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Back to the Future: Visualization of Development, Problems and Prospects of Artificial Intelligence, Data Science, Quantum Computing

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Abstract

The paper is designed as a review and analysis of the current situation in the field of information technology (IT). The relevance of the article arises from the need to popularize IT among young people, which is reflected in the documents of the Ministry of Digital Development, Communications and Mass Communications of the Russian Federation, as well as from the high demand for experts in the field of digital technologies and the need to increase the digitalization of Russia. According to GeekBrains (the first programming school in Russia, which appeared in 2010, and the leader in the field of training for digital professions, which operates in 85 regions of the Russian Federation and 21 countries of the world), the number of IT job vacancies in this country will grow up to 2 million by 2027. All large organizations are looking for specialists in different IT branches, which are described in this and the following research paper. In this article, which is the first part of the study, the capabilities and problems of the following advanced technologies are considered: artificial intelligence, Data Science and quantum computing. The concepts of technologies are analyzed from the viewpoints of their everyday use and professional application. The topics are closely related and complement each other in one way or another. The article follows the logic and chronology of events in the global IT sphere. The conclusion contains a description of the author's thought experiment about bringing machine intelligence to life, it accumulates the mentioned technologies while taking into account the laws of physics. The calculations for this experiment are given as well. The materials from one of the GeekBrains's educational shows “The Way to IT” were used, including the GIF animation, which is reproduced only on the website of the “Scientific Visualization” journal.

Keywords: information, neural network, artificial intelligence, machine learning, data science, quantum computing, quantum computers.

1. Introduction

The emergence of book printing in 1440s revolutionized the way civilization develops, providing a base for the modern technologies. However, in this research paper we will limit ourselves to examining modern cutting-edge technologies and exploring topics that are currently in the spotlight. These technologies are rapidly evolving, requiring a large number of specialists in these fields, and all major and smaller companies are seeking experts in these technologies.

According to the “Development Strategy of the Information Technology Industry in the Russian Federation for 2014-2020 regarding the process up until 2025” provided by the Ministry of Digital Development, Communications, and Mass Media of the Russian Federation, popularizing activities in the field of information technology (IT) is one of the main tasks for

the development of Russia's IT industry. According to the Ministry of Digitalization, the shortage of IT experts in Russia makes up more than one million people [1].

The level of income they offer is also quite significant: specialists in various IT fields can expect a salary of more than $1000. In general, the world is moving towards the future. The described technologies are related to it and will accompany the development of our civilization. The article can be considered as a kind of continuation of the work [2], however, the publications are not connected, the authors of the articles are not affiliated with each other, and this paper reflects completely different aspects of the digital world.

2. Artificial Intelligence

2.1 General Features

Artificial Intelligence (AI) is the ability of a computer to learn, make decisions, and perform actions that are specific to human intelligence. It is an attempt by humans to teach computers the behaviour similar to human activity, i.e. to reproduce cognitive capabilities (the intellectual ability of humans that allows a machine to act like a human: to talk and hear, to understand human speech, interact in a comprehensible voice interface) as well as perform actions such as picking up a remote control, phone, moving, seeing through computer vision and so on. All of this was already thought out in the old children's book about Mapoduma. To begin, AI is subdivided into stages according to its development: there is weak AI, strong AI and superintelligence. This means that in terms of the current state of AI market's development we are only in the weak AI stage. The following part deals with the difference between weak AI, strong AI and superintelligence.

Weak AI is a system that uses interfaces to interact with humans (voice and text) and solves narrow specialized tasks. One of the most popular examples which took place back in 1996 is the computer Deep Blue II – a chess supercomputer that defeated Garry Kasparov, the at that time current world chess champion, in 1997 (fig. 1).

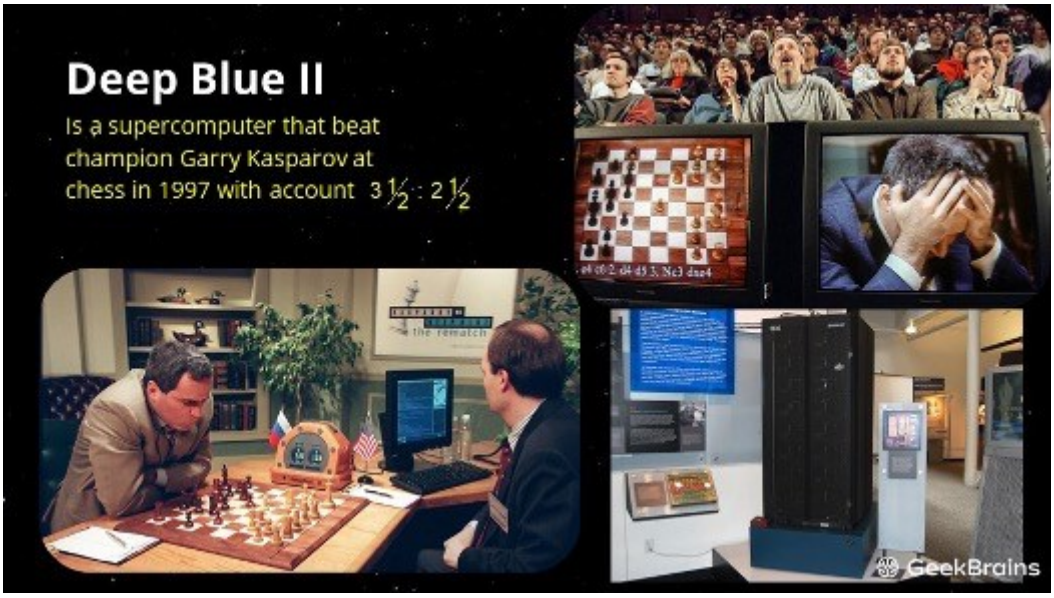

Fig. 1. The Deep Blue II supercomputer beat Garry Kasparov

The game was conducted as follows: a human operator entered Garry Kasparov's moves into the computer, after which the computer generated its own moves on the screen. The human then made the moves on behalf of the computer – this was exactly the AI, which simply took in the input of the human move and responded with its own move.

Deep Blue evaluates over 200 million positions per second. The total number of possible chess piece combinations is approximately 10^{120} (Claude Shannon's number). To evaluate all

of them Deep Blue would need at least 1 quadrillion 585 trillion 489 billion years[1]. Quantum computers, which will be discussed further, will allow this to be calculated in just a few minutes.

Deep Blue lost the match to Garry Kasparov with a score of 2:4 in 1995. Nevertheless, this event caused a revolution in the world of computer technology, even though Deep Blue could solve one and the same task: it could not answer a text query, talk to a child, find out what mood it was in, go to a store instead of a human, etc. [4].

There is a more recent example: in 2015 the AlphaGo programme defeated Fan Hui, had won European Go Championship for three times, in all 5 matches – this was also a breakthrough in the AI scientists and developers' community. The thing is, it is impossible to consider all possible positions in the game of Go – their number is $2 \cdot 10^{170}$, which is larger than the number of atoms in the observable universe, which is roughly 10^{82} atoms. Even all atoms were the size of our universe, the number of possible moves in Go would still exceed the total number of atoms in these new universes. It is worth noting that deep neural networks were used here, not a fractal solution (decision tree).

Superintelligent systems, on the other hand, are human-like systems that could potentially replace humans in certain tasks. These systems could go to the store, chat with children, play the piano when requested, search the internet, etc. As an example, currently, in Russia and the West, there are ongoing projects aimed at creating self-piloting cars. One such project is Waymo Cars (fig. 2), which are self-driving vehicles that operate within cities without the need for a human driver, ensuring safety for passengers and other road users.

Fig. 2. Unmanned Waymo Cars

This is also an example of a simple weak AI, which can solve a single task: moving a car from one point to another taking the traffic situation into consideration. However, there are numerous problems that need to be addressed. For instance, the capabilities of smart speakers in recognizing, searching, and processing voice information are also limited. Navigators that provide suggestions, social networks that recommend different content and etc. – these are attempts of weak AI in solving narrow specialized tasks, addressing a specific issue. In order to learn and evolve, it needs human assistance: people change algorithms, add data to make it more optimized [5]. The major disadvantages of weak AI are:

- it solves only specific tasks or parts of them;
- it does not learn from its mistakes – needs human assistance.

[1] For comparison: the age of our Universe is estimated to be only 15 billion years.

2.2 Machine learning as a component of AI

The following is the attempt to see what is "inside" AI, how it is structured internally. If we divide it, it consists of two major blocks:

The first block – machine learning (fig. 3) – a way to train a computer without human programming;

The second block – neural networks (see section 2.3) – a computational system for modeling analytical actions of the human brain.

Neural networks can be described as a specific type of machine learning algorithms [4-5]. Other, more detailed classifications of AI, are also possible.

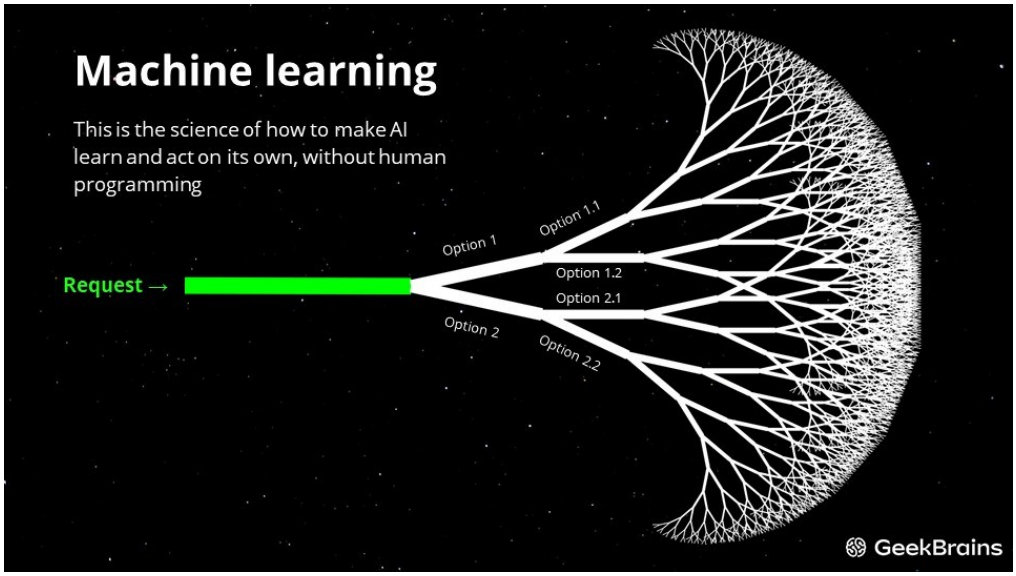

Fig. 3. Machine learning – computer training without programming done by a human

One of the main machine learning algorithms is "decision tree", which is used for automatic data analysis and can be infinitely large.

In fig. 3 there is a certain infinite fractal[2] of decisions. In a specific situation, for example, choosing between two objects (cups), we always choose the larger cup. We can further complicate the decision-making process based on the specific task at hand: if we are going to drink tea, we choose the largest cup; if we are going to drink coffee, we choose the smallest cup. Depending on the type of coffee such as cappuccino or espresso we make decisions on the size of the cup accordingly, the decisions thus split [6]. The system thus follows these conditions or steps – (1) what drink? (2) to drink we need a cup – which cup, for tea or for coffee? If it is tea, then we look for the largest cup. We conduct a search and selection procedure to find the cup with the largest capacity, which then will be used for tea.

As a result there is a tree of branching decisions, which should have a huge number of subdivisions depending on the conditions and parameters embedded in the system to give it maximum plausibility. For example, let us consider the most common example that will reveal a general understanding of how the system learns and what machine learning is.

We are shown pictures of cats and dogs. For a human, it is clear: this is a cat and this is a dog – we will always correctly determine who is who. In order to teach a computer to identify this, we need to:

1. Define an algorithm – introduce the concept of what a cat in the picture is, what it looks like, what it consists of, and break it down into elements.

2. Identify distinguishing features – in what elements a cat should differ from a dog: eye shape, pupil type (dogs have round pupils, cats have elongated ones), ear shape, fur, size, colors, sounds produced, etc.

[2] Fractal (lat. – *fractus* – crushed, broken, shattered) is a set with the property of self–similarity.

3. Load the dataset – the amount of training data and training time depends on the desired accuracy, as well as the chosen model and the hardware used. In some cases, achieving good accuracy may require a large amount of data and computational power. To teach a child to distinguish between a cat and a dog, they need to see these animals at least once (or several times) and be taught by pointing to each animal and saying, “This is a cat” and “This is a dog”. The child will always be able to tell the difference between them, regardless of whether they attach dog ears to a cat or a dog tail to a cat. A computer, on the other hand, is more likely to make mistakes. The machine may give a higher probability that the animal is a dog due to the ears, instead of the probability that it is a cat. Therefore, it may conclude that it is a dog even though it actually is a cat [6].

AI learns from various situational scenarios and events. This process can be time-consuming and depends on the volume of training data available. However, further in the article we will discuss the fact that it is anticipated that quantum computing and quantum computers could accelerate the machine learning process by their ability to process large volumes of data and identify patterns within them more efficiently than classical computers.

AI also teaches the computer to mimic human emotions. A person smiles in front of the camera, becomes angry, and the machine reads the facial expressions, facial features, eyes, and the way eyebrows change, as well as what happens to the person's body parts. The machine then attempts to replicate these changes (fig. 4).

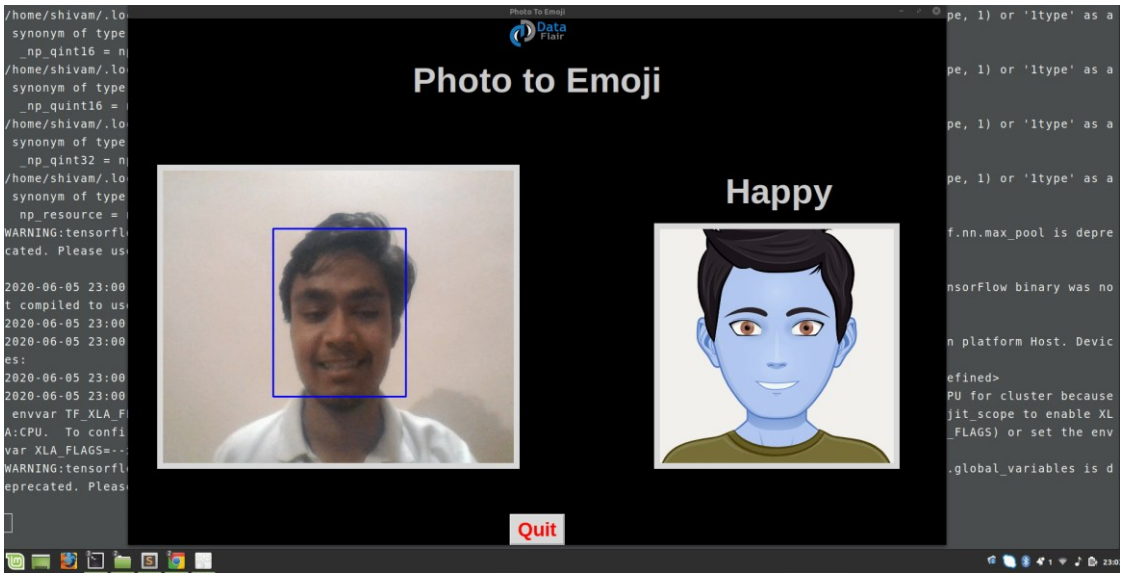

Fig. 4. Emojify AI repeats emotions after human (GIF animation)

Emojify is a facial expression recognition neural network that outputs results in the form of emojis. The machine learning process relies on a specific mathematical framework of terms, without which the technology would not function (fig. 5). The underlying principles are linear regression and Bayes' theorem [7].

