Honorata Balicka

CHMURY OBLICZENIOWE ORAZ WYBRANE ZASTOSOWANIA UCZENIA GŁĘBOKIEGO W BANKACH

Streszczenie

Współczesne zagrożenia systemu bankowego wynikają z rozwoju kryptowalut, a szczególnie Bitcoina, co jest sprzeczne z podstawami bankowości, gdyż pomija się przede wszystkim rolę banków centralnych. Ponadto kryzys gospodarczy związany z panującą powszechnie pandemią może wywołać poważny kryzys finansowy, a nawet bankowy. Warto zatem zastanowić się nad możliwością pokonania powstałych zagrożeń przez banki. Celem pracy jest scharakteryzowanie kierunków rozwoju bankowości w zakresie stosowania nowoczesnych technologii informatycznych opierających się na chmurach obliczeniowych oraz głębokich sieciach neuronowych. Zdaniem Autorki właśnie taka strategia stwarza duże szanse na uniknięcie poważnego kryzysu bankowego z powodu rozwoju pandemii oraz kryptowalut.

W artykule omówiono wybrane modele zastosowania chmur obliczeniowych oraz deep learningu w bankowości. Zaproponowane modele uczenia głębokiego cechują się istotnym potencjałem w zakresie wzrostu konkurencyjności przedsiębiorstw bankowych. Wymagają jednak efektywnego wykorzystania superkomputerów i chmur obliczeniowych w procesie długotrwałego treningu tej klasy aplikacji informatycznych. W szczególności scharakteryzowano klasyfikację wniosków kredytowych, przewidywanie kryzysu bankowego, a także przewidywanie kursów walut na giełdzie papierów wartościowych.

Tak rozumiana inteligentna chmura bankowa umożliwia skuteczne konkurowanie w warunkach rozwijających się globalnie gospodarek opartych na wiedzy i nowoczesnych technologiach. Szczególnie w obecnych warunkach kryzysu gospodarczego wywołanego przez pandemię Covid-19 kluczowe znaczenie odgrywa szybkość reakcji i działania na zmieniające się warunki popytu. Trafne podejmowanie decyzji finansowych w warunkach rozległego i głębokiego kryzysu także na rynku pracy może być zrealizowane za pomocą inteligentnego przetwarzania dużej ilości różnorodnych danych (Big Data). Właściwymi metodami są zwłaszcza metody uczenia maszynowego wykorzystane w środowisku chmur obliczeniowych. Z tego powodu omówiono wybrane aspekty precyzyjnego podejmowania decyzji w relatywnie krótkim czasie w bankowości.

Słowa kluczowe: bankowość, uczenie głębokie, sztuczne sieci neuronowe.

CLOUD COMPUTING AND SELECTED MODELS OF DEEP LEARNING IN BANKING

Summary

Contemporary threats to the banking system result from the development of cryptocurrencies, especially Bitcoin, which is contrary to the basics of banking, as the role of central banks is largely ignored. In addition, the economic crisis associated with a widespread pandemic could trigger a severe financial and even banking crisis. It is therefore worth considering the possibility of banks overcoming the threats that have arisen. The aim of the work is to characterize the directions of banking development in the field of using modern information technologies based on cloud computing and deep neural networks. According to the author, such a strategy creates a great chance to avoid a serious banking crisis due to the development of the pandemic and cryptocurrencies.This article discusses selected models of cloud computing and deep learning in banking. The proposed deep learning models have a significant potential to increase the competitiveness of banking enterprises. However, they require the effective use of supercomputers and cloud computing in the process of long-term training of this class of IT applications. In particular, the classification of loan applications, forecasting a banking crisis, as well as forecasting exchange rates on the stock exchange are characterized.

Intelligent banking cloud enables effective competition in the conditions of globally developing economies based on knowledge and modern technologies. Especially, in the current economic crisis triggered by the Covid-19 pandemic, speed of response and response to changing demand conditions is crucial. Accurate financial decision-making in the conditions of a widespread and deep crisis, also in the labor market with access, can be achieved through intelligent processing of large amounts of various data (Big Data). In particular, machine learning methods used in the cloud computing environment are appropriate methods. For this reason, selected aspects of precise decision making in a relatively short time in banking were discussed

Keywords: banking, deep learning, artificial neural networks.

Introduction

Contemporary threats to the banking system result from the development of cryptocurrencies, especially Bitcoin, which was worth over $40,000 on 8 January 2021. Besides, Bitcoin is contrary to the basics of banking, as the role of central banks is largely ignored. In addition, the economic crisis associated with a widespread pandemic could trigger a severe financial and even banking crisis.

It is therefore worth considering the possibility of banks overcoming the threats that have arisen. The aim of the work is to characterize the directions of banking development in the field of using modern information technologies

based on cloud computing and deep neural networks. According to the author, such a strategy creates a great chance to avoid a serious banking crisis due to the development of the pandemic and cryptocurrencies.

It is worth to underline that there is a gap in the literature on the subject in this respect. There are no clear ideas on how to apply artificial intelligence and cloud computing to strengthen the role of the banking sector and increase its competitiveness against cryptocurrency systems.

This article discusses selected models of cloud computing and deep learning in banking. The proposed deep learning models have a significant potential to increase the competitiveness of banking enterprises. However, they require the effective use of supercomputers and cloud computing in the process of long-term training of this class of IT applications. In particular, the classification of loan applications, forecasting a banking crisis, as well as forecasting exchange rates on the stock exchange are characterized. The last decade has seen significant expenditure on improving the information infrastructure to improve the access of financial institutions, including banks, to supercomputers and computer clouds. An important reason for this tendency is the fact that the provision of efficient distributed systems enables quick and precise determination of forecasts or solutions, as well as simulations using deep learning methods for many companies, which can thus gain a competitive advantage.

It is worth noting that currently in Poland there is an appropriate IT infrastructure with sufficient and not yet fully used computing power. The American supercomputer Roadrunner by IBM, which in the spring of 2008 became the first machine in the world with a capacity of 1 Pflop/s (quadrillion of operations per second), is characterized by lower computing power than the 1.25 Pflop/s s supercomputer Triton available at the Gdańsk University of Technology since 2015. Although currently the fastest computer in the world is Japanice supercomputer Fugaku with a performance of 415 Pflop/s, American supercomputers are characterized by a total computing power exceeding the capabilities of their counterparts in the European Union, China or Japan. There is also a noticeable correlation between the level of economic development and the advancement of computer technology. Supercomputers are essential for effective training of artificial neural networks with the use of deep learning.

Supercomputers can provide advanced virtualization for multiple simulations in banking, transportation, marketing and business. Building physical models of new products takes a long time, but you can simulate these models in virtual environments to quickly see how the products will sell or use. This way, you can save weeks or even months in the design and testing phase, giving you a certain advantage over competitors.

The basic research methods include a critical analysis of the literature on the subject. In addition, modeling was used to develop simulation models of the game on the stock exchange using deep learning. Also, intensive compu-

tational experiments related to the analysis of the quality of solutions were carried out, which were determined using the proposed methods of artificial intelligence.

