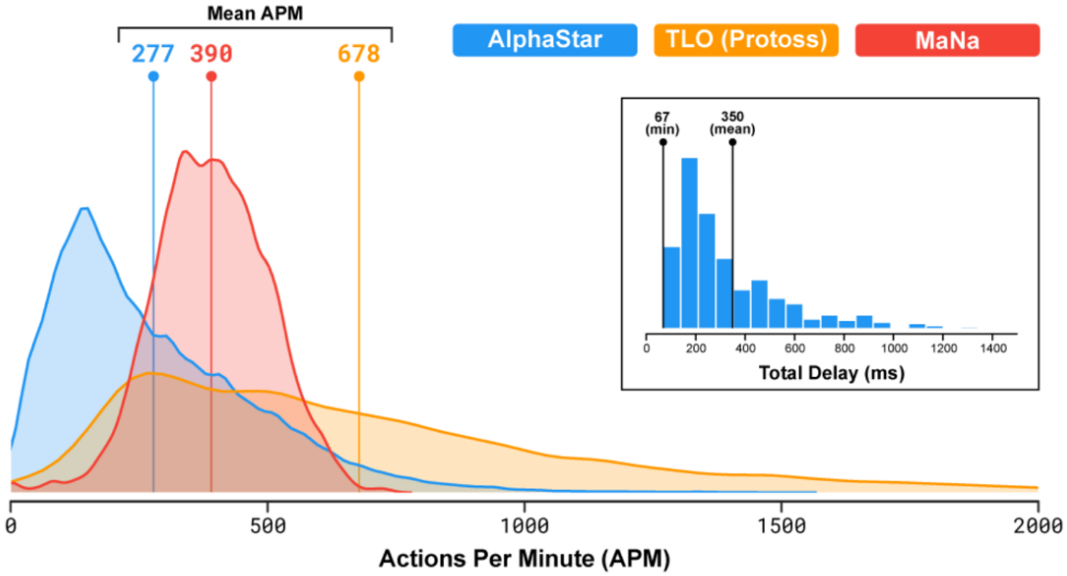

Figure 15: APM (The AlphaStar Team, 2019)

4.3.5 Visual processing

The next important criterion of comparison of AI and human capabilities is visualization. AI constantly monitored the entire explored territory through the available interface, without moving the camera, and people had to move around the map, focusing their attention at each moment in time only on one area. This gave AlphaStar an edge.
In the next pictures, difference between the AI and human vision of the screen is presented.