Linear regression is a statistical technique that allows us to determine the strength and nature of the relationship between one or more independent variables x and a dependent variable y. In creating a decision tree model, it is essential to understand which path to take. This involves determining whether to move to the right or left, depending on the specific parameters.

Bayes' theorem provides a method for calculating the probability of an event occurring based on prior events that are related to it. To illustrate it, let us consider two products that a customer has a preference for, bread and cheese, in a store. When a customer visits the store, the use of Bayes' theorem can assist in estimating the quantitative likelihood of finding these preferred items in stock, taking into account factors such as the frequency of visits and previous purchases of bread and cheese by the customer.

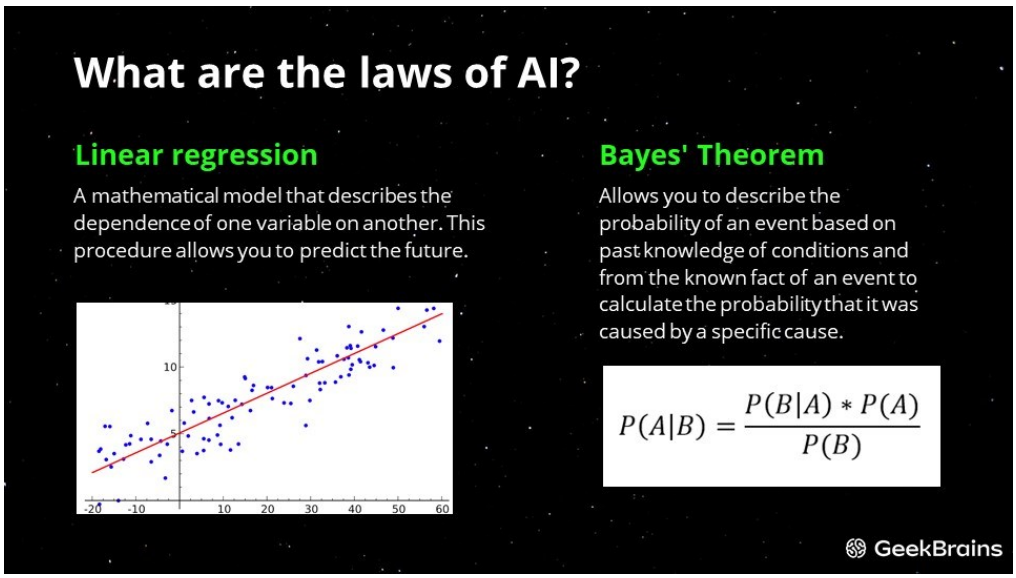

Fig. 5. Mathematics underlying machine learning

The customer has visited the store 100 times, of which 90 times bread was in stock and 85 times cheese was in stock. 75 times both bread and cheese were available. If the customer could visit the store again today, the probability of finding both products would be 75%. It is possible to determine the optimal time to visit the store by considering the time at which bread and cheese are delivered. By finding the intersection points between these delivery times, we can choose a time that maximizes the chances of both products being available. Additionally, it is important to consider factors such as the human element, time of year, and traffic conditions when planning a visit to the store [7].

These elements are used in machine learning in order to train an AI to:

1. Collect information about the current situation;
2. Perform the action until a positive or negative result is obtained;
3. Analyze which actions lead to which result (fig. 6).

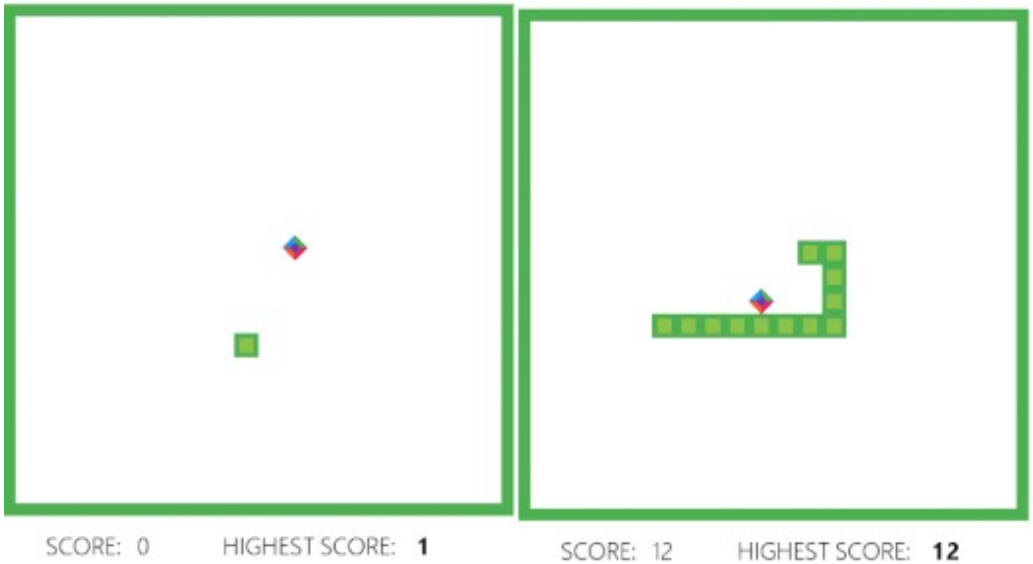

Fig. 6. AI learns to play “Snake” from scratch. There are no rules, the machine performs random actions (GIF animation)

2.3 Neural networks as a component of AI

The neural network system allows a machine to analyze and memorize information, fetch it from memory, and solve tasks of the same type. In order to understand the principles of human intellectual activity and their application during the development of software neural networks, scientists study the neocortex – the largest structure of the brain and the main structure responsible for intellectual activity.

The neocortex (lat. *neocortex* – new cortex) is the youngest part of our brain that sets us apart from other living beings and makes up the main part of the cortex. It is responsible for higher nervous functions – sensory perception, interaction, motor command execution, making non-trivial decisions, conscious thinking and speaking.

Taking into account individual variability, the number of neurons in our brain ranges from 80 to 100 billion nerve cells. Due to this, we can remember information, make quick decisions, learn new things, talk, walk and more. The approximate number of neurons, which different animals have, is shown in Table 1 [8].

Table 1. The number of neurons in the brains/nervous systems of some animals

Animal	***Neurons in the brains/nervous systems***
Sea sponge	0
Medicinal leech	10 000
Lobster	100 000
Ant	250 000 (this number varies depending on species)
Honey bee	960 000
Cockroach	1 000 000
House mouse	71 000 000
Nile crocodile	80 500 000
Golden hamster	90 000 000
Green-rumped parrotlet	227 000 000
Guinea pig	240 000 000
Rock dove	310 000 000 (only brain)
European rabbit	494 200 000
Octopus	500 000 000
Cat	760 000 000
Dog	2 253 000 000
Lion	4 667 000 000
Brown bear	9 586 000 000
Giraffe	10 750 000 000
Gorilla	33 400 000 000
Humans	100 000 000 000
African bush elephant	257 000 000 000

Each skill is determined by the presence of neural pathways that implement that skill [9]. Each neuron is a physicochemical element capable of memorizing information and transforming it.

The neuron itself has a process called axon. This axon has synapses at its output, and on the other side it has dendrites – some kind of "interfaces" for interaction with other neurons (see fig. 7).

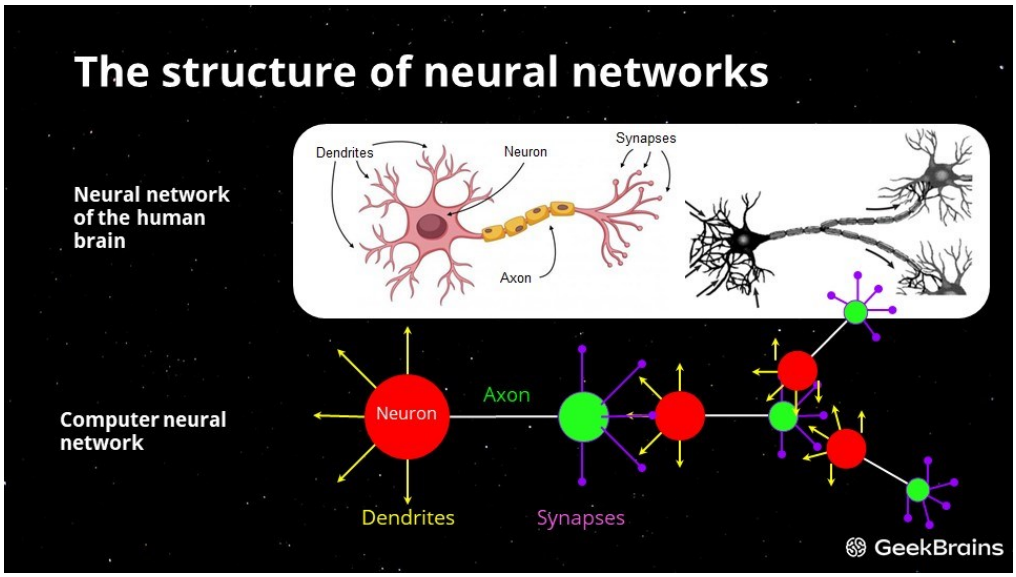

Fig. 7. The structure of neural networks

These synapses, located on one side of the neuron, and the dendrites, located on the other side, are connected to one another. This means that synapses of one neuron connect to the dendrites of another neuron. The neurons thus form a new network. Thanks to the presence of these neurons that are capable of learning to solve different tasks, the network can complete the specific task in question.

When scientists fully understood this phenomenon, they decided to emulate the function of the brain and its neurons on a digital platform using the current computing capabilities. In 1957, Frank Rosenblatt proposed the concept of an artificial neural network, which was later implemented on the Mark-1 neural computer in 1960. This mathematical model, known as a "perceptron", was a miniature computer equipped with a table of several hundred photoelectric cells. The device had interfaces for input (dendritic cells) and output (synaptic connections). For example, a neuron might be given two numbers, it would add them and then output a single result. Then five such neurons can be considered, each performing a specific function: addition, subtraction, multiplication, division, and square root extraction. When we provide more input variables to the first neuron in a neural network, it processes them and sums them up. This information is then transmitted to the next layer of neurons. At the output, we obtain the correct solution of the problem, with all the necessary calculations carried out (this is a highly simplified example). Neural networks thus help us to solve simple problems [9].

Thus, each neural network solves a specific task (fig. 8). When many different tasks need to be addressed, we need to create multiple neural networks, and therefore each neural network will be unique.

If, for example, we wished to process human speech using a neural network, we could employ a single network for this purpose. However, if we desired to generate meaningful text that a computer could speak and pronounce, this would require a different neural network. Recognizing images could be achieved using a third neural network, while addressing complex problems may necessitate combining various networks together.

Let us now consider some examples of existing neural networks and their functions. The DALL-E neural network, which falls within the category of "Text to Image" networks, is designed to generate an image based on a given text query.

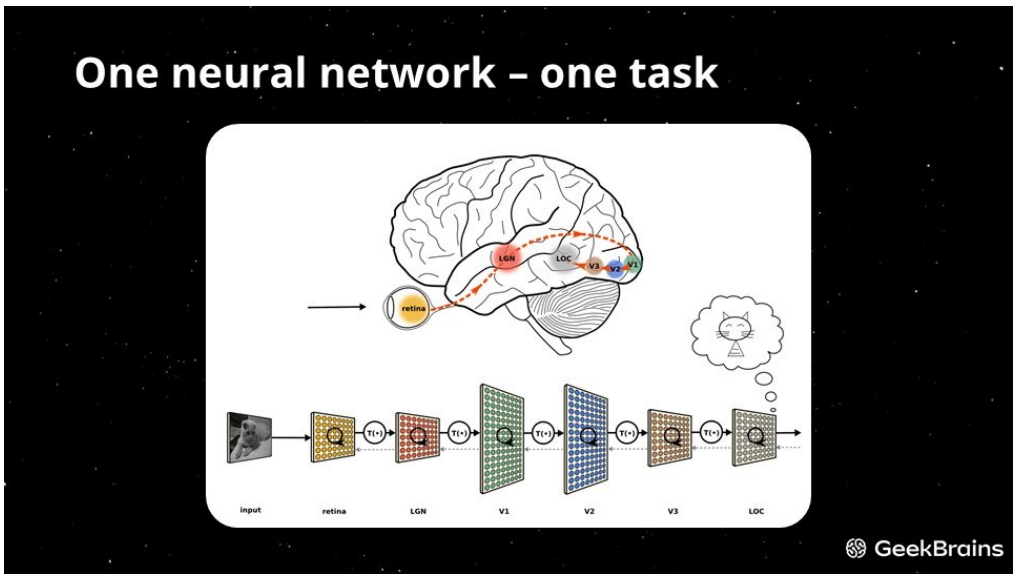

Fig. 8. One neural network – one task

Below are the results of running the text query “Draw a fox sitting in a field at dawn in the style of Claude Monet.” Based on this, the neural network generated a corresponding image (fig. 9). In other words, the text was processed by an algorithmic processor and transmitted into the neural network as input, resulting in the generation of an image that corresponds to this request. The question arises, whether the source of this image is the result of autonomous neural network activity or a suitable image was located on the internet and processed using a “Claude Monet-style” filter.

Fig. 9. The DALL-E neural network imitates an artist

Let us consider the way this process is carried out. The neural network, after receiving a request to identify a fox, field, dawn, and Claude Monet-style image, converts this query into a vector representation. This vector representation is then compared to vector representations of images within the database, based on their contents, color characteristics, and other features that define those objects. After this comparison, the neural network returns images from the database which best match the query. This result is arranged on a canvas, according to the principles of composition, as laid out algorithmically. Distinctive features of Claude Monet's style, in comparison to other styles such as presented by Picasso, Van Gogh, or I. I. Shishkin, are also algorithmically parameterized and clearly defined. Next, the style of Claude Monet is applied to this canvas as a filter, as it was done with filters that allowed users to

change the visual appearance of faces in real-time using the aging effect or other transformations through image processing technology based on generative adversarial neural networks (GANs). In figure 10, you can see things that do not exist, drawn by DALL-E.

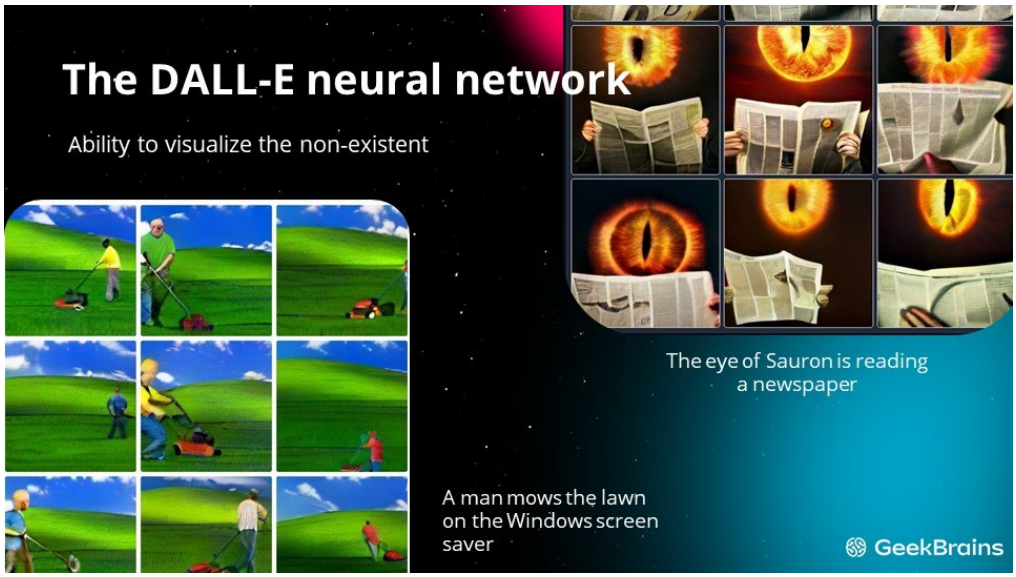

Fig. 10. The DALL-E neural network – unscientific visualization

Let us explain that there is a man mowing the lawn in a Windows desktop wallpaper, while the Eye of Sauron from The Lord of the Rings trilogy is reading a newspaper. DALL-E can also substitute some elements (for example, replacing a cat with a dog in fig. 11).