The scientific study presented in this article was a verification by simulating the feasibility of using deep learning based systems on the marketplace. The results exceeded the estimates described in the literature on the subject. The mean error is estimated at less than 5% when using convolutional networks. Therefore, it should be assumed that also the other deep learning paradigms will be an effective tool in banking.

The article is organized as follows. Section I discusses two important risks for the banking system: the Bitcoin currency system and the reduction of the world economy because of a pandemy Covid-19. The section II, in turn, describes an uncontrolled development of the Bitcoin system. Conditions for the effective use of cloud computing are presented in Section III. European concepts on the use of supercomputers are discussed in Section IV, and section V discusses modeling and virtualization with graphics cards, which can also be used in deep learning. Section VI, on the other hand, is devoted to the extremely important paradigm of artificial intelligence, which is genetic programming. Intelligent development agents are characterized in Section VII. Section VIII refers to the use of artificial neural networks to support stock exchange I vestments. The illustrated examples also relate to the assessment of creditworthiness and warning against banking crises. Finally, conclusions and future work are presented.

1. Survey of main threats for banking system

Supercomputers, grids and clouds are modern computer systems that can be used to gain advantage of banks over the market competition by implementing unique calculations using high-power computers. They can also introduce new financial systems, including currency systems.

For example, grids are used to carry out transactions with the Bitcoin cyber currency, creating a rather unusual model of cyber currency (Fig. 1). Without a network of efficient computers, it would not be possible to introduce the dynamic development of this social currency system. The performance of the community-maintained Bitcoin grid is several orders of magnitude greater than that of the fastest supercomputers and grids.

Forecasting trends in finance is an important issue solved with the help of parallel deep learning algorithms, which are characterized by high requirements for the computing power of computers[1]. The prediction of financial trends can therefore be made with the use of computing clouds. The computing

[1] Mylonakis J., Diacogiannis G., *Evaluating the likelihood of using linear discriminant analysis as a commercial bank card owners credit scoring model*, "International Business Research", Vol. 3, No. 2, 2010, p. 12.

performance of one of the fastest Folding@ home grids is estimated at 48 [Pflop / s]. To obtain such a high intensity of data processing, 182 thousand. computers. In Poland, the largest grid is the nationwide Pl-Grid. It is also worth mentioning the Comcute PG grid, in which the computational volunteering paradigm was implemented based on software developed at the Gdańsk University of Technology[2].

The Prometheus supercomputer has the computing power of 1.658 PetaFlops, which is provided by 1,728 servers of the HP Apollo 8000 platform connected by the InfiniBand network with a capacity of 56 Gbit/s. A total of 41,472 computing cores (the latest generation of Intel Haswell processors) are available. The size of the total operating memory is 216 TB (DDR4 technology). The disk storage capacity (two file systems) is 10 PB which are available at 180 GB/s.

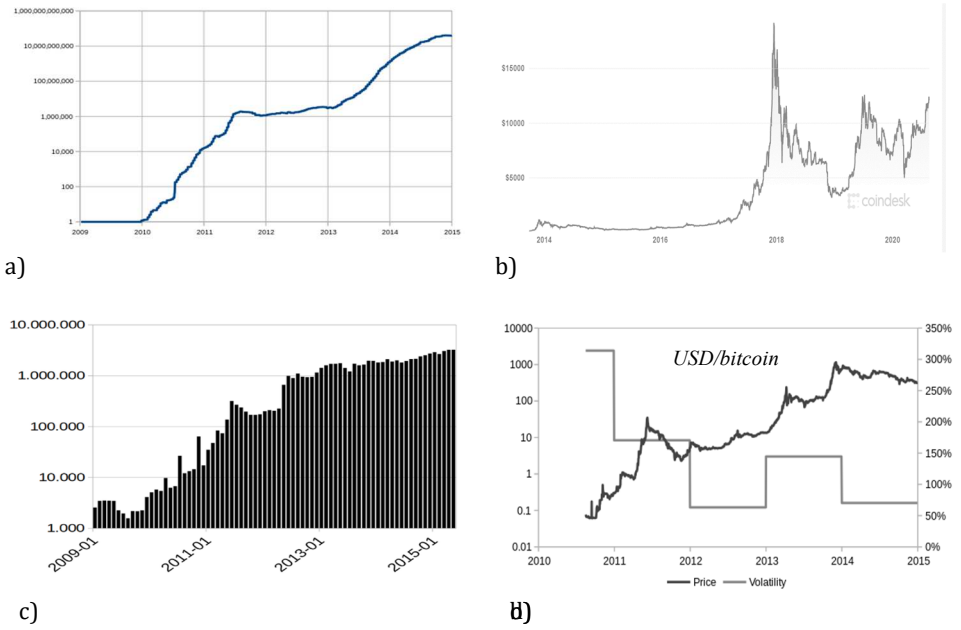
Also, banking sector crises in a given country can be predicted by implementing deep learning methods on supercomputers. The above is extremely important as the turning point in banking systems can upset the stability of the financial sector even on a global scale. The banking system resembles interconnected vessels, and troubles or bankruptcy of one of the banks may trigger a domino effect and plunge the entire sector. Therefore, the cooperation of banks is important, which was missing in the case of the bankruptcy of Lehman Brothers Holdings Inc in 2008. This bank was one of the largest investment banks in the US.

It is worth emphasizing that although financial crises occur relatively frequently, banking crises are rarely observed. About 100 banking crises in different parts of the world have been observed in the last fifty years. The banking crisis in Poland in 2009 shook the domestic economy, which resulted in the annual decline in GDP by almost 14%. Thanks to EU funds, already in 2010, GDP returned to the level of EUR 360 billion, and in 2014 the value of GDP reached EUR 408 billion[3].

[2] Balicka H., Balicki J., Korłub W., Paluszak J., Pastewski M., Przybyłek P., Zadroga M., Zakidalski M., *Artificial intelligence methods to support banking information systems*, In: K. Kreft, D. Wach, J. Winiarski (red.): IT systems in the economy, Publishing House of Gdansk University, Gdansk 2013, s. 127 (in Polish).

[3] Eurostat. http://ec.europa.eu/eurostat/, [Access: 12.01.2021].

Fig. 1. Selected trends related to the development of the Bitcoin cyber currency[4]:
a) the relative complexity of mining the currency; b) the value of the currency within 2014–2020,
c) the monthly number of transactions; d) the value of the monetary unit and its dynamics of changes.



Source: Bitcoin.org, https://bitcoin.org/en/faq#what-is-bitcoin, [Access: 10.01.2021].

The effects of the crisis in other European countries were much more serious, which is confirmed by the fact that the Czech Republic, Spain, Hungary and Italy only in 2013 came close to the 2008 GDP level. Interestingly, the reduction of GDP in the US took place two years earlier in 2007 and lasted for two consecutive years. US GDP fell from EUR 1.103 trillion in 2006 to EUR 1.056 trillion in 2007 and then to EUR 1.001 trillion in 2008[5]. In general, the banking crisis is preceded by a two-year period of gentle decline in GDP, and then continues for the next two years with a significant decline in GDP (over ten percent). Overcoming a banking crisis usually takes another two or four years[6].