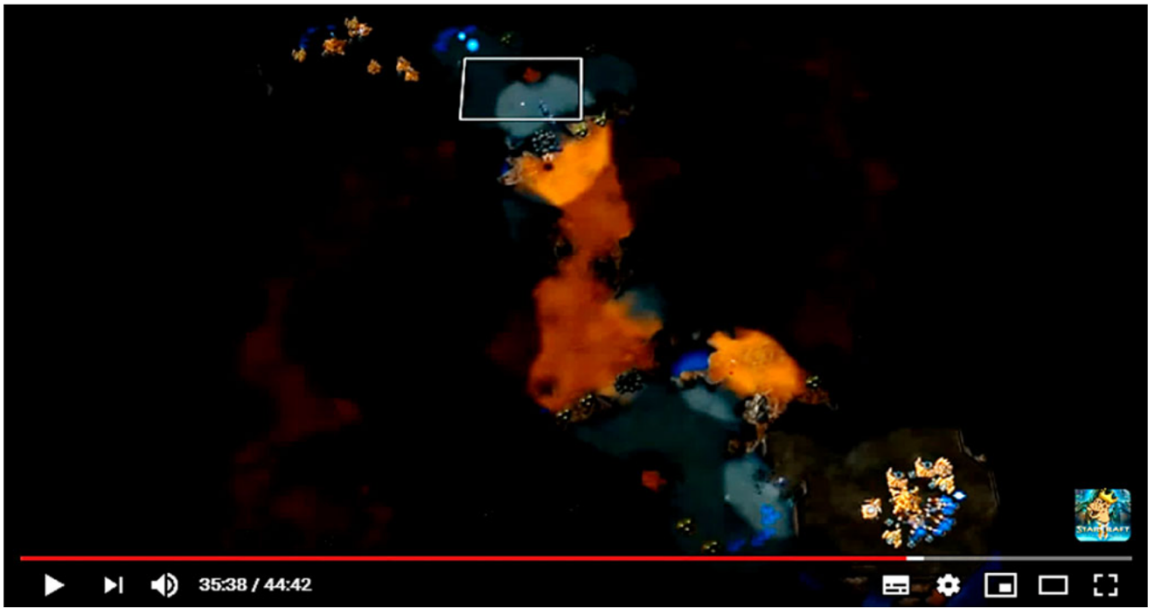

Figure 16: AI vision (Dellinger A, 2019)

Figure 17: Human vision (Steven Brown, 2019)

In competitions AlphaStar could see the attributes of his own and visible enemy units on the map directly, AI did not need to move the camera as it interacted through the basic interface or row interface. Playing in a reduced view of the territory was effective for AlphaStar. Comparatively, people needed to focus the camera during the game and about 30 times per minute the player switches his attention.

To make the conditions between human and AI equal, AlphaStar was transferred to a video interface, where it could move the camera 30 times per minute, thereby changing the perception of the game for AI.

AlphaStar spent a week learning to play in new conditions and new version using the video interface has reached almost 7000 MMR. Under the new conditions, Mana was able to defeat AlphaStar once, catching the AI on an unknown strategy. The total score is 10:1 in favor of the AI.

The following graph shows the comparative result of the game with and without switching the camera. The result between them is not very different, thus we can conclude that in the visual processing, AI is stronger than a person.

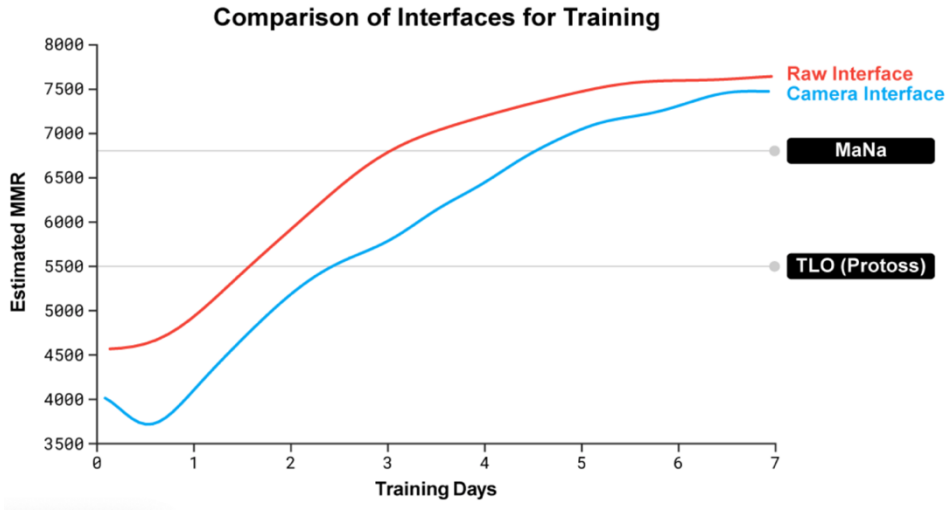

Figure 18: Camera vision (The AlphaStar Team, 2019)

5 Discussion

The AI capabilities in numerical computation have been enhanced for quite a long time. A computing device calculates suitable moves much faster using the so-called brute force, using minimax algorithms. The primary aim of numerical skill is to figure out how easily you get to the correct answer. AI capabilities in such calculations are much higher than humans.