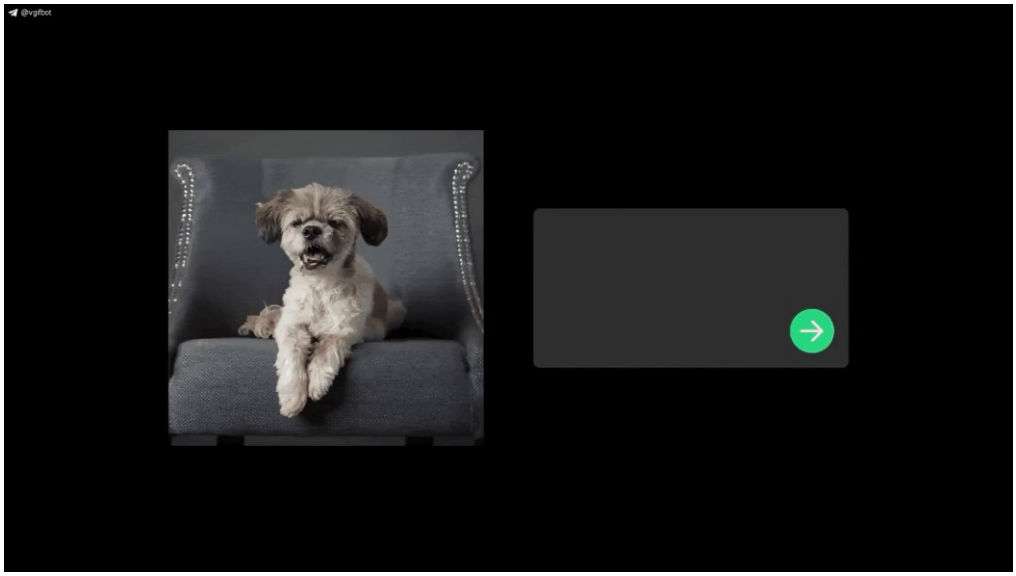

Fig. 11. The DALL-E neural network replaces animal images in the picture (GIF animation)

In addition to DALL-E, which has evolved into DALE 2, chatbot ChatGPT that understands even abstract questions became famous. The most significant features of ChatGPT are described in the article [10], and they are constantly being improved. Neural networks, in particular, Midjourney, what Russian proverbs look like (fig. 12).

Fig. 12. Neural networks visualize phraseological units [11]

However, all images from [11] have been pre-processed manually, so it is not yet possible to discuss the presence of humor (emotional) intelligence in the machine. The neural network used in the Artemy Lebedev studio, with its narrow specialization (fig. 13), is able to create logos according to specific parameters (which are Artemy's trade secret and know-how).

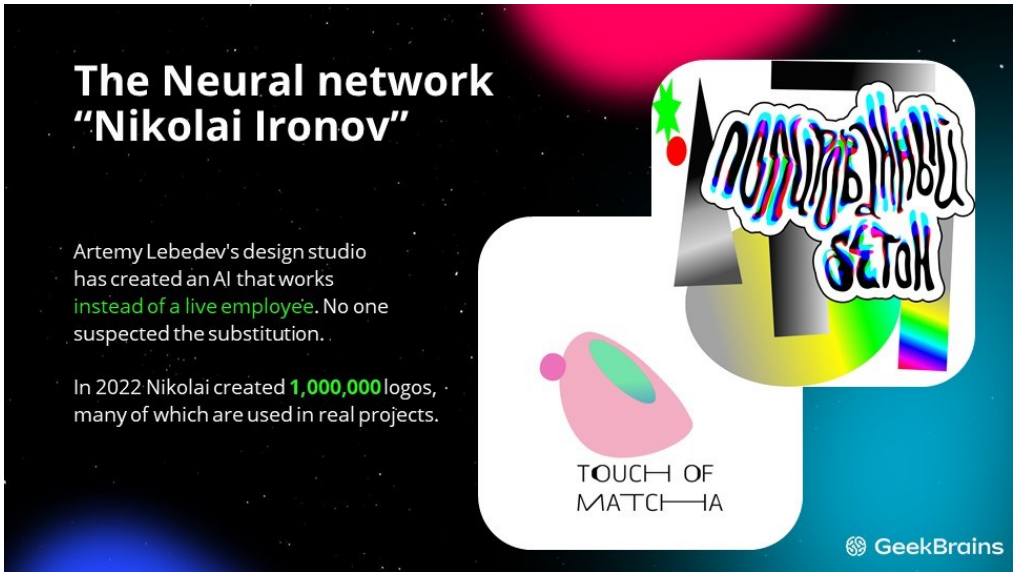

Fig. 13. The neural network of the Artemy Lebedev design company

The project was developed under strict confidentiality. In order to keep the secret existence of the AI, it was presented to external parties as a remote employee by creating a profile page with the name “Nikolai Ironov”.

Another neural network capable of discussing certain topics is illustrated in fig. 14. When a person utters something, the machine responds to them, resulting in a natural dialogue. At some point, people listening to this conversation vote on the winner of the debate. Often, opinions of listeners regarding who is more argumentative, a person or system, are divided. The system, for example, has access to the Russian State Library, which it can use, and it is able to quickly extract information and present it accurately. After this, the neural network presents a rather serious argument in its statements.

Fig. 14. Neural network participating in the debate

Nevertheless, all AI-based text generation models have their limitations and disadvantages:

1. Limited understanding of context: processing information at the text level, which can cause difficulties in understanding a wide context or ambiguous queries;

2. Lack of emotional and ethical understanding: AI models lack emotional intelligence and ethical understanding, which can lead to inappropriate or unsuitable responses in certain situations;

3. Low ability to think creatively: despite the fact that the AI models are able to generate text, they are limited in their ability to think creatively and innovatively.

We will consider disadvantages in more detail in the following paragraphs. However, despite them, text generation models are still important tools for automating communication and providing information.

2.4 Weak Sides of Neural Networks

In this study, we will also examine the issues and disadvantages associated with the use of neural networks that have been presented. However, the disadvantages identified are of a similar nature.

• AI does not consider the facts. A neural network merely remembers the answers and does not comprehend the data or identify patterns. When a human perceives and analyses a complex situation, they evaluate it from multiple perspectives. However, a neural network only considers the parameters programmed into it, and it operates within the algorithm it has been given. Although secondary factors may be important to a person, they are not significant to the system because it simply does not recognize them [6].

• AI is not capable of making reasoned decisions. Neural networks cannot draw the most basic conclusions with consistent reasoning. ChatGPT's understanding of context within a single question branch is the result of constructing multi-stage dialogues using linear regression models (see fig. 5) and simple switching of boolean-type logical flags, which will be the focus of one of the authors' upcoming works. The ability of a neural network to prove theorems or hypotheses is due not to the utilization of conventional methods in mathematics, but deep learning techniques to solve problems across various fields, such as game theory and image recognition.

• AI does not possess common sense. Unlike humans, neural networks cannot evaluate situations based on reality and logic. They predict how a situation may unfold, what factors influence it, and whether there are other actors involved. The neural network only sees zeroes and ones – a digital code – that transmitted into it.

As a small-scale experiment, let us examine the 6 images in fig. 15 and attempt to find out which images were created by a computer neural network and which were drawn by a human. Several images were generated by a neural network. Will the reader be able to identify any signs indicating that the image was created by a neural network?

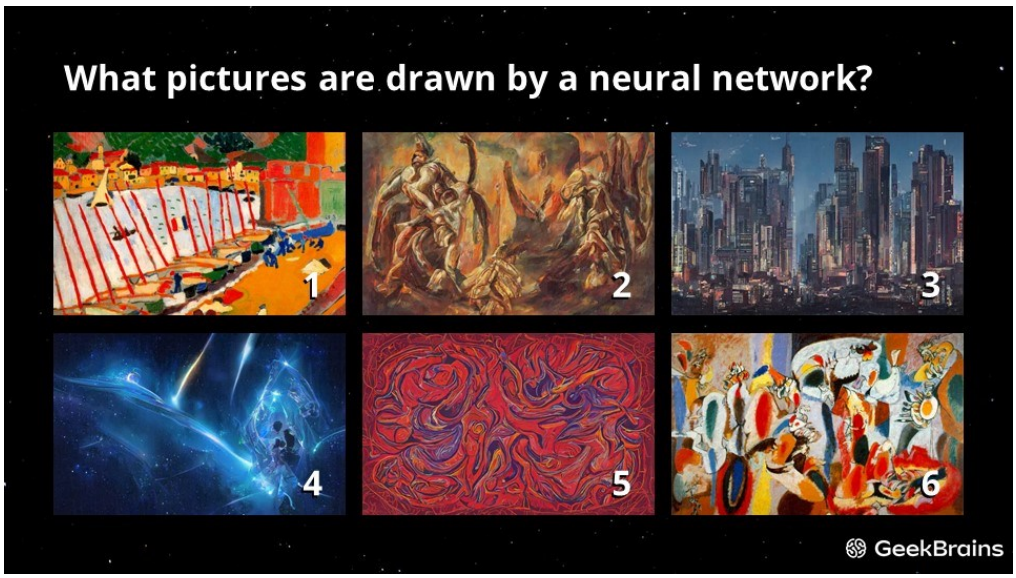

Fig. 15. Experiment “Guess the artist: human or neural network?”

Let us consider the main aspects that distinguish paintings painted by a neural network from paintings painted by an artist:

1. The Creative Process. Neural networks produce paintings based on the large amounts of data and the study of styles and elements of other works of art. Every individual artist has a unique approach to creativity.

2. Emotional engagement. Paintings generated by a neural network may appear technically flawless in terms of their craftsmanship, but they frequently lack a deeper emotional undercurrent, often recognizable at an intuitive level.

3. Uniqueness. Neural networks are able to produce paintings that visually resemble the work of famous artists or combine several styles. In contrast, artists strive for the uniqueness of their creations.

In general, the paintings created by neural networks and real artists differ in appearance, context, and emotional content. The answer is: four of the images (the second, third, fourth, and fifth) were created by neural networks, while only the first and the sixth were drawn by actual people:

1 – “The Port of Collioure”, Andre Derain, 1905;

6 – “The Liver Is the Cock's Comb”, Arshile Gorky, 1944.

To summarize, there is machine learning, which creates algorithms for self-learning and making decisions based on specified parameters. There are also neural networks which can solve specific problems. Therefore, machine learning and neural networks are combined to create an AI that accepts input data, solves a specific problem, and, depending on the circumstances, selects the most suitable option and produces a result. For instance, a navigation device searches for the optimal route from home to work.

2.5 Strong AI

What is Strong Artificial Intelligence (SAI)? SAI is defined as an intelligence that has the ability to learn, think, and perform tasks using some sense organs and human-like tools, certain manipulators. SAI can be seen in actions such as a humanoid robot moving and laying out objects, or a robotic manipulator taking and shifting objects (see fig. 16 and fig. 17).

Fig. 16. Strong AI is similar to a human (GIF animation)

SAI imitates human behaviour, attempts to communicate and move around, i.e., in its actions and thought processes, it approaches that of a person. Such examples include chatbots, robotic assistants, neural networks and virtual assistants. However, all these are still just attempts, the provided examples, acting through sensors developed today, have not yet passed the Alan Turing Test[3]. ChatGPT, which states the opposite in [12], did so conditionally, and the attachment to a virtual partner in the "Replika" app is more like gambling. Let us consider an example of a manipulator (fig. 17).

Fig. 17. AI learns to sort and arrange objects (GIF animation)

There is a human hand capable of picking up a glass, a remote control, or a phone; lifting a table; and touching a flower. The person does not shatter the glass, carefully handles the phone and remote, and is able to use them. However, up to this date there has been no universal robotic manipulator able to replicate this ability. The robot will either crack the glass, fail to use the phone or remote, or tear off the flower while not touching it – it is still a rather complex challenge.

Additionally, there are ethical issues in the field of SAI that need to be taken into account. Let us consider self-driving cars as an example and compare them to humans. When driving, humans solve a vast number of situations, especially in emergency situations. How should one respond if a car in front of one suddenly stops or if someone jumps into the road? Should

[3] This is confirmed by a CAPTCHA, which is the Completely Automated Public Turing Test to Tell Computers and Humans Apart – a fully automated public test designed to differentiate between computers and humans.

one steer to the right or left, slow down or accelerate, hit a cat, a human, crash into a tree? What about a more complex situation, such as two people on the road, where one must make a decision based upon ethical principles and experience? A human driver considers these factors when making decisions.

Millions of people complete questionnaires assisting AI in learning optimal behavior in a specific critical situation related to ethical principles, which slows its immediate orientation to the environment [13]. An example of this is the so-called "trolley problem" from the fields of cognitive science and neuro-ethics[4].

Thus, the problems which developers face are as follows:

- Machine ethics: the example is the same: who should be saved save – a child or a senior?
- AI is not a human: how to embed personal qualities in system behavior?
- Long processing times: learning can take a long time, up to 10 years.

Comparing the response time of a skilled driver and AI can be challenging, as they operate in different ways. A skilled driver is able to react instantly to critical situations on the road due to their skills and instincts, making quick decisions based on changing traffic conditions.

AI requires more time to understand the situation, as it needs to analyze and process a significant amount of information before it can make a decision that takes into account ethical considerations. These processes hinder its ability to react instantly and, in critical situations, delay their response.

Thus, a highly experienced driver, may have a quicker reaction time in sudden situations on the road. Conversely, SAI may take a longer time to make decisions due to its complex information processing. Nonetheless, AI has the advantage over a human driver in terms of its making mistakes, as the "knight of the roads" is not susceptible to emotions, fatigue, or distractions, thus tending to behave more accurately and predictably in traffic, reducing the risk of collisions. Its ability to operate around the clock, without the need for rest, allows for improved efficiency and increased availability of services. However, the machine does require cooling.

2.6 Superintelligence

Let us not consider the example of superintelligence (the future). In the TV series "Westworld," a world is portrayed in which it is impossible to determine whether a person is interacting with another person or with a machine. It can only be discerned from "hardware" whether it is a living individual or a machine with a metal frame (fig. 18).

To put it simply, a superintelligence should be human-like not only in appearance, but also in terms of its interfaces, actions, and sensations. It should be able to speak, hear, see, shake hands, and not break the hand at the same time. It should also be capable of performing human functions (raising children, writing music, poetry, solving problems, reading books, writing program code, etc.). It should be fully human-like in all respects.

Another significant area of research that scientists worldwide are currently exploring is the development of tactile sensors. Human skin, for example, is a unique organ that has evolved over millions of years and is difficult to replicate (by synthesizing elastic, tactile skin for robots).

Above, we mentioned such a thing as the Turing test, which shows whether a machine can think. Its essence lies in the fact that a person guesses who he or she is corresponding with: a person or a computer program. If the computer can deceive at least 30% of the interlocutors, convincing them of its "naturalness", then the test is passed by the machine [14].

[4] The fundamental issue relates to a person's moral dilemma: whether to save one life at the expense of several others. Research and analysis into this area can aid in understanding moral quandaries, as well as their connection to personal characteristics.