However, in some cases the course of the banking crisis has been more dramatic. The prolonged banking crisis in Greece reduced the country's GDP to 2003 levels, as well as civil unrest and a political turning point. As a consequence, Greece's exit from the euro area in mid-2015 was considered. It is

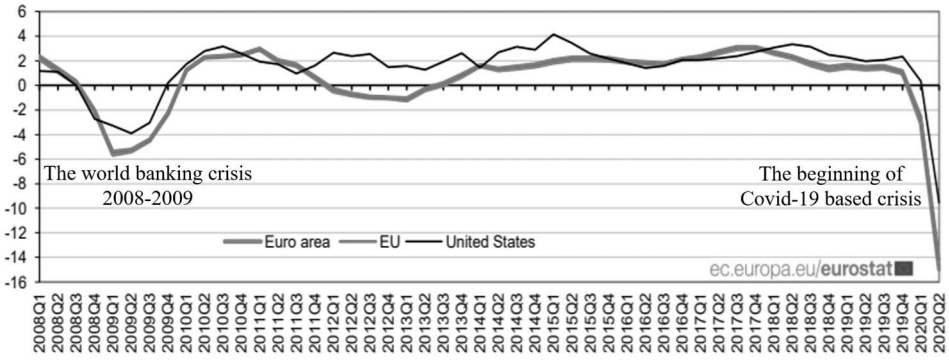
[4] Bitcoin.org, https://bitcoin.org/en/faq#what-is-bitcoin, [Access: 10.01.2021].
[5] Ibidem.
[6] Balicka H., Balicki J., Korłub W., Paluszak J., Pastewski M., Przybyłek P., Zadroga M., Zakidalski M., *op. cit.*, p. 128 (in Polish).

worth noting that since 2010, Greece has received 240 billion euros from the European Union and the International Monetary Fund in rescue programs, which exceeds its GDP. It is difficult to imagine what the negative consequences would be if Greece did not receive such aid. Against this background, an interesting issue is banking sector risk estimation using the support vector method for early warning of banking failures, which creates some room for decisions to mitigate the effects of the crisis[7].

However, we are now dealing with a much more severe crisis related to the Covid-19 pandemic, which has triggered a much more severe economic crisis and could trigger another financial and then banking crisis (Fig. 2).

Compared with the same quarter of the previous year, seasonally adjusted GDP decreased by 15.0% in the euro area and by 14.1% in the EU in the second quarter of 2020, after -3.1% and -2.5% respectively in the previous quarter. These were also by far the sharpest declines since time series started in 1995.

Fig. 2. GDP growth rates over the same quarter of the previous year % change, based on seasonally adjusted data[8].



Source: Eurostat. http://ec.europa.eu/eurostat/, [Access: 12.01.2021].

During the second quarter of 2020, GDP in the United States decreased by 9.5% compared with the previous quarter (after -1.3% in the first quarter of 2020). Compared with the same quarter of the previous year, GDP decreased by 9.5% (after +0.3% in the previous quarter).

Interesting methods that require supercomputers are deep learning methods in the context of research on the credibility of borrowers. Too liberal lending in a not-so-affluent society and with high unemployment may lead to bank bankruptcy or to high social discontent in the case of probate inheritance law and restrictive debt collection. Therefore, a compromise is needed between the

[7] Balicka H., Balicki J., Korłub W., Paluszak J., Zadroga M.: *Supercomputers to support economic processes with particular emphasis on the banking sector*, "Contemporary Economy", Vol. 4, Issue 5, 2014, p. 12. (in Polish).
[8] Eurostat. http://ec.europa.eu/eurostat/, [Access: 12.01.2021].

liberal lending strategy in order to stimulate the economy and the upward trend of irregularly repaid loans emerging with a delay of several years.

2. Uncontrolled innovation – Bitcoin's social currency

Avoiding innovation in financial systems, in particular, may lead to the uncontrolled development of a new currency system, as is the case with Bitcoin. It is worth noting that Bitcoin is both the name of the cloud computing and the name of the digital currency with which you can make payments around the world between internet users who have an account in this system. The Grid is based on a P2P (peer-to-peer) architecture, and the banking model does not assume the existence of a central bank and financial supervision control, thus the so-called Social banking is extremely original. Previously, it seemed that such models of currency systems could not compete with traditional ones.

The first version of the system with its early specification was published in 2009 by Satoshi Nakamoto[9]. Currently, the project is actively developed with the use of open-source software[10]. The correctness of the transaction is verified automatically by nodes belonging to the network, which contributes to lowering the costs of making payments. Significant features are: no possibility to cancel a completed financial transaction and greater anonymity of its participants.

The execution of a payment by a Bitcoin grid user is no more difficult than with traditional services. For this purpose, the wallet application is launched on a personal computer, tablet or smartphone. When creating an account, the user receives an address and a private key, which can be compared to setting up a traditional bank account, in which the address corresponds to the account number and the private key - a password. However, unlike setting up an account, the Bitcoin address is assigned without registering any user data and signatures[11]. The wallet balance is calculated based on the blockchain, which is determined based on the principles of cryptography[12].

However, payment in the system can be compared to sending an e-mail. Transfer between wallets consists in creating a new record that contains previously generated wallet addresses and a signature determined with the payer's private key. You can define for the record who is the payer in the transaction. One of the tasks of signing is to prevent attempts to reuse the currency. The record is sent to the recipient and to the control computers that should confirm the transaction.

[9] Bitcoin.org, *op.cit.*
[10] Bitcoin, http://nakamotoinstitute.org/bitcoin/, [Access: 11.01.2021].
[11] How do Bitcoin Transactions Work, http://www.coindesk.com/information/how-do-bitcoin-transactions-work/, [Access: 11.01.2021].
[12] How does Bitcoin work, https://bitcoin.org/en/how-it-works, [Access: 11.01.2021].

The transaction approval process adds a new entry to the blockchain. Searching for the so-called Evidence, also known as mining, is based on the principle of competition, after which the winner receives an amount expressed in Bitcoins for finding the proof. After finding the proof, the system moves to the next challenge[13]. As a result of the development of this monetary system, the complexity needed to set the challenge also grows[14].

The power of computers, expressed in the number of evidence produced per unit time, plays an important role. Classic processors in PCs are characterized by an extraction intensity of less than 4 kH / s, with H being a unit of calculation corresponding to the determination of the value of the so-called hash function (hash). The more advanced Xeon E5-2650 processor has a performance of 130 kH /s, with the cost of the processor being PLN 5,000 PLN. Along with the development of the Bitcoin grid, graphics cards were used to extract the currency, the mining speed of which ranged from 50 to 1,500 kH/s[15]. The most frequently used system was CUDA from NVIDIA, which made it possible to connect multiple graphics cards, multiplying the computing power.