Logical reasoning is a type of thought process in which a person uses logical constructions. The tasks of identifying contexts, which are easily solved by humans, are completely inaccessible for artificial intelligence, which is equipped only with formal logical tools. The fact is that the consistency of certain acts, processes, operations, reasoning is recognized not only by their "logical form". In order to be able to meaningfully apply "logical types," AI must be able to understand not only logically correct reasoning, but also that the AI is really in front of reasoning, not just its meaningless similarity.

Natural Language Processing (NLP) is a wide field of artificial intelligence and linguistics. It investigates the issues of natural language machine analysis and literate text production. The solution of these problems will enable a more convenient form of interaction between a computer and a person. The quality of understanding is influenced by a number of factors, including the natural language, national culture, and the interlocutor himself. One of the challenges in the natural language processing segment is the creation of universal language models and architectures that can solve a variety of text-related problems with a single system. That is, a system that would be able to "understand" textual information and communicate with an individual in the same way that someone who has read the text and has some experience will.

Learning is certainly an important criterion that can be compared. From the results of the games, it can be concluded that the AI needs less time to train. While the best players have honed their skills for years, the AI took days. Any knowledge in some situations may be less or more useful or not used at all. The distinctive capacity of the human brain or computer to
determine which data to store in short-term memory and which in long-term memory. Each type of information that we see, hear, feel or perceive is stored in memory for further establishing relationships with other objects and situations that we face in the future and helps in the decision-making process. AI does not find problems with memorizing more information, and how the human memory is structured is still being studied.

Visual processing is the ability to interpret visual information received from the outside world. Some people can understand and process information better if they see it in different forms (video or picture). During the game all players didn’t see the entire map of the territory and thus they chose strategies that led them to lose. But for AI there were no such issue since it sees all that happens at once and therefore increases the probability of its victory. Even in conditions when AI should switch the cameras to see the whole map it shows best results than humans. But it's important to note that this scenario is observed in gaming applications only. In other applications, like face recognition, AI does not exceed humans in visual processing.

We are faced with many random situations in real time, which involve a response from our side. A vigilant mind is required for all routine activities, such as playing, studying, cooking, driving etc. However, the timeliness of the response is very important. The ability to respond properly and in any given situation in a minimum amount of time can be considered a function of the brain's intelligence. So, for example, many players during the competition reacted more slowly to the attack from the AI, as they were in a stressful situation. A person in different conditions reacts to what is happening at a different speed and thus gives a different result. It should be noted that the reaction speed to attacks in the case of AI is higher and humans speed is lower.

Rational decision making is a process when a person makes a decision based primarily on impartial reasoning and logic rather than on emotional and haphazard thinking.
Such process makes easier to find effective solutions of problems. But the decisions that a person makes depend on external factors and the environment. Emotional and physical factors may influence the players in making decisions during the game, although no one was able to distract the opponent. Human ability to make rational decisions is lower than artificial intelligence.

5.1 Review of features for humans and machines in gaming scenarios

Intelligence feature	AI	Human intelligence	Notes
Numerical computation	Stronger	Weaker	AI computes numerical tasks faster
Learning	Programmed	Unforeseeable	The ability of human to memorize and learn information is still unpredictable
Rational decision making	Stronger	Weaker	Decision making of humans are depended on external factors
Logical reasoning	Weaker	Stronger	Human is more capable of logical thinking than AI.

Natural language processing	Weaker	Stronger	AI is much weaker at recognizing words and the meaning of text than humans.
Visual processing	Stronger	Weaker	People are restricted in visuality during the game
Reaction time	Stronger	Weaker	Human more likely to show slow reaction under stress conditions

Table 4: Review of features for humans and machines in gaming scenarios (own source)

5.2 Utilization of AI

It's possible to use the AI functionality in games in several respects. For example, it would be beneficial to use it in complex forecasts with a long sequence: in weather forecasts and climate changes and also in forecasting natural disasters, in understanding human speech and different natural languages. AI techniques from games can also be useful in studying AI's security and reliability. AI can also make mistakes, and such a mistake can cost the life of a human in such cases as self-driving cars or other vehicles. To avoid such results, the safety and reliability of AI systems in general needs to be improved.