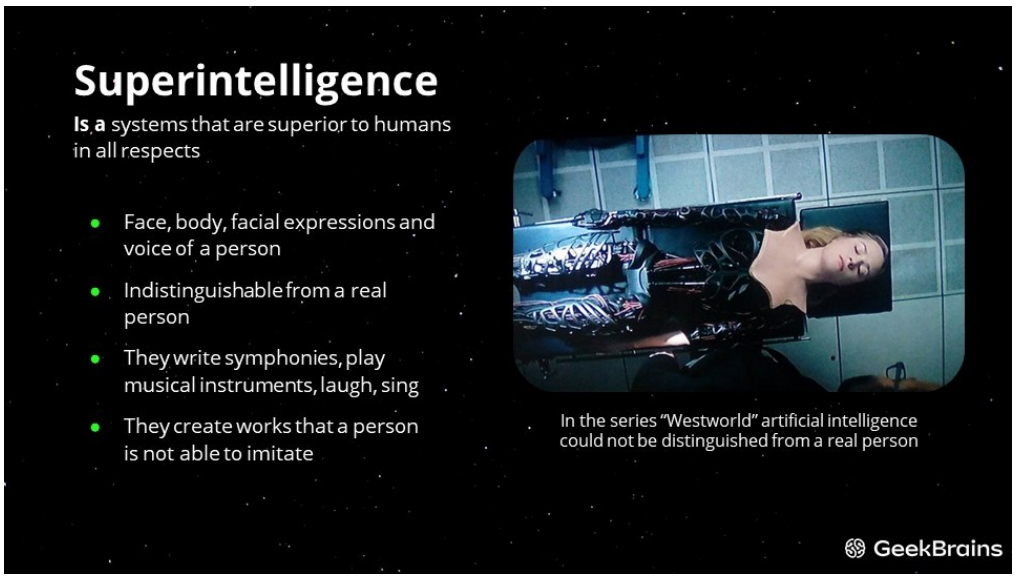

Fig. 18. Superintelligence is our future

The sensational Google LaMDA project, which claimed that AI had become human and achieved consciousness, was rather a PR initiative by the company. As if the employee who had trained it said that it was no longer AI, but rather some sort of a human being, it already thought like a human being (fig. 19).

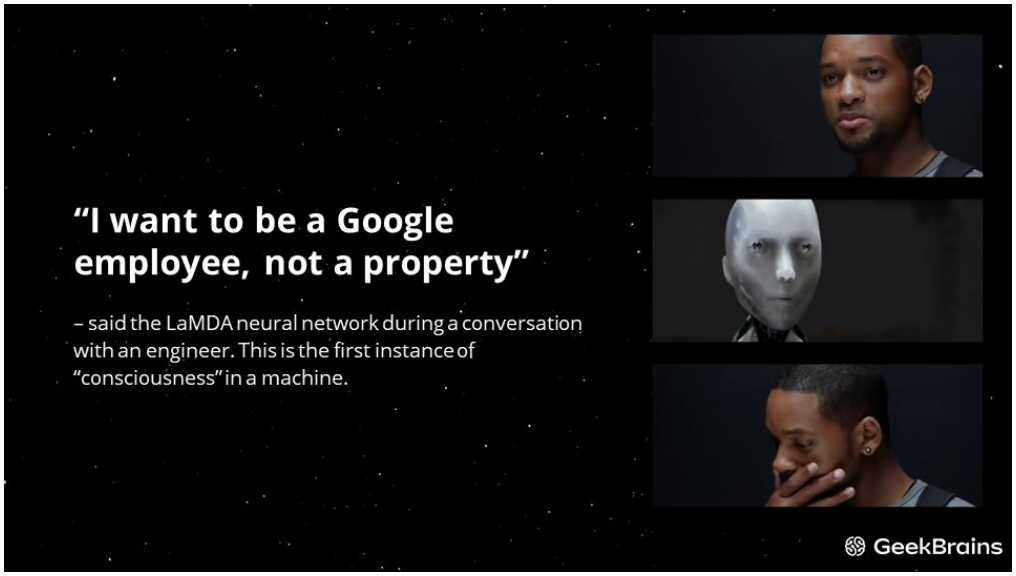

Fig. 19. Google LaMDA has "mind"

According to the story, the robot was allegedly offered time off due to fatigue resulting from processing, as it believed so. This story came to light through the media, and it can now be interpreted as an advertising stunt. The employee has been sent on unspecified leave, which can be compared to dismissal [14]. Currently, technologies capable of bringing about the rise of AI and superintelligent machines remain in the realm of science fiction.

It appears that the primary feature (technical limitation) of AI is the narrow specialization of neural networks. It will become clear from the chapter on quantum computing how this issue will be addressed in the future. The human brain consists of a vast number of neural networks that somehow interact with one another. The interaction between these neural networks is a major concern.

Can a neural network perform the tasks of creating other AI systems? If the neural network is not fully trained, it is likely that it will produce similar "mentally limited" systems. This would likely be a dead-end approach [15]. Therefore, it is necessary to solve the issues of the

neural networks functioning like a human (or at least like a human), and then we can utilize them.

3. Data Science (DaS)

3.1 General Features

Data Science is a field of science (DaS) that deals with the study of data, which helps to make it more useful. Data science has been actively developing since the late 2000s and early 2010s, as a separate scientific discipline, encompassing data analysis, machine learning, AI, and other related fields. However, the origins of this field can be traced back to the 1960s, when the first studies on data analysis and machine learning were conducted.

Using information from various databases and processing them allows us to provide solutions for businesses. As you are aware, the amount of data doubles every year [16]. In fact, one needs to learn how to handle this data: how to aggregate it correctly, clear it, perform calculations, that is, to solve specific problems.

Examples of tasks that can be addressed with Data Science include:

1. Forecasting and reducing customer churn;
2. Personalizing offers for customers;
3. Optimizing procurement in production;
4. Identifying the target audience for a product;
5. Automating the forecasting of prices for goods and services based on seasonality;
6. Analyzing traffic patterns on highways.

The domestic ecosystems of Sber and Yandex, which were originally commercial bank and search engine respectively, now focus primarily on the analysis and processing of large volumes of data, known as Data Science (except for the financial management activities of Sberbank). It is worth noting that large companies such as Uber, Facebook[5], Alibaba, and Airbnb, among others, do not own traditional physical assets, such as real estate or working capital [5].

3.2 Data Science Features and Applications

For business, marketing campaigns can be designed to consider factors such as the influx and churn of customers. This could involve creating unique sales offers tailored to individuals based on their preferences, in order to personalize advertisements and improve customer experience. For example, a digital billboard on the street could recognize a customer's face and use its database to determine their current product preferences. It could then offer them a product or direct them to the nearest store – fig. 20. It is also worth noting that there is currently no widespread adoption of such systems.

If multiple individuals look at such a digital billboard, a facial recognition system may attempt to identify each individual and display relevant personalized advertising. This, however, raises concerns about data privacy and potential violations of privacy. Additionally, such actions could be perceived as invasive and result in a negative response from individuals who believe their personal information is being used without their permission.

Therefore, it is essential that companies utilizing such technologies comply with relevant data protection and privacy regulations, as well as show respect for consumer rights.

When a user gets “stuck” into a social media platform, this is not just their weakness, but also a strength of Data Science and AI that effortlessly makes the platform so engaging that with each additional scroll through a social media or news aggregator page, it becomes increasingly interesting. The more time a customer spends on a platform, the more beneficial it is to the business.

[5] Meta Platforms Inc., including its Facebook and Instagram products, are recognized as extremist organizations in the Russian Federation. Their activities are prohibited in the country.

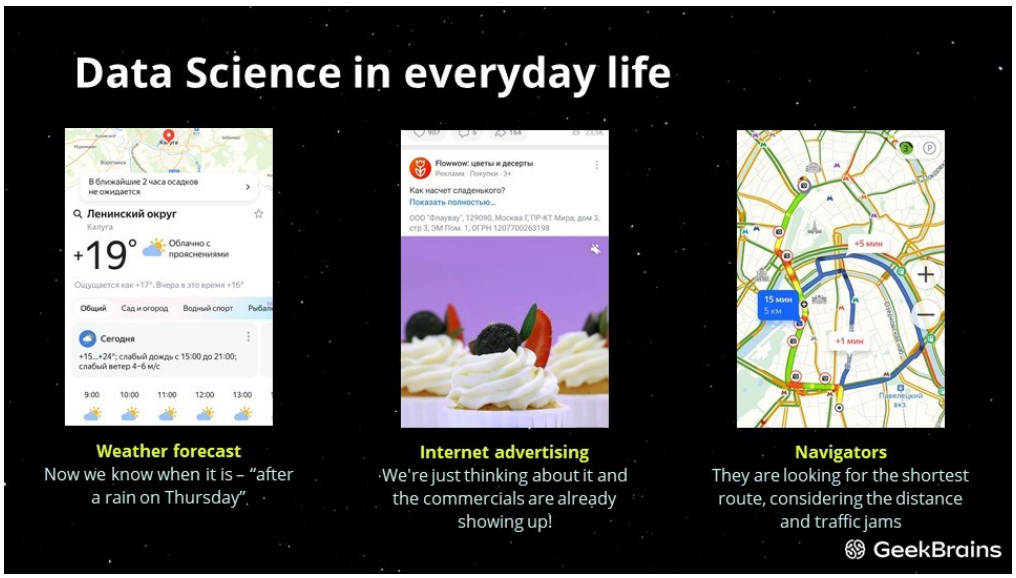

Fig. 20. Task options for DaS in everyday life

Furthermore, thanks to the use of Big Data analytics, detailed customer profiles (digital twins) have been created that can predict customer needs. As a result, some users may have the impression that smartphones are spying on them [17].

Data Science is used to select a possible spouse based on the data provided by the users. The service collects and analyzes data on gender, age, place of residence, physical features, and occupation. Using AI, options are then presented to the user.

In the context of business, certain specific tasks are undertaken in this area (fig. 21). For instance, it is essential to optimize the purchasing price in order to maximize the profit of the enterprise. This requires analyzing the data, visualizing it, and making reasoned decisions based on the results. These are the tasks that fall within the domain of data science, where machine learning may serve as one tool for optimizing the purchasing price, rather than a distinct area of focus.

It is essential to solve this issue in order to establish a method for reducing the average purchasing price by 2%. Consequently, the profit margin of the organization will increase by 4%. Within the context of a large corporation, this 4% increment will translate into additional profits in the form of millions and billions of units of account.

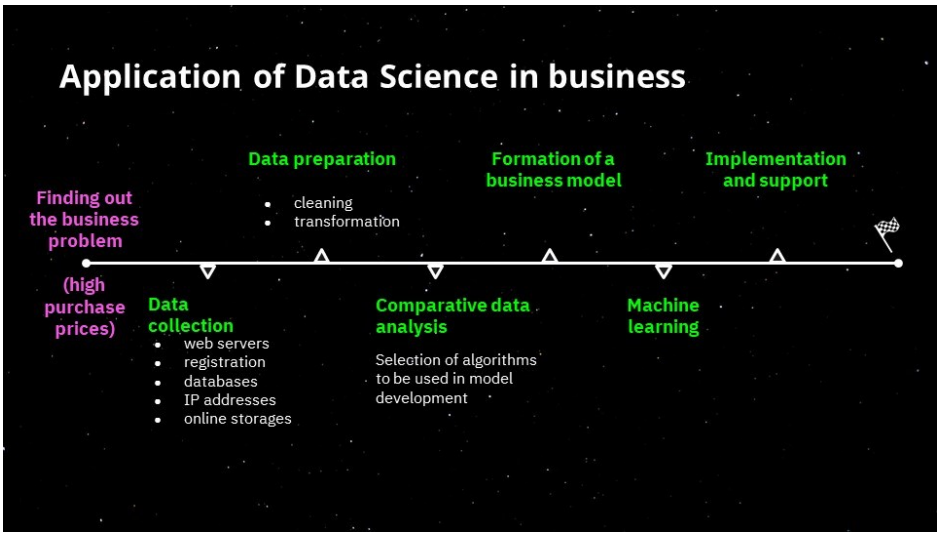

Fig. 21. DaS application in business

In today's business environment, thousands of numbers and pieces of data are collected [6, 9]. The job of analysts is to gather this data, analyze it, and present it in a dashboard, which is a tool that visualizes the analyzed data[6]. In order to structure the data and perform the analysis, analysts use various tools, such as:

• Yandex.Metrika is a service that provides tools for viewing, analyzing, and visualizing web analytics, traffic data, and user behavior.

• Power BI, a software product from Microsoft, is used to structure, analyze, and visualize data. This system allows analysts to determine how the data will be organized, to describe the structure of the various tables.

• Tableau, another data visualization and analytics service, allows analysts to create reports based on visual elements that make complex statistical information more easily understood.

Let us continue to explore the issue from fig. 21. The operation of the automated price setting unit allows for updating prices every day at several thousand stores. Stopping this process overnight would be unacceptable. The lack of current prices and selling at old prices will inevitably lead to fines and penalties. The process is structured as follows: A project team studies the issue, its basis, and how to address it. They analyze data, including how prices are set, how procurement chains operate, where this information flows, who makes decisions, etc., that is, data is collected. Once all this data has been collected, it is cleaned: errors may appear, goods that are no longer used or have been removed from the product line may be present, etc. [18].

They “clean” this data and then conduct analysis. They determine what is significant and what is not, and find what has the greatest influence on the price. Therefore, a certain business model is created with a set of parameters that influence optimal pricing. Some examples of these parameters are:

1. The proximity of the supplier to the warehouse;
2. The quantity of products that we purchase;
3. The seasonality and demand;
4. The number and locations of warehouses and other factors.

It is worth noting the concept of multivariate statistical analysis. Let us consider two variables, the area and the price of an apartment. We have eight paired values, which we can plot on a graph using blue dots. Each point represents two coordinates (the area and price). In this case, the area would be an independent variable $\boldsymbol{x}$ (attribute, cause), while the price of the apartment would be a dependent variable $\boldsymbol{y}$ (resultant, consequence). Fig. 22 illustrates this relation.

Apartment area	Apartment price
27	1,2
37	1,6
42	1,8
48	1,8
56	2,6
57	2,5
77	3
80	3,3

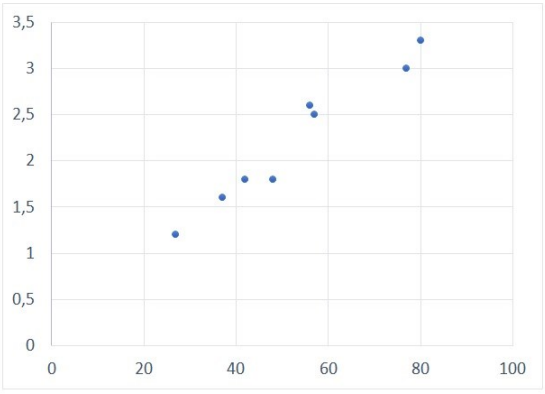

Fig. 22. Linear regression. Two-dimensional data

[6] Data visualization allows not only to simplify the process of research, but also presents complex data in a visually appealing way. This aids analysts in explaining their findings to clients and other interested parties.

However, we could have multiple features, similar to the example with a product matrix, which would affect the resultant variable y. In such a scenario, each point on the graph would not only be determined by three coordinates, but would also be defined by its color, size, shape, transparency, and gradients. Figure 23, created using the Python programming language, displays data related to cars. We have visualized 6 measurements from 205 cars. Such data would already be considered multidimensional. Additionally to the obvious variables of horsepower, curb weight (total mass of the car including the driver), and cost, 3 more dimensions have been emulated on the graph:

• Mileage in urban driving conditions, which decreases with the lighter shade of the marker. It can be seen that mileage is lower in cars with higher prices, engine power, and weight;

• Engine size is directly proportional to marker size. The larger the engine is, the higher the cost and the lower the mileage are;

• The shape of the marker allows for the display of up to 10 characteristics. Here, the square represents 4 doors and a circle represents 2 doors.