As of 2014, these solutions do not provide a balance between the cost of equipment, energy consumption and the profit from taking evidence. For mining, specialized Application Specific Integrated Circuit (ASIC) integrated circuits are used, which are designed to perform a specific computing task, which makes them smaller, cheaper, faster, consuming less energy and more reliable than universal processors. The cost of an efficient chip called SP35 Yukon Power is $ 1,564 with an energy consumption of 3.6 KWh[16]. The mining power of these chips reaches 5.5 TH / s, so it is almost 4,000 times greater than the performance of graphics cards. BitCrane T-720 chip with a power of 7.2 TH / s, energy consumption of about 8 kWh and a price of USD 2,500 is slightly more efficient and expensive. One of the fastest solutions is the Antminer S5 with a capacity of 112 THz and a price of around USD 28,000[17].

Despite the growing popularity of Bitcoin, legal issues are not regulated in many countries. This is the case in Poland, where no legal act regulating the use of Bitcoin has yet been created. It is stated that the use of Bitcoin is legal, although it cannot be considered legal tender and is also not electronic mon-

---

[13] *Ibidem.*

[14] *Bitcoin: A Peer-to-Peer Electronic Cash System*, https://bitcoin.org/bitcoin.pdf, [Access: 12.01.2021].

[15] *Mining hardware comparison*, https://litecoin.info/Mining_hardware_comparison, [Access: 12.01.2021].

[16] *Ibidem.*

[17] Balicki J., Beringer M., Korłub W., Przybyłek P. , Tyszka M., Zadroga M.: *Collective Citizens' Behavior Modelling with Support of the Internet of Things and Big Data*, "Proc. of the 8th Int. Conf. on Human-System-Interaction HSI'2015", Warsaw, Poland, June 25–27, 2015, pp. 63.

ey[18]. Many financial institutions, including the European Banking Authority, warn against the use of virtual currencies such as Bitcoin due to the lack of appropriate regulations and the lack of guarantees of this type of currency stability[19].

Bitcoin is enjoying a growing interest in emerging markets, e.g. in parts of Africa where there is a lack of developed payment systems[20]*.* The reasons for this can be seen in the wide availability of the service, as well as its transparency. More and more companies allow payments with Bitcoin, eg Microsoft accepts such payment for its products. Unfortunately, anonymity carries the risk of interest in this currency by criminal groups[21].

3. Review of conditions for the effective use of cloud computing

The main problem in the use of high-performance computing by business companies, which after all create jobs, is the lack of prepared staff of designers of this class of applications. Thousands of companies would probably benefit from supercomputers, but for financial reasons they cannot afford it, leaving their economic potential largely untapped[22]. The above prompted some universities and research institutions in the US to launch projects that will provide companies with access to high-performance systems as well as technical assistance. It is worth mentioning the Ohio Supercomputer Center project in Columbus and the Welding Institute. Edison, who conducts research on the applications of welding technologies in the economy.

In one supercomputing application, a wide range of material joining data is made available to engineers via a web user interface. Engineers can run simulations that show, with a slight delay, how some welds will behave under the given loads on the structure. The application makes the resources of supercomputers available through a browser, without the need for time-consuming and advanced programming. It was found that modeling and simulation can significantly increase the competitiveness of production based on this class of applications. Therefore, it seems that the skilful use of supercomputing software may also improve the competitiveness of the Polish industry, especially the shipbuilding industry.

---

[18] *Bitcoin*, *op. cit.*

[19] *EBA warns consumers on virtual currencies*, http://www.eba.europa.eu/-/eba-warns-consumers-on-virtual-currencies, [Access: 11.01.2021].

[20] *Forbes*, http://www.forbes.com/sites/techonomy/2014/08/07/bitcoin-momentum-grows-in-emerging-markets/, [Access 11.01.2021].

[21] Frankel J. A., Rose A. K.: *Currency crashes in emerging markets: an empirical treatment*, "Journal of International Economics", Vol. 41, no. 3-4, 1996, p. 355.

[22] Balicki J., Korłub W., Paluszak J. : *Big Data Processing by Volunteer Computing Supported by Intelligent Agents*, "Proc. of 6th Int. Conf., PReMI 2015", Warsaw, Poland, June 30 - July 3, 2015, Lecture Notes in Computer Science, Vol. 9124, p. 277.

The project implemented by Indiana University and Purdue University provides computing power from the IBM Indiana center to companies in the pharmaceutical and automotive industries that already have extensive experience in the use of high-class IT systems. In particular, it is possible to provide standard software packages as well as friendly tools for implementing your own application code. Specialist help in parallelizing the application is also important.

An important application of supercomputers is the verification of utility model designs in terms of copyrights. Verification is an essential task performed by corporate solicitors to make sure that a proprietary product does not infringe third party copyrights and licenses. The application of the above class is one of the proven systems implemented in the IBM Indiana computing center.

The Louisiana State University project, together with California-based Electronic Arts Inc., aims to ensure quality in the design of computer games and other interactive entertainment software. The project is related to the development of digital media, which includes academic research in the field of visualization with supercomputers. The reason for the involvement of a large amount of state funds is the desire to build an economy based on the visualization and virtualization of products. This step towards the knowledge economy is already possible as the computer architecture, software and network infrastructure have been developed to support the environment of this type of business.

Cloud computing offers an alternative way to gain access to supercomputer resources, which can also be used to support industrial processes. Scientists from Rice University in Houston used cloud services for this purpose: Amazon.com Inc Elastic Compute Cloud and EC2. However, they noted that access to high computing power is only one important aspect. First of all, applications in economic applications should be adapted to work in parallel environments, which causes a growing demand for designers who can adapt systems of this class. Therefore, faculty members at Rice University provide affordable and readily available parallel programming training. As part of this project, relevant books can be downloaded from the Internet, some of which are created through a competition for authors of books on parallel computational issues. Chevron Corp, Sun Microsystems Inc and Nvidia Corp collaborate with the university to support the project and seek highly qualified associates.

American investment banks, which employ almost all university graduates with computer modeling skills, are particularly involved in numerous projects using supercomputers. This approach is also observed in relation to other sectors of the economy. For example, Purdue University provides an interactive Web 2.0 class portal called Hubzero.org, which is used to educate research communities to use interactive simulation tools.

The US economy is believed to be successful because of the aggressive absorption of technology. Concerns about market competition are one of the reasons for the dynamic growth in the use of supercomputers. It is worth noting that Asian manufacturers are also supporting their activities with supercomputers to develop products, which reduces the competitiveness of non-Chinese companies.

As part of the economic stimulus package in the US, laboratories and research centers, as well as universities in the use of supercomputers, were financed. In addition, interest in climate modeling has made great strides in the development of supercomputers. Much hope is also placed in the financing of education, which could help in the economic use of supercomputers.

The Competitiveness Council in Washington, composed of representatives of large companies and universities, recommends the dissemination of HPC in economic applications as an important goal for the coming years. In particular, the US defense industry, which develops "dual-use" technologies, was called to make its supercomputing computing power available to US manufacturers, innovators and entrepreneurs. It was emphasized that HPC technology is perceived as one of the country's strategic assets.