From the above table with the results, it can be seen that the AI is superior to the human in the visual processing of the terrain during the battle with the opponent. Such opportunities taken from the game scenario can be used by the army. For example, an army can use artificial intelligence for targeted attacks on positions of probable destination. Satellites that will receive photographs of the battlefield can be used for such implementation. The corresponding images will be sent to the ground data processing station, where an analysis will be carried out by an AI system that identifies the location of enemy targets. Then these coordinates are transmitted to the command post, where the system can determine what kind of weapon is needed to strike an enemy’s objects.

Medical imaging includes any technology or method that allows people to visually display the inner "secrets" of our body.
With the help of machine vision systems and robotic microscopes can be obtained better images of tissues which will facilitate and speed up the work of doctors. Also, for example,

deep learning algorithms can help doctors in developing countries interpret ultrasound images and thus better treat heart diseases.

Since AI is stronger than humans in numerical calculations and processing speed, it is possible to create a machine learning program that can create artificial intelligence itself. Such a function is essential in self-driving cars and augmented reality systems. Artificial intelligence will not replace humans in software development, but it can help less skilled programmers.

Many investment funds are planning to integrate more artificial intelligence into investment processes, machine learning and natural language processing for data analysis, news and content. Banks often use solutions based on artificial intelligence in assessing credit risk and in related areas. Banks expect the greatest financial impact from artificial intelligence technologies in such areas as the identification of fraudulent transactions, debt collection and credit scoring. Also, AI can be used in the following financial practices: virtual personal assistants for better management of personal finances, stock trading and personal investments; personalized scripts based on information from social networks and other sources for communication with overdue debtors; replacement of manual labor of bank employees with robotic algorithms; remote video identification of clients.

Computer games have turned from children's entertainment into a huge industry and have become officially recognized esports discipline.
AI can also be used in the sports and esports industry by replacing human coaches. Game or sport mentors until now had practically no tools to assess the physiological and psychological state of sportsman. Analyzing the data of demo files, statistics, sensors using artificial intelligence can be built battle tactics, simulated a game scenario, hone gamer’s skills and study the enemy's actions, as well as receive detailed recommendations for each of the competitor. In computer competitions, as in traditional competitions, everything is decided by experience, quick reaction and the ability to work in a team. AI and the use of sensors may help to improve these metrics, making the average gamer a true esports pro. Artificial intelligence would, therefore, allow human to win in the most effective way. This will help them to rank higher and win prizes.

6 Conclusion

In this bachelor thesis I have gained a deep knowledge in the field of applications of artificial intelligence.
In the theoretical part of the thesis the main aspects of applications of artificial intelligence were described. Also, the key methods for neural network processing, as well as the various types of robots and their differences were described in this part. The subject of Game Theory was touched upon, which made it possible to reveal the main goal of the work, which was a comparison of two scenarios for the manifestation of AI in games.

In the practical part, a comparison was made between the games of two scenarios, one with a human player and the other with AI. Games in which humans and AI played against each other were selected. These games were: Chess, Semantris, StarCraft. The analysis of the course of the game and the results of the best players in the world in chess and StarCraft was studied. For the game Semantris, a team of players was assembled, for whom a survey was conducted with accompanying questions and conclusions were drawn from the results obtained. Based on gained knowledge, the main criteria were identified by which the abilities of AI and humans were compared. The table that was provided earlier shows these parameters and the results of comparison. A study of the potential use of AI in various areas of life was carried out as the final part of the results obtained. Many startups and companies may get ideas and inspiration for potential ventures from this work.

AI is our present and the advancement of this field of science will continue in the future. Therefore, it is necessary for humanity to know the strengths and weaknesses of AI, which was demonstrated in this work, using the example of different games.

7 Literature review

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