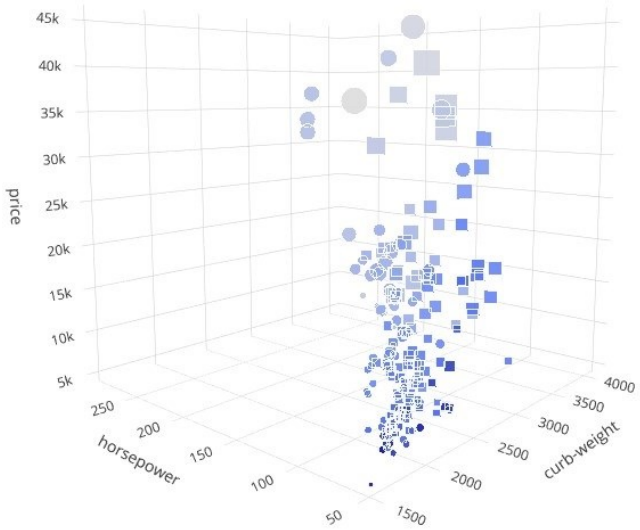

Fig. 23. Analysis of multidimensional data on the example of the automobile market

Multivariate statistical analysis, which is a branch of mathematical statistics concerned with the analysis of experiments involving multivariate observations, is employed in the analysis of these data.

Let us now turn to the business scenario involving grocery warehouses. Within this scenario, we identify the optimal parameters and configure the system so that we may select the optimal suppliers for each group of goods, as well as determine the optimal purchase quantities for each good. The resulting system is detailed and integrated into a daily process for determining the optimal range of goods to purchase from various suppliers, thereby automating procurement processes and enhancing their efficiency as an integral part of daily operations.

After the development process is completed, implementation and subsequent testing as well as any available improvements are carried out. This allows businesses to purchase goods at discounted prices and companies to gain additional opportunities to increase their profits. However, this process can be much more challenging in reality. In order for this to happen, parameters must be collected, analyzed, a model built, automation implemented, and the process launched. This process eventually generates income for the business, taking from several weeks to several months [6, 9], depending on the size of the enterprise, the difficulty of the issue, its parameters, and the experience and qualifications of IT analysts.

When analyzing the production process, it is essential to apply optimization techniques, considering the significant number of movements, warehouses, deadlines, and coordination of all phases as well as other factors (see fig. 24).

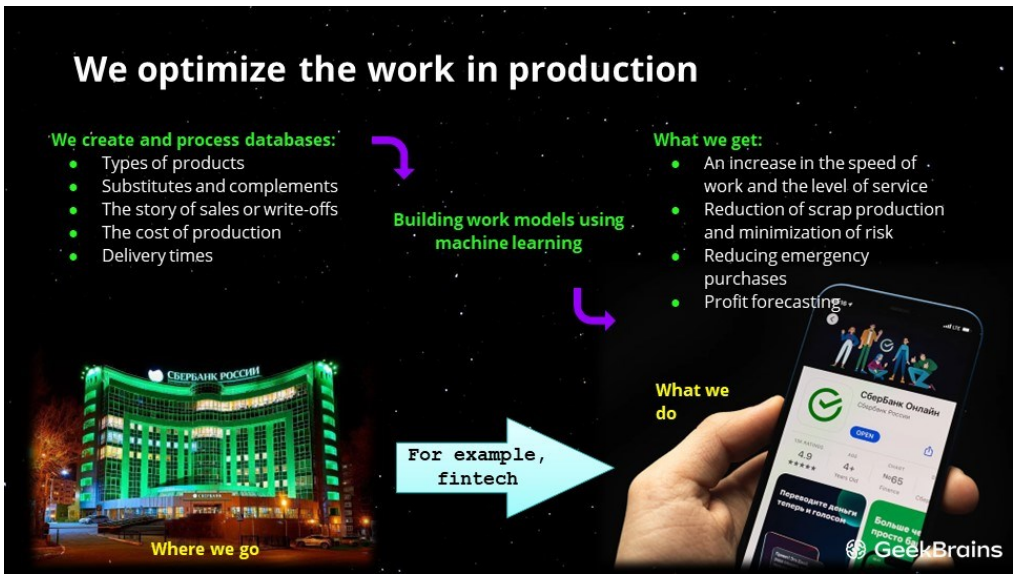

Fig. 24. An example of optimizing production [6]

Here, as well, a multifactorial model is being developed, some optimal paths for the movement of parts or assembled goods are identified, and at the end during production it operates more efficiently, reducing the number of steps that need to be taken, the number of errors, and the number of defective goods, etc. Therefore, data science and machine learning are also being actively applied in production for optimization purposes [19].

3.3 Professions in the Field of Data Science

Let us consider who can be called a Data Science expert. It is a specialist with expertise in three areas:

- Math sciences, including probability theory, operations research and other related fields;
- Programming, big data analysis and development;
- Understanding the field of research (retail, medicine, insurance and finance, it means a specific area of expertise).

Let us consider the various specialties available in working with data (fig. 25), as well as their combination of skills in programming, development, mathematics, and understanding the field of data science.

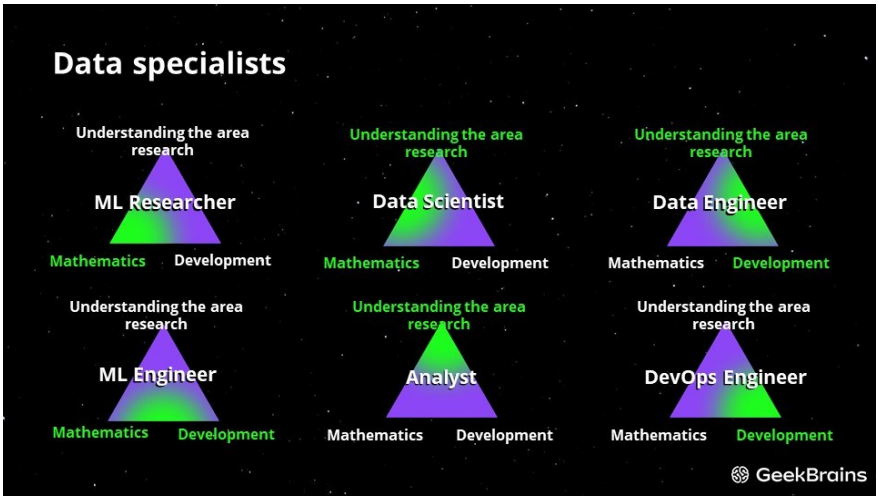

Fig. 25. Competencies of data specialists

1. A Machine Learning (ML) Researcher is a professional who conducts research and develops models for learning systems. In this role, the emphasis is made on mathematics and

mathematical modeling, as this occupation relies on a mathematical framework that enables one to identify and create this optimal model;

2. A Data Scientist can be considered a mathematician who also understands the subject matter. For this profession, development is less important and the professional works with data independently of business tasks;

3. A Data Engineer is someone who works directly with data and has a deep understanding of the subject matter. They have development skills, which means that mathematics plays a secondary role in their work;

4. A Machine Learning Engineer (ML Engineer) is a specialist in machine learning. They implement models developed by an ML Researcher into real-world hardware and software, and train the system to take decisions. They require knowledge of math and programming skills[7]. The specific subject area is not essential;

5. The Analyst knows well the subject matter and has gained experience. For instance, a good analyst knows that the time required for the delivery of fresh fruit and vegetables exceeds 6 hours and chilled items can be stored for 24 to 60 hours, which are some industry standard practices. This information is utilized in the analysis process. Depending on the specific business objectives, analysts may be categorized into:

- Business Analyst;
- Digital Analyst (web analyst or Internet marketing analyst);
- Product Analyst;
- Financial analyst, etc;

6. DevOps Engineers are professionals who work with the design and implementation of Data Science solutions or practices. As a software-based solution, DaS involves the deployment of servers on which specialized software is installed, which in turn allows for the use of specific models. This individual is responsible for maintaining this entire infrastructure. They no longer require mathematical skills or knowledge of the specific subject matter;

The analysis of IT professionals reveals a distinct need for mathematical expertise. For some individuals, mathematics may be optional, whereas within other professional fields, it serves as an essential tool. Nevertheless, even basic knowledge of mathematics offers benefits in a variety of fields related to numbers.

3.4 The Mathematical Apparatus of Data Science

Let us discuss the mathematical apparatus of DaS, which is necessary to understand machine learning, models creation, and processes optimization.

Binary search allows us to find the maximum and minimum, or to search for an extremum. Recurrence computing plays a significant role in modeling the dynamic of a process or phenomenon over time, and allows us to predict what will occur in the future, based on the current state. Periodic functions operate on series of values, when information is collected, processed it, and certain patterns are identified (see fig. 26).

Probability theory and mathematical statistics are areas of significant importance. The main areas of these disciplines that an IT professional needs to be aware of are listed in fig. 27. Statistics play a crucial role in machine learning and DaS, it used to collect and analyze large volumes of data, which helps to make informed decisions based on probability calculations. These calculations can help determine the most likely outcomes, the optimal suppliers, and the likelihood that a particular supplier will not meet their delivery obligations, among other factors. This accumulated information, derived from long-term analysis, forms the basis for the development of mathematical models that can be used to make accurate predictions and decisions.

[7]It is important to note that the skill level of a software developer can be categorized as Junior, Middle, or Senior, and such categorization does not necessarily rely on the developer's age.

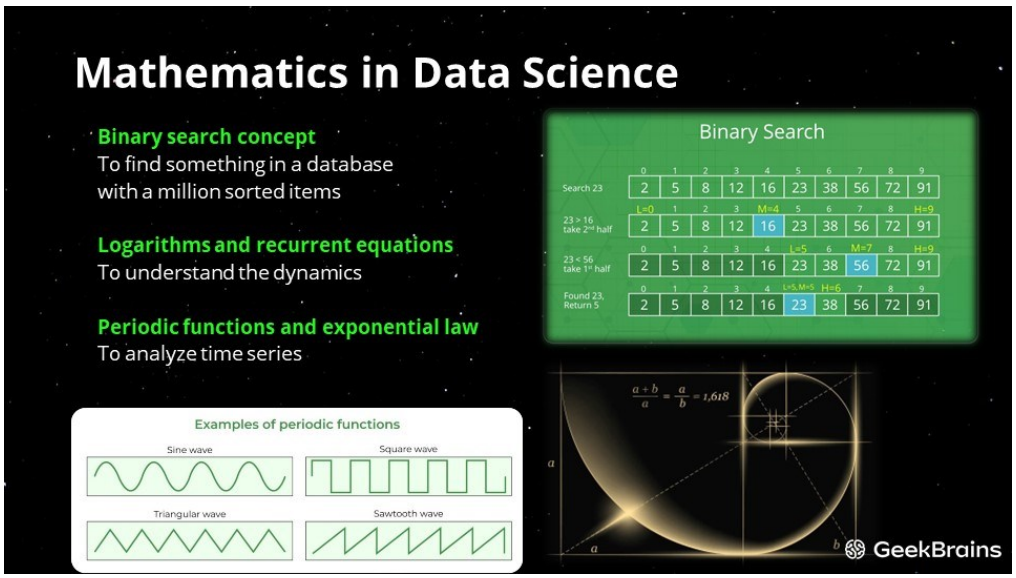

Fig. 26. Functions, graphs and working with variables in DaS

Probability theory is also utilized in this case. The likelihood of a supplier delivering goods on time is calculated: in 99.9% cases, one supplier delivers the goods in time, whereas in half cases, the other supplier does not deliver in time – it is evident that we will not engage with the latter, but with the more dependable supplier [20]. Let us briefly discuss the derivative discipline of "A/B testing", which originated in 2000. We segregate the sample of goods into two categories (test and control), and observe how they are delivered within a month. Afterwards, we determine our course of action.

A/B testing is also employed in web development and marketing to analyze how visitors respond to changes in the elements of the store's website. This enables businesses to optimize user experience and improve conversion rates.

Probability distributions are utilized for multivariate modeling. Regression analysis reveals the impact of time on supply chains and allows businesses to assess how changes in supply volume or products assortment expansion can influence the efficiency of suppliers. That is, statistics are employed to process accumulated data, reveal patterns in it, and make informed decisions.

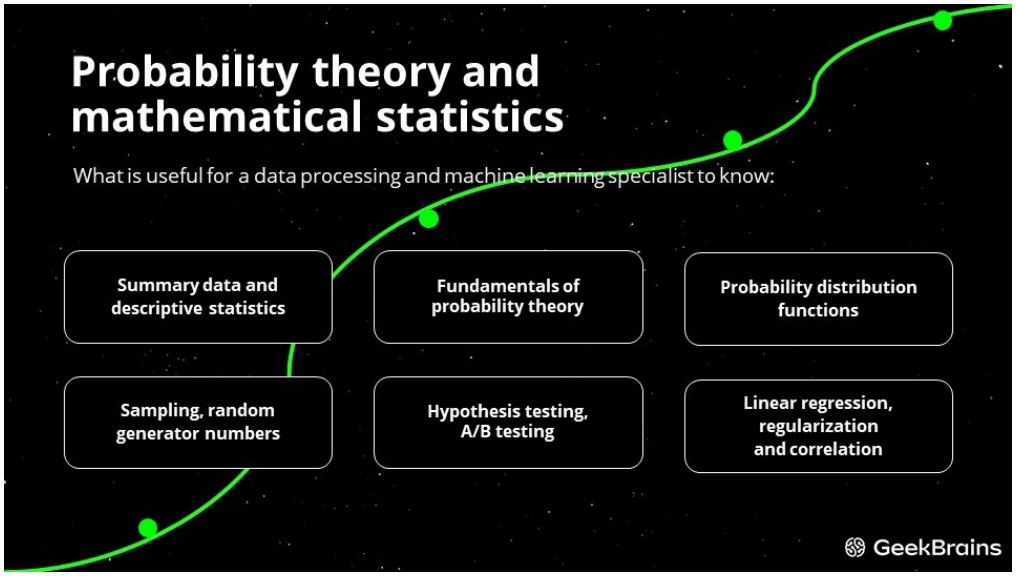

Fig. 27. Probability theory and mathematical statistics in DaS

One of the fundamental concepts in probability theory should be recalled in this situation: the Bayes' theorem (fig. 5), which reflects related probabilities. There are two events to con-

sider, and it is necessary to determine the probability that they will occur simultaneously or within a certain time interval. For example, if a person has not had enough sleep and had a poor breakfast, what is the likelihood that this person will perform well today at work?

Linear algebra (fig. 28) is a branch of mathematics that deals with mathematical objects of a linear nature, such as vector spaces, systems of linear equations, and matrices.