An interesting example of combining artificial intelligence and parallel computing is the supercomputer IBM Watson (Thomas Watson is a co-founder of IBM), which won the Jeopardy quiz in 2011 (in Poland it was a game show called Va Banque). After defeating the world champions in checkers, chess or backgammon, the next application turned out to be better than the human. Of course, this would not be possible without the proper use of computing resources, including 32,400 eight-core Power7 processors with a total power of 80 TFlops and 16 TB memory. This supercomputer will probably find application in business analysis, and will also be designed for searching in extensive knowledge bases. It can be helpful in making decisions, including medical diagnostics, where it is estimated that only 50% of diagnoses are correct. Currently, a supercomputer equipped with artificial intelligence enables correct diagnostics in 90% of lung cancer cases. The extensive use of IBM Watson in education is also planned – In May 2011, the computer program passed the exams in the second year of medical studies[23].

Supporting the choice of lung cancer treatment method is the first major commercial use of this computer, which was successfully implemented at the Memorial Sloan Kettering Cancer Center in 2013. The program answers the questions "What does a patient with the following symptoms and medical history have?", And provides a treatment regimen with warnings about contraindications for specific medications. The medical knowledge base includes:

[23] Balicki J., Korłub W., Tyszka M.: *Harmony search to self-configuration of fault-tolerant grids for big data*, In: Z. Kowalczuk: "Advances in Intelligent Systems and Computing", Vol. 386, 2016, p. 411.

605,000 methods of preparing specific medical diagnoses, 12 million pages of selected text from 290 journals and 200 monographs, as well as 25,000 training patterns. The software training required over 14,700 hours of computer learning in a hospital setting.

During the year, several dozen copies of the supercomputer were sold at an average price of USD 1.5 million. A software server is offered, or you can access an application installed in a cloud computer to benefit from its expertise. Thanks to the cooperation of IBM with the Wellpoint trading company, further contracts will be implemented in the near future with WestMed Practice Partners and the Maine Center for Cancer Medicine & Blood Disorders.

IBM began working with Nuance Communications Inc., under which Watson is to be equipped with speech recognition skills and even greater medical knowledge, which would allow it to be applied more widely in medical diagnostics. With the help of doctors from Columbia University and the University of Maryland, the possibilities of applying this technology in medical practice are being investigated. IBM is also exploring the use of Watson as a lawyer assistant. Finance will also be an important planning application of the system[24].

4. European concepts for intelligent supercomputers

Europe is trying to keep pace with the United States (45% of resources), China (12%) and Japan (10%) in terms of providing entrepreneurs with access to adequate computing power, especially in Great Britain, France and Germany[25].

The European network of supercomputers DEISA (Distributed European Infrastructure for Supercomputing Applications) supports modeling of fusion in fusion reactors. The use of supercomputers accelerates research into meeting Europe's energy needs and, in a sense, may lead to independence from gas and oil supplies. The above goal is very likely to be achieved, all the more so as the energy released from one gram of widely available fusion fuel is equivalent to that obtained from eleven tons of coal. Fusion simulations and the study of material properties with supercomputers are necessary to make real fusion experiments possible. It is important that fusion energy experiments are safe and meet ecological standards.

The distributed European Infrastructure for Supercomputing Applications DEISA uses the GÉANT2 computer network, which enables data exchange with an intensity of 10 Gb / s. DEISA provides high-performance computing services and computing power to 12 of the 100 fastest supercomputers in the world,

[24] Shouwei L., Mingliang W., Jianmin H.: *Prediction of Banking Systemic Risk Based on Support Vector Machine*, "Mathematical Problems in Engineering", Vol. 2013, April 2013, p. 5.

[25] Balicki J., *Multi-criterion Decision Making by Artificial Intelligence Techniques*, Proc. on the 8th Int. Con. on Artificial Intelligence, "Knowledge Engineering and Data Bases", February 2009, Cambridge, pp. 322.

creating a powerful, homogeneous and easy-to-use supercomputing environment. The European agency Euratom plans to build the ITER reactor in Cadarache in the south of France. The aim of the ITER global research project is to verify that nuclear fusion can be an ecological, safe and sustainable source of energy. The European Union provides almost half of the funding, in addition to co-financing from Japan, China, India, South Korea, Russia and the USA.

It is also worth mentioning that scientists used supercomputing infrastructure as part of an EU-funded project to study the effects of sea water turbulence on pipeline and platform infrastructure. The work has the potential to improve the design of the drilling rigs with possible benefits for the environment and worker safety. Turbulence can be a serious problem when water is flowing around a platform or pipeline, creating small eddies with high intensity. Consequently, the eddies of the water exert enormous force on the security of the infrastructure, inducing vibrations. The greater the turbulence, the greater the vibration caused by the vortices. Even under relatively small undulations, vibrations occur. In underwater oil well structures such as offshore risers and pipelines on oil rigs, the problem is very serious.

Such structures are often exposed to heavy and harmful loads. Scientists are working to develop sufficiently detailed understanding of the interaction between seawater turbulence and structural elements to develop new pipeline design methods that minimize the occurrence of vibration. For this purpose, the operation of the turbulence model was analyzed by computer simulation for various scenarios, which in fact is a huge and complex task. Fluid dynamics is one of the most difficult problems in mathematics and computer science, because even for relatively small turbulences, the computing power demand of simulation algorithms may exceed the performance of the most powerful supercomputers.

PRACE (the Partnership for Advanced Computing in Europe) is another major European project that aims to build an infrastructure with the capacity of 1 Exaflops. Currently, the basic infrastructure includes six supercomputers with a capacity of at least 1 PetaFlops (Table 1). An important requirement imposed on the architecture of computers is their low electricity consumption. The most important project, in which calculations are carried out on supercomputers 'PRACE', is research on graphene. More than 90 million hours of concurrent simulation on computers have already been carried out to investigate the various properties of this two-dimensional structure with monatomic thickness and composed of carbon atoms joined into hexagons. Graphene can replace silicon in processors and is suitable for the manufacture of roll-up touch displays. In addition, it can be used to generate and store renewable energy from solar panels. Graphene sensors record single molecules of a harmful substance, which can be used in monitoring and environmental protection.

The availability of 7 million hours of parallel computing on processor cores in the PRACE supercomputer network made it possible to carry out the neces-

sary simulations in less than a month, not ten years, as part of the DNANANO project, which tests the suitability of variants of DNA structures for therapeutic purposes at different temperatures. Molecular dynamics simulations were performed and characterized on the basis of experimental studies of the DNA structure of selected molecules.

Table 1. European supercomputers within the project *PRACE.*

Supercomputer name	Centre, country	Architecture	Performance [Pflop/s]
MareNostrum	*BSC, Spain*	*iDataPlex*	1
CURIE	*GENCI@CEA, France*	*Bullx cluster*	2
FERMI	*CINECA, Italy*	*BlueGene/Q*	2
SuperMUC	*GCS@LRZ, Germany*	*iDataPlex*	3
Hermit	*GCS@HLRS, Germany*	*Cray XE6*	5
JUQUEEN	*GCS@FZJ, Germany*	*BlueGene/Q*	5.87

Source: Balicki J., Korłub W., Tyszka M. : *Harmony search to self-configuration of fault-tolerant grids for big data*, In: Z. Kowalczuk: "Advances in Intelligent Systems and Computing", Vol. 386, 2016, p. 411.

French company ARIA Technologies performs calculations on *PRACE* computers to predict flood risk to insurance companies by simulating extreme rainfall. This approach is especially useful in situations where there is little data on actual extreme events. In addition, the impact of climate change on natural hazards is simulated.

It is worth mentioning one more interesting project which is being implemented in Lausanne, Switzerland. The IBM Blue Brain supercomputer is a slightly different approach to combining artificial intelligence and supercomputers. The task is part of the European Flagship Project of the Human Brain Project, for which the European Union allocated one billion Euro in 2014–2020.

Blue Brain simulates rat, bee and human brains. The scale of the simulation is huge as it includes models of 10,000, 10,000,000 and more of different types of neurons. There may be 200 of these classes of neurons, and in some models even 1,000. The large number of neurons requires the consideration of even more synaptic connections, which may be 30 million or even a billion. When trying to simulate the human brain, one should reckon with modeling 100 billion neurons and 1 trillion neural connections. Currently, the supercomputer Blue Gene / P with the capacity of 56 TFLOPS is used to simulate at most a million neurons and a billion synapses forming a multilayer network with 100 layers.

It is worth noting that the first completely reconstructed connectome (the complete network of connections of neurons in the brain) was developed using

an electron microscope and belonged to the nematode Caenorhabditis elegans, whose brain consisted of only 302 neurons and 5,000 synapses. Currently, magnetic resonance imaging with tomographs is used, so image processing requires a lot of computing power and memory of supercomputers. It is planned to use 1 Exabyte RAM to model the human brain, with the fastest supercomputer now having a memory capacity of 1,000 times less. Like Watson's IBM, Blue Brain will have wide applications in many areas of business and industry, including finance and banking. It can therefore be concluded that IBM Watson's medical applications will not necessarily be the most important[26,27].

In summary, European applications of computing on supercomputers cover the following areas[28]:

- Processing of credit card transactions;
- Weather forecast;
- Simulating climate change;
- Analysis of the simulation of nuclear explosions;
- Design of ships and airplanes;
- fluid dynamics;
- Sequencing of the human genome;
- molecular modeling;
- Cryptology;
- Advanced graphic animations;
- Analysis of geological data;
- energy management;
- shale gas exploration;
- Astronautics.

5. Virtualization with GPUs

Supercomputers are characterized by high electricity consumption, which in the case of Tianhe-2 is 17.8 MW. In addition, computers of this class weigh up to several tons, which makes their mobility difficult. Therefore, alternative solutions are sought that can extend current computing architectures. One of them are GPUs (Graphics Processing Unit), which were initially dedicated to displaying images on a computer screen. Today, GPUs are used for virtualization and general-purpose computing, such as the NVIDIA Tesla K80 computing copro-

[26] Balicki J., Szymański J., Kępa M., Draszawka K., Korłub W.: *Improving effectiveness of svm classifier for large scale data*. Proc. on 14th Int. Conf., ICAISC 2015, Zakopane, Poland, June 14–18, 2015, Part I, Lecture Notes in Computer Science, Vol. 9119, p. 677.

[27] Hanschel E., Monnin P.: *Measuring and forecasting stress in the banking sector: evidence from Switzerland.* Investigating the Relationship between the Financial and Real Economy, BIS Papers, no. 22, 2005, pp. 435.

[28] Balicki J., Przybyłek P., Zadroga M., Zakidalski M.: *Artificial neural networks and the support vector method in banking information systems*, "Contemporary Economy", Vol. 4, 2013, pp. 1–14.

cessor. Graphics cards usually consist of several hundred or even several thousand execution units that can process sets of image points in parallel to present it on a high-resolution monitor.

Graphics cards for universal computing called GPGPU (General-Purpose computing on Graphics Processing Units) usually do not have an interface to the monitor. However, they have built-in operating memory with a bandwidth significantly exceeding the capacity of RAM memory used by CPUs. The Tesla K80 graphics card has a bandwidth of 480 GB / s, and the Intel Xeon E5-2697 – 68 GB / s. Another advantage of the GPU is the favorable computing power to the energy used[29].

These features make graphics processors often used to build supercomputers[30]. On the other hand, the presence of graphics cards in PCs makes high-performance computing accessible to a much wider audience. As a result, the range of applications of these devices in various sectors of the economy is dynamically developing, despite considerable difficulties in programming this class of devices.

One area where the effective use of graphics cards has been documented is the analysis of econometric models. Aldrich et al. show that GPUs allow you to get 200 times faster computing than CPUs when analyzing business cycles in markets[31, 32].

Supercomputers based on graphics chips have significant potential in the field of processing and analysis of big data. Due to the high memory bandwidth and the possibility of parallel execution of tasks, coprocessors can significantly speed up database operations, such as: aggregations, joins or filtering results. This opens the way for the use of graphics cards in those areas of the economy where the efficiency of operations on large data sets is important. This is especially true for logistics and transport. Govindaraju et al. compared the execution times of database queries in SQL made on the NVIDIA GeForce 6800 graphics

[29] Abe Y. *et al*.: *Power and performance analysis of GPU-accelerated systems*, "Proc. of the 2012 USENIX Conf. on Power-Aware Computing and Systems (HotPower'12)", USENIX Association, Berkeley, USA, 2012, p. 12.
[30] *TOP 500 The List*, http://www.top500.org/, [Access: 12.01.2021].
[31] Aldrich E., Fernández-Villaverde M., Gallant J.R., Rubio-Ramírez A., Juan F.: *Tapping the supercomputer under your desk: Solving dynamic equilibrium models with graphics processors*, "Journal of Economic Dynamics and Control", Elsevier, Vol. 35(3), 2011, p. 387.
[32] Dziubinski M.P., Grassi S.: *Heterogeneous Computing in Economics: A Simplified Approach*, CREATES Research Papers 2012-15, School of Economics and Management, University of Aarhus, 2012, p. 23.

card and on the Intel Xeon processor clocked at 2.8 GHz. Their test results show times an order of magnitude better for the GPU compared to the CPU[33].

Graphics cards are designed to perform operations on points and basic geometric figures, such as triangles. These possibilities are used when displaying three-dimensional scenes on a computer screen, for which the graphics systems were previously intended. The same operations that are performed on the elements of a three-dimensional scene are used when working with maps saved in spatial databases. Bandi et al. used GPUs in the Oracle 9I database engine to improve spatial operation performance[34]. As a result, simulations related to the construction of highways, air infrastructure and sea ports are possible.

Another application of graphics cards in the area of large information analysis is related to their ability to stream data processing. These possibilities result from the original purpose of the coprocessors to work with the video image stream, which requires high memory bandwidth. These features allow the use of graphics chips for data mining, where the source stream of information can be immediately processed by the coprocessor. This allows you to reduce the amount of data that must be saved - the application using the graphics card performs the initial selection and facilitates the subsequent analysis of information.