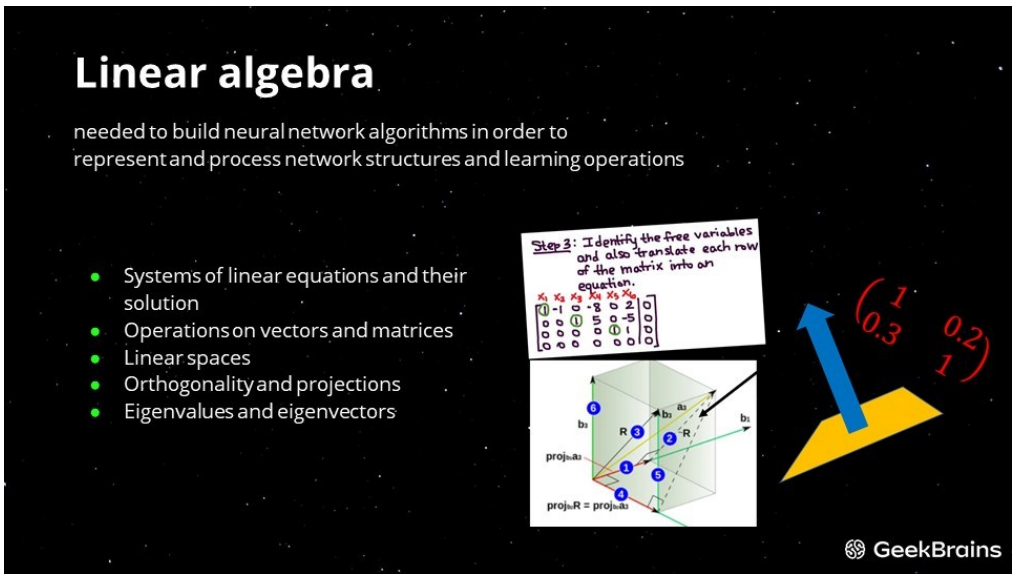

Fig. 28. Linear algebra in DaS

Mathematical analysis (fig. 29), as a branch of mathematics, studies the limit values, continuity, differentiability, and integrability of functions and sequences. Within DaS, this branch of mathematics is used to work with functions with a single variable. For example, it can be used to describe and analyze the dynamics of changes in the delivery speed of goods under various weather conditions.

We shall consider one factor – the weather – and examine how the delivery time varies. We then incorporate this information into the model, such that in winter goods are delivered at one speed and in summer at a different speed, depending on traffic situation, weather conditions, rainfall, and other factors. This involves the calculation of derivatives of complex functions, as well as the determination of maximum and minimum delivery times. It also utilizes standard special functions from integral calculus, such as Euler's gamma and beta functions. This allows for the simplification of other calculations (e.g., changes to delivery routes) [21].

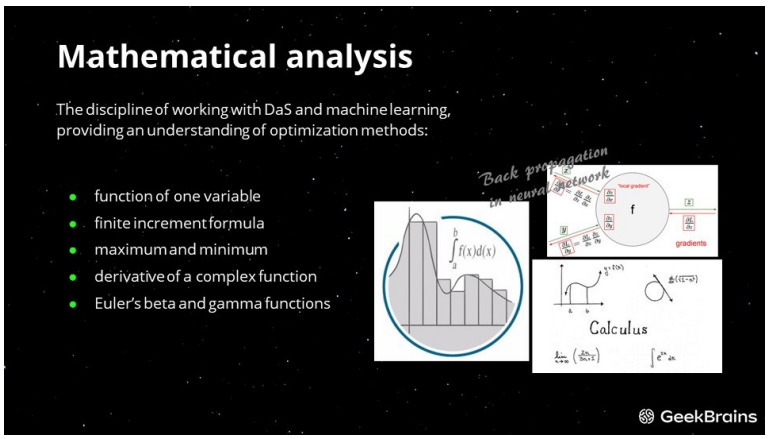

Fig. 29. Mathematical analysis in DaS

Discrete mathematics (fig. 30) is a branch of mathematics that deals with discrete mathematical structures, such as graphs and logical statements. These structures are used in pro-

gramming to as algorithms and data structures. Let us consider the following problem, which can be solved using graph theory:

There is a set of warehouses and stores connected by potential delivery routes. These are all represented on a graph, which is a set of vertices linked by a number of edges. The task is to determine from which warehouse goods should be taken to which store. These are logistical problems, including: determining the maximum capacity of a distribution center, finding the capacity of the entire network, and determining the daily number of goods that can be provided to all stores.

The Ford-Fulkerson theorem concerns the maximum flow through a graph. It states that the maximum flow in a path-based graph is equal to the minimum cut's throughput capacity. In other words, the maximum possible throughput of the entire graph is equal to the smallest value of a certain cut included. When considering stores and their associated suppliers, the Ford-Fulkerson theorem can be applied to determine the maximum number of products that can be delivered. This can be achieved by “cutting” all connections between the suppliers and finding the minimum throughput value of those remaining connections.

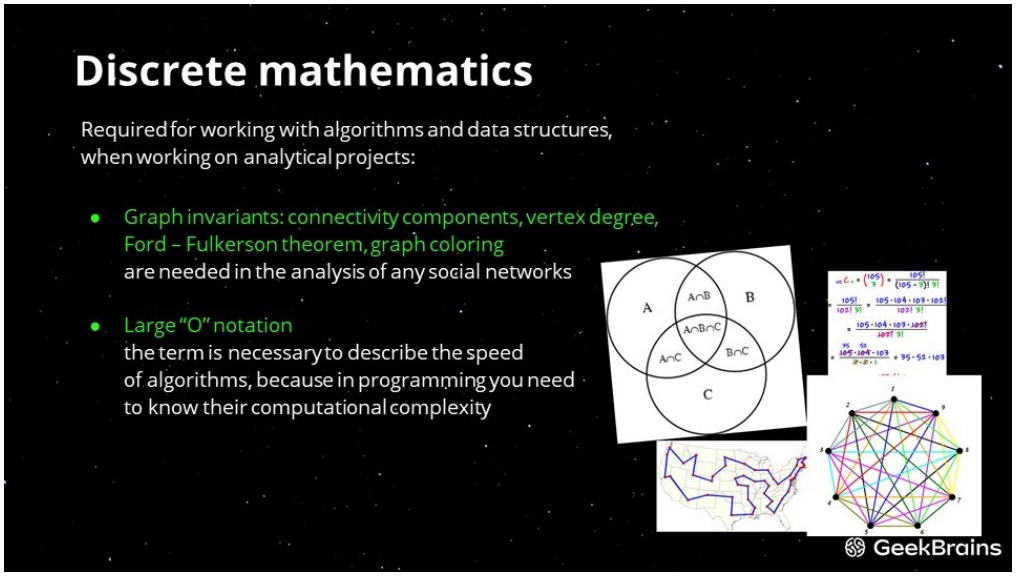

Fig. 30. Discrete mathematics in DaS

3.5 Disadvantages of Data Science

Data science contains elements that can cause difficulties and challenges, and there is no universally optimal solution:

1. A significant challenge is the lack of clearness while defining objectives. If the requirements are presented in an unclear manner, this can lead to significant expenditures on work that later proves to be unfeasible.

2. The most common issue is incomplete data, which results in a lack of information or an unreliable sample, negatively impacting further analysis and generating errors.

3. Inaccurate or dirty data – data cleaning and preparation takes up half the time of a project, especially when there are several information systems within an organization. The data from these systems needs to be combined, and some data may be insignificant or incorrect, so it should be removed or ignored. This is to ensure that only accurate and reliable data is used for analysis and modeling.

4. Lack of data – without access to certain information, it is impossible to accurately model anything. This is particularly true when there are legal restrictions on sharing data with external parties or when there are no agreements in place with important data partners.

In the last three years, the number of vacancies for DaS experts in Russia has significantly increased, which is particularly associated with the phenomenon known as the “brain drain”. According to the online recruitment platform HeadHunter for 2022, this increase was 433%

[15], which can be attributed to the need for businesses to utilize large volumes of data in decision-making. This need is prevalent in retail and telecommunications industries (especially when working with mobile network operators), and is widely utilized by major IT companies [21]. The lack of these specialists can make it challenging to design a successful project.

4. Quantum Computing and Quantum Computers

4.1 General Features

This topic will be discussed in order to demonstrate the potential of the IT sector. It should be noted at the outset that there has been a downward trend in interest in physics among Russian school students [22]. In recent years, a negative trend has been observed among graduates, who less opt for physics as their final exam subject. Despite this fact, quantum physics as well as computer science and economics continue to play significant roles.

A quantum is the minimum amount of any physical entity. Quantum computing is a form of computing that is carried out on devices using qubits and the principles of quantum mechanics. Such devices are significantly more powerful than the most powerful classical computers. More specifically, quantum computing involves a series of unitary operations on a single, two, or three qubit systems, these operations are controlled by classical computers. The concept of a qubit will be discussed in more detail later; for now, it is sufficient to say that, unlike bits, which represent a stream of electrical or optical pulses of duration 0 or 1, a qubits can be cold atoms, photons, or defects in a crystal lattice. Unfortunately, scientists have not yet been able to manipulate a significant number of qubits.

A classical computer makes all decisions within a central processing unit, its operation relies on transistors (fig. 31). The number and size of these transistors determines the processing power of the CPU. It is known to employ binary logic in its operations (where 0 and 1 represent false and true, respectively). The fundamental operations performed by these processors include shifting cases, addition, and subtraction using binary code (with all logic being binary) [23].

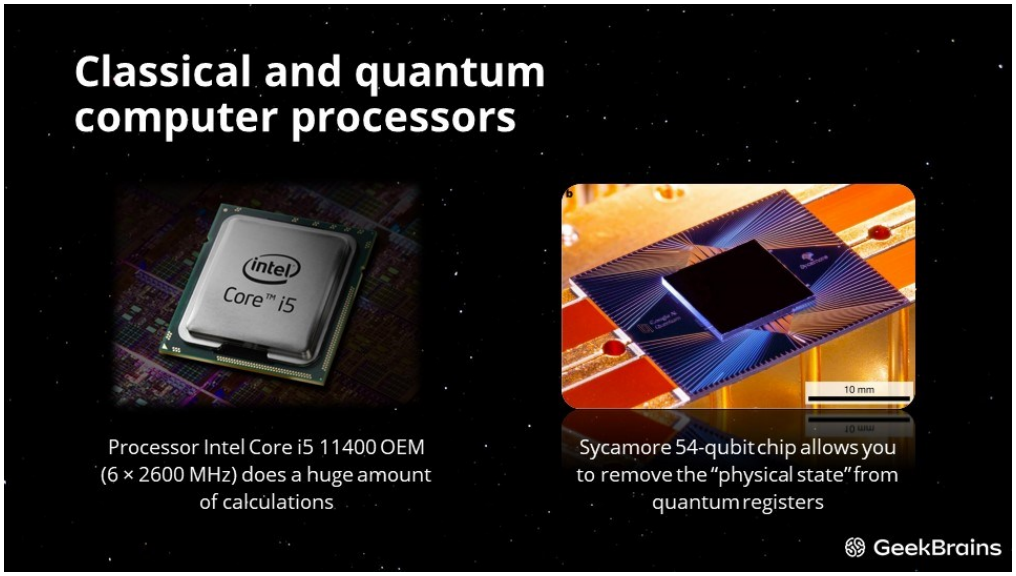

Fig. 31. Comparison of processors capabilities

A quantum computer is not merely a processor or a combination of devices, but it is a system that is analogous to natural systems in the physical world, characterized by a specific state that can be altered by external influences and factors affecting the computing process. Instead of bits (0 and 1) and their algorithmic interactions serving as input, the state of a quantum computer, represented by quantum bits (qubits) is taken as input. This allows for calculations to be performed at a much faster rate, utilizing quantum mechanical principles.

Conventional information processing by a traditional computer would require a significant amount of time to factorize a number with 30 to 40 digits (to get prime factors), approximately a billion years. In contrast, quantum computer completed this task in only 18 seconds. Additionally, quantum computer was able to solve the challenge of modeling superposition states within 200 seconds despite the fact that it would take a conventional computer approximately 10,000 years to complete this task [24].

Therefore, the future lies in solving machine learning challenges using quantum computing: if a conventional computer requires 500 years to differentiate between a cat and a dog (in the absence of parallel processing), then a quantum computer would take seconds (see fig. 32).

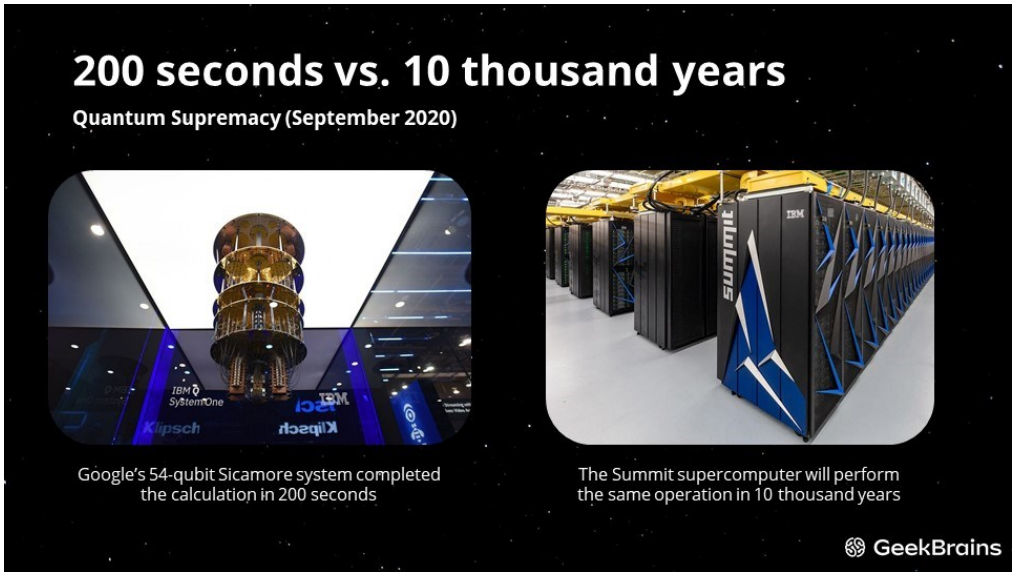

Fig. 32. Comparison of quantum and classical computers [25]

However, the effective management of this system requires the involvement of not only IT specialists but also physicists, given that the operation of this system is based on the physical characteristics of electrons. This means that the computational element of a quantum computer may be either an electron (which, when symbolized as minus or zero, represents the negative spin of the electron, whereas a plus or one represents the positive spin), or polarized light if it is photons. At present, the most widely recognized and promising computational element for the development of quantum computers is superconducting qubits, which are based on Josephson junction. Qubits based on the Josephson effect (Josephson qubits) are superconducting structures with tunnel junctions between two superconductors separated by a layer dielectric material, which is 10^{-7} cm thick. This system, in order to interact with the real world, must first be insulated from external influences so as to prevent external factors from affecting the computations, which must be "pure". To date, data cleaning has been one of the most challenging tasks for quality control.

These machines operate only at very low temperatures. Therefore, there are several physical limitations that must be addressed. IT experts, advanced programmers who develop algorithms for quantum computing, and top-level physicists from major companies such as Google and IBM, with appropriate funding, are working on this issue. Moreover, these are multi-billion-dollar initiatives [23, 25].

4.2 Quantum Race and the Tasks to be Solved

In 2016, IBM developed a quantum computer with 5 qubits (fig. 33). In subsequent years, it developed machines with 49 and 50 qubits. Since 2020 Microsoft has offered Azure, a cloud-based service that enables remote quantum computing. At the end of 2022, China introduced a personal quantum computer that costs approximately 590,000 rubles, which is

less than the price of a Lada Granta vehicle. This machine is intended as a basic introduction to quantum computing for educational institutions [26].