Concurrent software in a GPU environment, in particular, allows you to simulate a business venture to assess risk. Computationally complex statistical methods can be used in many areas of investing, such as: valuation of company assets, predicting share price scenarios, or valuation of options on the stock exchange[35]. These analyzes can be performed faster on supercomputers and can provide more precise results, which significantly supports decision making. The Monte Carlo mathematical modeling method in a GPU environment has a 77 to 124-fold performance gain compared to the CPU[36].

6. Development of other AI approaches

Besides deep learning, genetic programming is used as a prediction method in financial systems for two important reasons. The first is the fact that genetic programming takes into account the dynamically changing environment, which is an inherent feature of the modern market. The second reason is that the

---

[33] Govindaraju N. K., Lloyd B., Wang W., Lin M., Manocha D.: *Fast computation of database operations using graphics processors,* "Proc. of the 2004 ACM SIGMOD Int. Conf. on Management of Data", June 2004, p. 217.

[34] Bandi N., Sun C., Agrawal D., El Abbadi A.: Har*dware acceleration in commercial databases: A case study of spatial operations,* 2004, p. 1025.

[35] Solomon S.: *Option Pricing on the GPU*, High Performance Computing and Communications (HPCC), 2010, p. 23

[36] NVIDIA, *Computational Finance*,
http://www.nvidia.com/object/computational_finance.html, [Access: 20.08.2020].

strategies of players' behavior on the stock market are often complicated and require a broad view of the problem in order to choose the right solution[37].

Genetic programming is an alternative to classic stock exchange applications based on technical analysis, such as the CRISMA system, which was introduced in 1988 and as its authors showed, Pruitt and White set a positive return on investment within 10 years with transaction costs of 2%[38].

In financial applications, genetic programming is most often used to generate an investor behavior strategy in the stock market. Programs in the genetic population, using rules and data about the current state of the market, should indicate whether the decision situation is appropriate to sell or buy assets. The generated strategies are assessed with an adaptation function that takes into account the ability to generate profit by the programming agent. In the above model, the arguments are data from the stock exchange in a selected period of time. The choice of the procedures that make up a program is up to the analyst, and is usually limited to basic mathematical operations, majorities, and logical operators. It is also possible to use more advanced operations, such as trigonometric operations or statistical functions. An evolutionary algorithm that processes programming structures selects the best rules, and then uses transformations to produce even better programs. As a result, an advanced final program is created that automatically makes decisions about the strategy of the stock market.

Data from the stock market for a certain period, divided into three intervals, is usually used to teach and test programs in the population[39]. The first, called the training interval, is used to learn programs. It allows the development of rules for the behavior of the genetic application on the stock exchange. Then the validation interval is to check the behavior of individuals on new values, and also to help assess the population and select the best individual for the next stage. Finally, a test interval is performed during which the selected program is tested to check its performance. Usually, program performance is compared with business strategies to check their suitability. Most often it is a "buy and hold" strategy[40], but they may be more advanced autoregressive

---

[37] Bechler A., *Comparison of the effectiveness of neural networks and econometric models in supporting credit decisions, Application of statistical methods in scientific research*, StatSoft Poland, Cracow 2003, p. 28 (in Polish).

[38] Pruitt SW, White RE. *The CRISMA trading system: who says technical analysis can't beat the market?* "Journal of Portfolio Management", 1988, Vol. 14, p. 57.

[39] Chen S.-H., Kuoand T.-W. Hoi K.-M., *Genetic Programming and Financial Trading: How Much about "What we Know".* In: "4th NTU International Conference on Economics, Finance and Accounting", April 2006, p. 2.

[40] Schwaerzel R., *Financial Time Series Prediction and Evaluation by Genetic Programming with Trigonometric Functions and High-Order Statistics,* "Ph.D. Dissertation", The University of Texas at San Antonio. Advisor(s) Tom Bylander 2006.

methods[41]. Although the research shows the advantages of genetic programming in this comparison, there are publications where it is believed that this method has not worked. The effectiveness of genetic programming for finance largely depends on the selection of training data. Programs without adequate patterns behave unpredictably in new situations, and consequently perform worse compared to other solutions.

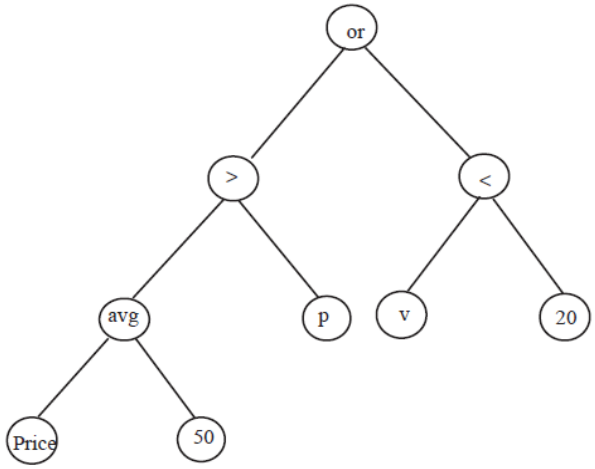
Potvin, Soriano and Vall proposed genetic programming to develop decision-making rules during dynamically changing conditions on the stock market. As technical analysis aims to develop rules for selling stocks to be used in the short term, it may be a viable alternative to an approach where assets are held over a relatively long period of time. The classic buy-and-hold approach can be used if the company and its sector of activity are viewed as promising, then the investor buys the company's stock and holds its assets for a relatively long period of time and sells when it makes a profit[42].

Genetic programming produces buy and sell rules that can be triggered when certain conditions are met. For example, the rule in Figure 3 generates a "buy" decision if the average share price of a given enterprise over the last 50 days is greater than its current price or the current transaction size is less than 20 shares. Otherwise, the shares must be sold. If the rule decides to buy, the possibility of executing the transaction, which can be "open" or "close", is still important. When buying a stock, the option should be set to "open" by the investor, and to "close" when selling. Obviously, the rule under consideration cannot be applied in all cases. Therefore, in genetic programming, the determined rules are assessed according to the investor's preferences, which are usually associated with a compromise between the dynamics of profit and the risk incurred.

[41] Svangard, N., Nordin, P., Lloyd, S., Wihlborg, C., *Evolving short-term trading strategies using genetic programming*, "Proc. of the Congress on Evolutionary Computation", Vol. 2, 2002, pp. 2006-2010.

[42] Potvin J.-Y., Soriano P., Vall M.: *Generating trading rules on the stock markets with genetic programming*, Computers & Operations Research, Vol. 31, 2004, p. 1033.

Fig. 3. An example of a rule for buying shares on the stock exchange.



Source: Potvin J.-Y., Soriano P., Vall M.: *Generating trading rules on the stock markets with genetic programming*, Computers & Operations Research, Vol. 31, 2004, p. 1033.