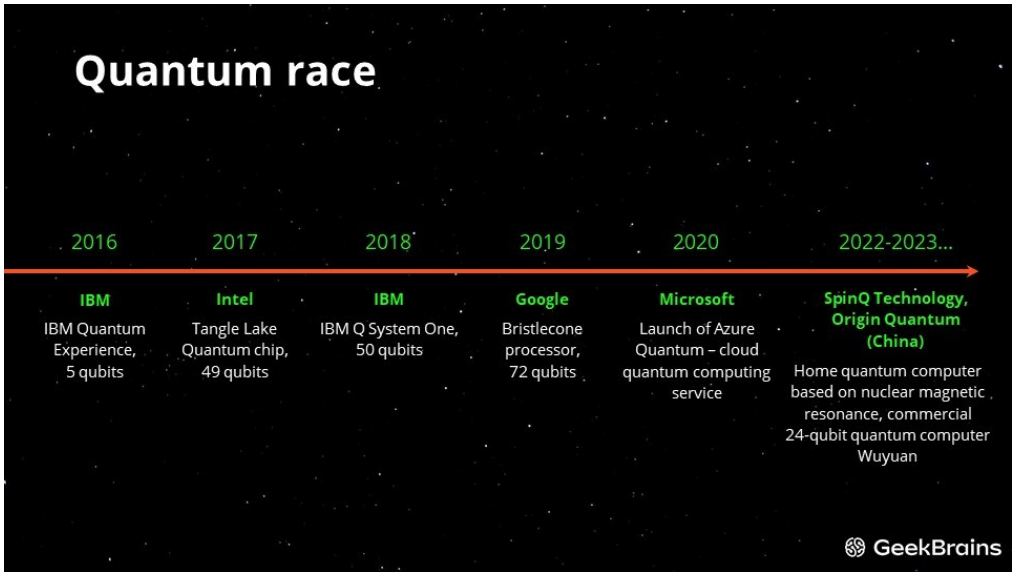

Fig. 33. Development of quantum computing

For comparison, the cathode-ray tube (Williams-Kilburn tube), which was developed in 1946, had a storage capacity of 1,024 bits, allowing for the output of two-dimensional arrays in Morse code (fig. 34). This tube was used as a storage medium in early computers.

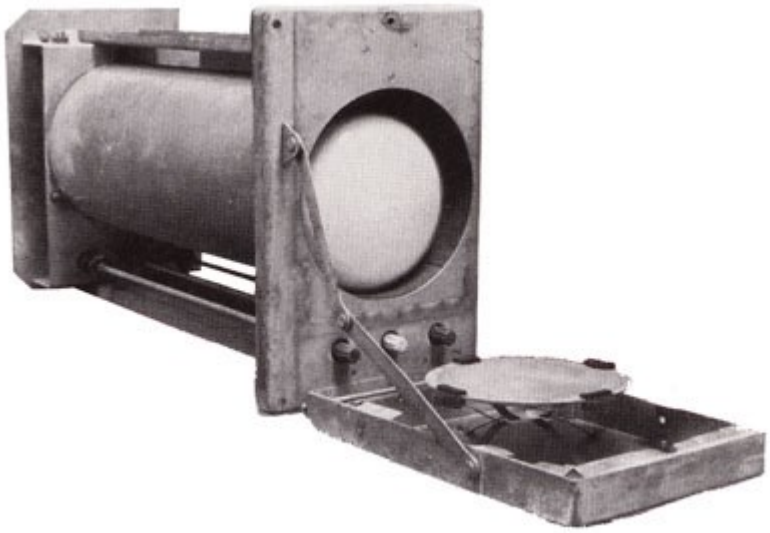

Fig. 34. Williams-Kilburn tube

Here is an example of the use of quantum computing in cryptography – the field of data protection. The RSA public-key protocol[8] is widely used for digital signatures. This protocol takes several decades for a conventional computer to break when using the Bruteforce method or some other type of accelerated algorithm selection. However, the Shor algorithm (Shor P. W.), proposed in 1994, reduces the problem of breaking the encryption to the technological challenge of creating a quantum computer by exploiting quantum parallelism.

[8] Symmetric-key cryptographic systems require the division of the responsibility for ensuring confidentiality between two parties, while public-key systems (such as RSA) allow each party to individually create and maintain their privacy requirements.

Therefore, a quantum computer opens such a key in less than a second. Consequently, as soon as the new quantum computers comes into effect, all encryption that has been in place until now can be considered “outdated” and must be reinvented. That is, cryptography will need to be significantly strengthened to ensure that it is impossible for a password to be cracked and access to a bank account gained through exhaustive search [23, 27] (fig. 35). Consequently, this will present additional challenges for IT personnel.

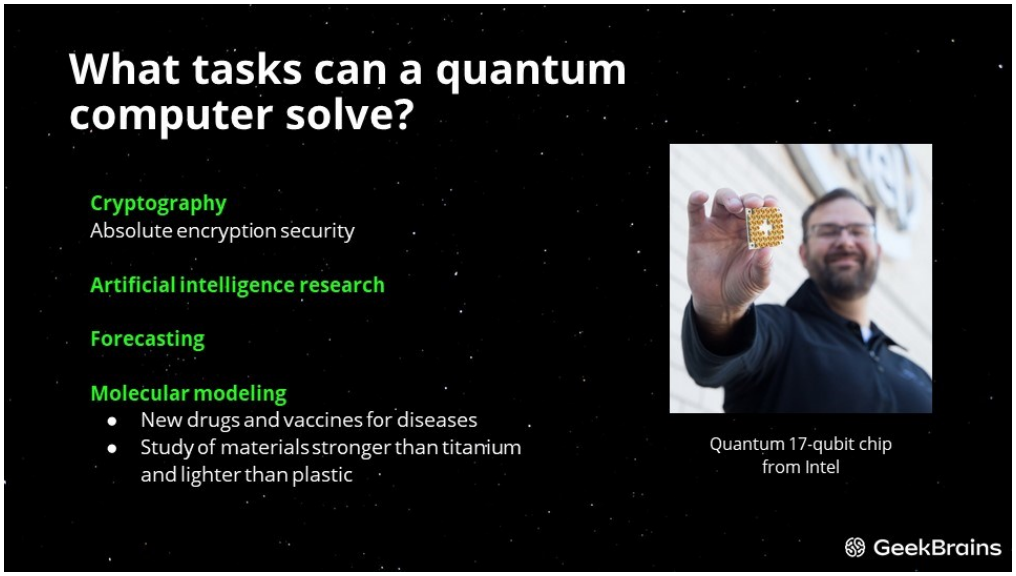

Fig. 35. Examples of issues to be adressed by quantum computing

When computing systems such as AI and machine learning are able to make decisions at a rate several times faster than the current level of development, it will indicate significant progress in the IT field. For instance, weather forecasting remains a challenging task, which is a multifaceted model, but quantum computers could accurately predict the probability of various scenarios. Close to perfect encryption security[9], the study of previously unidentified diseases, the modeling and synthesis of different medicaments, and the understanding of disease processes are likely to lead to the fifth industrial revolution [28, 29].

4.3 Qubit – quantum bit

As we stated previously, in a classical bit, there is a binary value of 0 or 1 (transistor on/off), and it is always in one of these two states. However, in a quantum computer, a qubit, which is a quantum version of a bit, is always in a superposition state, which means it can be both 0 and 1 at the same time (fig. 36). The binary number system used in classical computing is also employed in quantum computing, but the state of a qubit cannot be unambiguously determined as 0 or 1, as the qubit is in a superposition. Instead, the output of an algorithm may be a sample from a probability distribution of possible outcomes, including possible errors. This means that the operation of a quantum computer is based on a probabilistic approach.

The superposition principle is a fundamental principle of quantum mechanics that allows the existence of any linear combination $\Psi_3 = c_1\Psi_1 + c_2\Psi_2$ for acceptable states of Ψ_1 and Ψ_2 in some quantum system. This combination is called the superposition of states of Ψ_1 and Ψ_2 (the superposition principle of states). Let's try to explain this with a simple example.

[9] The first principle of cybersecurity states that there is no perfect protection. This principle may not hold true in the future, given the potential development of quantum computing

Determining a person's emotional state through their appearance is a challenging task, as a person may simultaneously experience both positive and negative emotions, even while displaying certain facial expressions or body language. Furthermore, facial expressions and body language can be intentionally controlled and may not always accurately reflect a person's true emotional experience. Until a person is asked how they feel, it is unknown whether they are experiencing positive or negative emotions – this state can be referred to as a "superposition". Similarly, a qubit also exists in a state of zero and one simultaneously until the superposition is disrupted [30, 31].

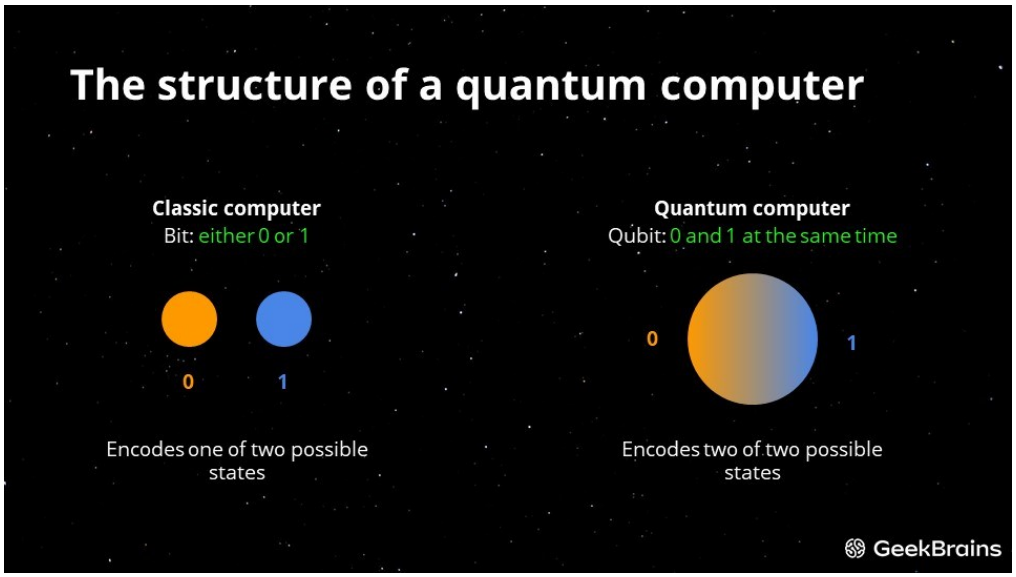

Fig. 36. Representation of a quantum bit

If we consider a classical register consisting of three bits (for example, 101, which gives as a certain value), a quantum register consisting of three qubits simultaneously contains $2^3 = 8$ values, i.e., all possible combinations of 0s and 1s that can be represented by three digits (see fig. 37).

In this example, we can see an advantage already. Three classical bits represent one number, while three qubits represent eight times as many. When we use 4 it will be $2^4 = 16$ while 5 quibits will be $2^5 = 32$ and so on. As the number of qubits increases, there is an exponential increase in computing power, whereas in a conventional system there is only a quadratic increase. Several numbers can be represented using 100 classical bits (for example, numbers from 0 to 1,023 would require 10 bits). Short text messages (such as "Hello") would require 40 to 50 bits. Character codes (such as the ASCII set) would require 12 bits per character. Computer instructions and various data types, such as binary data or simple commands, would also fit within this limit. 100 qubits could potentially hold numbers, short text messages, entire programs, audio files, low-resolution images and videos. However, the exact amount of data that can be stored depends on the specific type of data being used and how it is compressed.

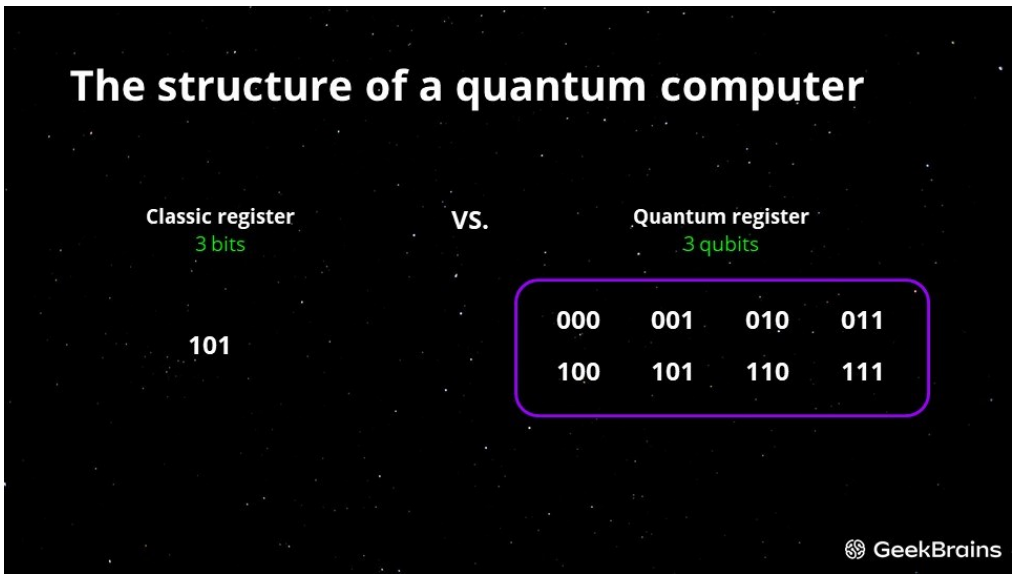

Fig. 37. Digital record of the quantum register – qubit

3.5-inch floppy disks could hold 1.44 megabytes of data, our first flash drives enabled us to store 32 or 64 megabytes. Now, this capacity has grown to gigabytes and terabytes. In terms of qubits, this represents a vast number of possible states that can be stored simultaneously. As in the example with a person, they can contain millions of different characteristics at once: their mood, their condition, the amount of money they have, whether they have a phone or not, whether they are married, have children, parents, an apartment, cottage, car, wallet keys and so on. All this information can be contained within a single person simultaneously and we can interact with them and find out what they have and do not have and how everything is connected [32]. Normal socks can demonstrate the principles of quantum network. When a sock is placed on the left foot, it becomes the left sock automatically, while the other becomes the right sock, regardless of their location: in another room or even on another planet. Until the moment of placing the socks on, their condition cannot be determined, as the socks exist in a superposition state.

The most probable outcome of the quantum computer's work is the best possible result. It is worth noting that at present, there is no quantum memory available [33]. Quantum memory refers to a specific type of information storage, which utilizes the unique properties of quantum to store and manipulate quantum data. As a result, for the foreseeable future, quantum computers will remain tied to classical computing.

Therefore, the foundation on which quantum computers and quantum computing are built:

1. The superposition state, as previously defined, is when a system is simultaneously in all possible states. In quantum mechanics, a qubit can be likened to Schrödinger's cat, as it is a thought experiment that suggests the cat is both present and absent (see fig. 38).

Let us suppose there is a sealed container and a cat is inside it. Until the container is opened, it is not possible to determine whether the cat is alive or not. The cat exists in a state of superposition, meaning that it is both alive and dead simultaneously. If the container is opened and the cat is found to be alive, then the superposition can be said to have been resolved. However, before this point, the status of the cat is uncertain, and it is possible that it is neither alive nor dead.

2. Quantum entanglement (fig. 39) – the phenomenon where the quantum states of two or more particles become linked, even when they are separated by large distances. The electrons remain connected forever, regardless of how far they are apart. If the spin of one electron changes, the spin of the other one will also change, creating a permanent connection between them. This property allows for the creation of entangled states. For example, if a person forgets their keys, their mood may change. No programmer can specify all these conditions us-

ing conditional statements, functions, and other programming techniques [18]. Quantum entanglement enables the simultaneous representation of all possible states, and these states are all interrelated, due to this fact quantum computers naturally allow for parallel processing.

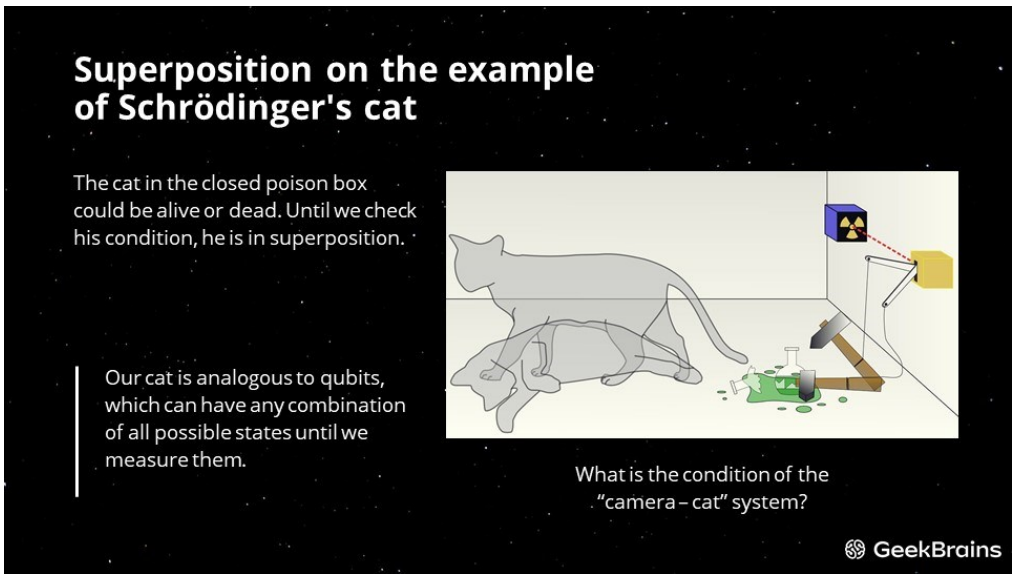

Fig. 38. The Schrodinger's Cat thought experiment

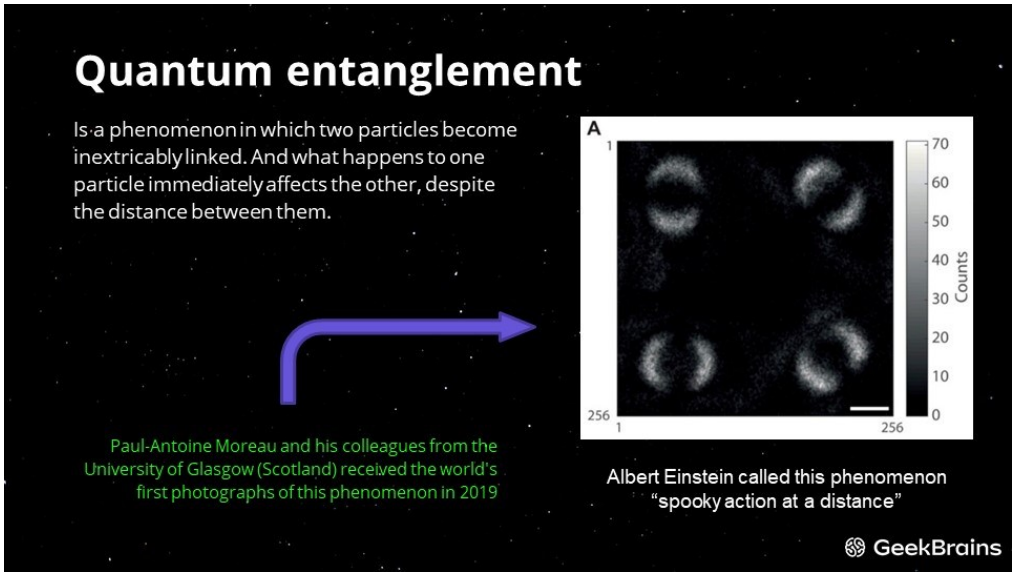

Fig. 39. Quantum entanglement [34]

Currently, a few large multinational companies with significant revenue only use quantum computing. For instance, Volkswagen Group, one of the largest automobile manufacturers in the world, is a notable example. Additionally, digital corporations utilize this technology for their manufacturing and complex computational needs, such as Google, IBM, and Apple, they are among the leading companies in their respective fields today (see fig. 40).

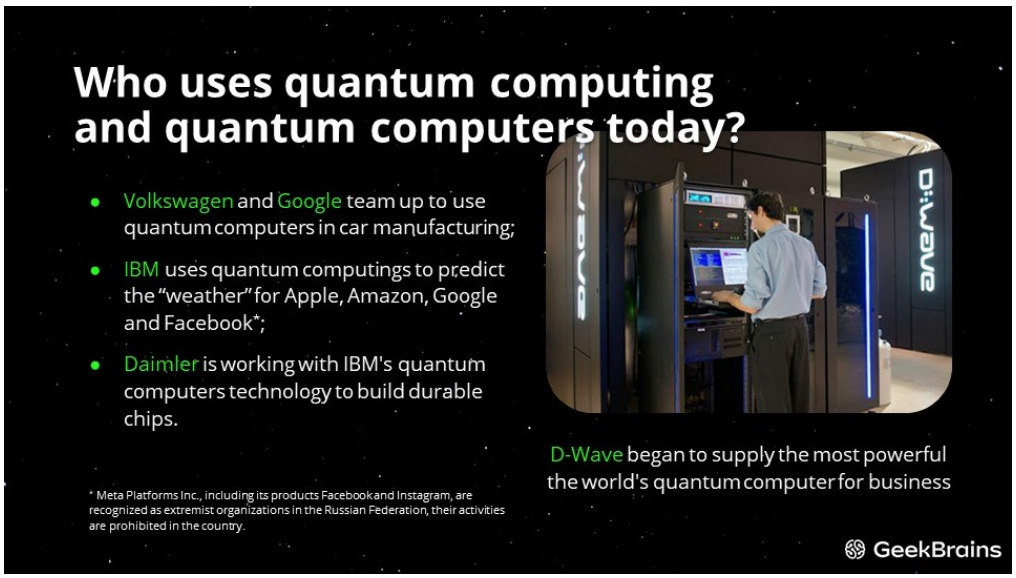

Fig. 40. The use of Quantum Computing and Quantum Computers

4.4 Disadvantages of quantum computers

However, quantum computers are not currently as widely used as to personal computers, due to their high cost and lack of standardized models (with the exception of a limited implementation in China, as shown in fig. 33).

To improve the accuracy of calculations, a very low temperature is required and the creation of conditions under which the quantum computers will be isolated from external influences, as changes in the external environment can affect the connectivity between elements. As the number of qubits increases, the system's stability decreases – all qubits inevitably interact with each other and may lose their superposition state (see fig. 41).

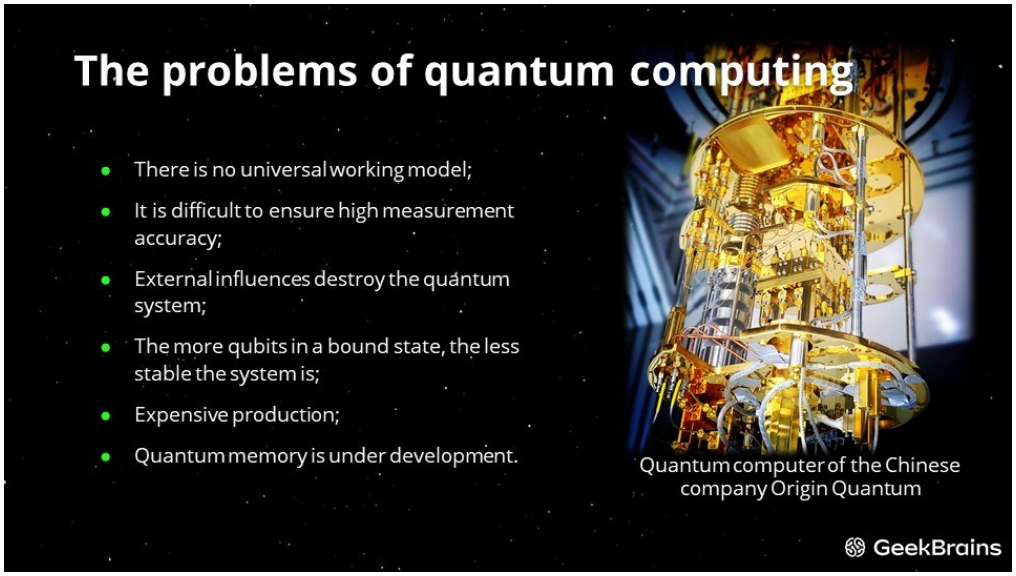

Fig. 41. The problems of quantum computing and Chinese quantum computer

As previously mentioned, we are in the very early stages of the development of quantum memory and quantum computers in general. In November 2022, a scalable quantum memory was recently developed, which has a lifespan of more than two seconds [35]. The development of quantum technologies in Russia is still in its early stages.

Like any new technology or startup, the implementation of quantum computing and quantum memory must meet certain conditions. Firstly, it must have legal authorization (in some

cases, the “regulatory sandbox” principle can be applied). Secondly, it should have competitive advantages. Thirdly, these technologies must be safe.

5. Conclusion

The first part of the research will conclude with an analysis of the semi-fantastic concept proposed by the authors. This concept, although closely related to reality, remains unfeasible at present. Research in the areas of AI, Data Science, quantum computing, and digital ecosystems is interconnected. For the first time, this study proposes an original approach to “revitalize” computers by integrating natural forces into the components of the digital world (fig. 42).

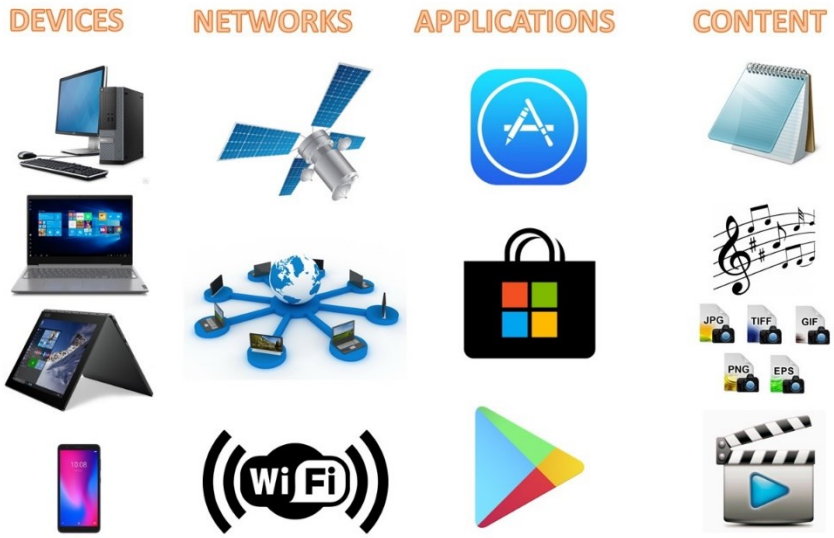

Fig. 42. DNAC Components of the digital world

If we consider the human being, the owner of natural intelligence, we can see that they have not only a brain capable of intelligence, but also a physical body (in fact, a “battery” for the brain). No human being can exist in a vacuum. Perhaps it is the natural environment, both physical and social, that influences our conscious decision-making. Is it possible to create a “breathing cybernetic organism” that will function and make decisions independently, using natural forces (such as atmospheric electricity) and big data analysis, without the need for regular battery charging? Physics suggests that this is possible.

In the book [36], a variant of a pseudo-perpetual engine is presented that utilizes the forces of nature to generate energy[10] and operates until its components become worn out, without violating the principles of thermodynamics (fig. 43). The exploration of obtaining energy from air (also known as atmospheric electricity) via chemical transformations could enable the “linking” of neural network technologies and their advancement to natural forces (without human interference; self-learning AI is no longer a novelty).

The collection and analysis of large volumes of data on the gravity of nearby objects and other actual parameters (physical phenomena in the atmosphere, social conditions, individual characteristics, etc.), forms another (or a major) component of future AI. Therefore, the predictions of the British futurologist and science popularizer Dougal Dixon regarding the human of the future could be tempered by the unfortunate conclusion that the advancement of AI may lead to the extinction of humanity.

However, let us perform some calculations for our thought experiment. Winding up a clock requires a certain amount of energy per day – $1/7 kgf \cdot m$ – measured in kilograms of force-meters (kgf-m). A modern computer, on the other hand, consumes significantly more energy,

[10] For example, the use of the barometer movement for winding up clock mechanism.

approximately $120-200W\cdot h\approx 0.2kW\cdot h$ or $4.8kW\cdot h=1762069.616kgf\cdot m$ in 24 hours of continuous use. Let us estimate the cost of a clock's winding up mechanism at 1 kopeck, then the cost of a computer "winding up" mechanism would be $4.8/3.9\cdot 10^7\approx 123077$ RUB. (Not to mention supercomputers, which consume megawatts of energy). Assuming the cost of electricity in Moscow to be 5.92 rubles per $1kW\cdot h$, i.e., approximately 142.1 rubles per computer per day, this is $123077/142.1\approx 866$ times less than the cost of a pseudo-perpetual mechanism. This makes it economically unfeasible.

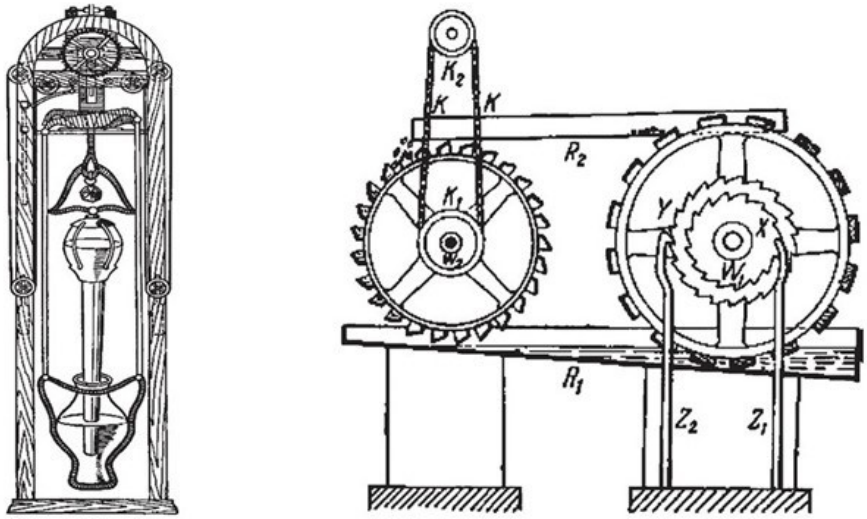

Fig. 43. The "Eternal" clock, which is wound up with the help of the forces of nature

It would seem that 123,077 rubles may be a small amount when considering computer power supply, but let us remember that we are comparing it to a single kopeck. Let us now assume that, in fact, the winding up mechanism for a pseudo-perpetual clock costs at least 10,000 rubles (or 1 million kopecks). Therefore, 123.1 billion rubles for one "perpetual" home computer (given that progress does not stand still) means that the investment is not worth it.

Therefore, the hypothesis of combining pseudo-perpetual engine technology and neural network technology is currently considered impractical due to economic considerations, although it is theoretically possible. However, the history of computing goes back less than a century, with the development of computers beginning in the 1950s [14]. However, nowadays quantum computing is advancing, and quantum computers will address the limitations of neural networks' narrow specialization, significantly exceeding the processing speed of traditional computers. At the same time, machine intelligence's evolution is not necessarily confined to the Alan Turing Test and may take as long as human evolution itself. By the middle of the 21st century, the implementation of elements of Web 4.0 – the Neuro-Net – will begin. This is discussed in the second half of the research paper, where the possibilities and challenges of cybernetics, smart devices, blockchain networks, the concept of Internet Web 3.0, and metaverses will be highlighted. It is likely that today's most powerful supercomputers correspond to the level of ciliates in biological evolution.

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