7. Solution based on intelligent development agents

Deep learning is used in computer games based on behavioral models, which inspired similar applications in financial systems. Programming agents are most often used in two areas: to simulate phenomena taking place on capital markets and to support decisions made on stock exchanges. Agent systems have a set of features that make them suitable for modeling phenomena. Some of these features uniquely fit into the requirements of capital market analysis, making this approach particularly effective[43].

Virtual agents should make financial decisions taking into account their owners' profit-seeking and prudential preferences. It is assumed that the propensity to take risk depends on the personality of the investor, and therefore the virtual agent representing him in the financial system should behave similarly. These psychological aspects distinguish agents from other approaches.

Agents are credited with the ability to operate under conditions of uncertainty. Algorithms and architectures that describe agent behavior, such as belief-desire-intention, layered architectures, and behavior-tree-based architectures, allow incomplete knowledge decision making. Some of them are characterized by the orientation of the agent's actions towards specific goals. On the way to achieve them, reactive actions may be performed - in response to

[43] Henley W.E., Hand D.J., *A k-nearest-neighbour classifier for assessing consumer credit risk*, "The Statistician", Vol. 45, Issue 1, 1996, p. 77.

changes in the environment, as well as proactive actions - not requiring external motivation[44].

This corresponds to the situation on financial markets, where the number of factors influencing current trends exceeds the possibilities of a complete analysis, and decisions are made under uncertainty. Each operation is simultaneously oriented towards the goal which is usually profit. The capital market is modeled as a set of autonomous entities, each of which has the same goal. The ability to model interactions between rival agents facilitates the simulation and analysis of occurring phenomena. The strategies of cooperation and negotiation of agents are also taken into account.

An important feature of programming agents is the ability to operate in a dynamic environment and adaptation to rapidly occurring changes.[45] Behavior trees, in addition to focusing on the agent's target, allow you to prioritize various behaviors that may change during application runtime. The decomposition of the agent's strategy into the form of atomic behaviors, grouped in subtrees, each of which serves a specific purpose, additionally facilitates reacting to changes and modifying current intentions[46].

Agent-based simulation allows you to verify how the market will react in response to specific events. In particular, it allows to predict the impact of changes in interest rates on the economy or to determine the reaction to exceptional market situations without threatening the stability of the real financial system[47].

On the other hand, simulating the market situation allows you to predict trends and make recommendations for transactions[48]. Moreover, agents can be introduced into the real system to automatically execute operations on behalf of investors based on recommendations[49]. After all, a computer agent exceeds a human-investor in terms of working time and reaction time, which are often crucial for the success of a transaction. It can also buy and then sell stocks in a split second.

---

[44] Wooldridge M., *Introduction to MultiAgent Systems*, John Wiley & Sons, June 2002, p. 223.
[45] Leyton-Brown K., Shoham Y., *Multiagent Systems: Algorithmic, Game- Theoretic, and Logical Foundations*, Cambridge University Press, 2008, p. 73.
[46] Kaminsky G. L., Reinhart C. M., *The twin crises: the causes of banking and balance-of-payments problems*, "American Economic Review", Vol. 89, no. 3, 1999, p. 477.
[47] Bosse T., Siddiqui G.F., Treur J., *Supporting Financial Decision Making by an Intelligent Agent Estimating Greed and Risk*, "Proc. the IEEE/WIC/ACM Int. Conf. on Web Intelligence and Intelligent Agent Technology", Vol. 3, Aug. 31-Sept. 3 2010, p. 367.
[48] Majer I., *Application scoring: logit model approach and the divergence method compared*, Department of Applied Econometrics, Working Paper, No. 10-06, 2006, p. 21.
[49] Pandey V., Wee-Keong Ng, Ee-Peng Lim, *Financial advisor agent in a multi-agent financial trading system*, "Proc. 11th Int. Workshop on Database and Expert Systems Applications", 2000, p. 487.

8. Research of deep learning to support stock market investments

ANN artificial neural networks are also used to support stock market investments[50]. ANNs are learned based on historical data that is available through technical analysis[51]. A classic unidirectional network is usually composed of three layers of neurons: input, hidden and output (Fig. 4). Multilayer networks make it possible to predict the value of the studied features[52]. Prediction can apply to both numerical and symbolic values. In the case of the anticipation of numerical values, we speak of regression, and in the case of symbolic values – classification. The operation of a neural network is based on the detection of implicit relationships between features in the learning process, which requires the provision of a set of learning examples. In the context of stock market prediction, we are dealing with a specific problem of predicting time series[53].

It is possible to teach with the teacher when test data from the exchange are fed to the network inputs, and then the network calculates the result. This result is compared with a benchmark result, which allows you to adjust the weights[54]. Stock market prediction based on data from historical quotations is a difficult task[55].

The cause of the problems is the characteristics of the data, which is largely influenced by random factors. Usually there are large sizes of training sets. The size of the training sets depends on the frequency of downloading data from the exchange, which can take place even every second. Analyzing so many training sets requires a lot of computing power, which only supercomputers can provide. For this reason, some authors suggest a significant reduction in the intensity of downloading data from the stock exchange[56].

---

[50] Gately E. *Neural networks. Financial forecasting and design of transaction system, Warsaw*: WIG-Press, 1999, s. 232.

[51] Chaveesuk R., Srivaree-Ratana C., Smith A.E., *Alternative neural network approaches to corporate bond rating,* "Journal of Engineering Valuation and Cost Analysis", Vol. 2, 1999, p. 123.

[52] Nazari M., Alidadi M., *Measuring credit risk of bank customers using artificial neural network*, "Journal of Management Research", Vol. 5, No. 2, 2013, p. 322.

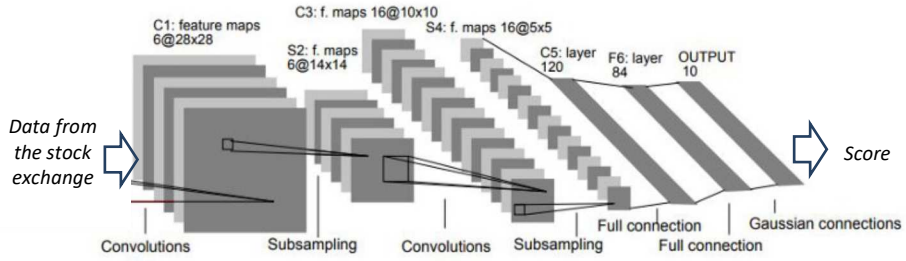
[53] Baesens B., Setiono R., Mues C., Vanthien J.: *Using neural network rule extraction and decision tables for credit-risk evaluation*, Management Science, Vol. 49, No. 3, March 2003, p. 317.

[54] Davis E. P., Karim D., *Comparing early warning systems for banking crises*, "Journal of Financial Stability", Vol. 4, no. 2, 2008, p. 89.

[55] Srivastava R. P., *Automating judgmental decisions using neural networks: a model for processing business loan applications*, "Proceedings of the 1992 ACM Annual Conf. on Communications", p. 355.

[56] Demirguc-Kunt A., Detragiache E., *Monitoring banking sector fragility: a multivariate logit approach*, "World Bank Economic Review", Vol. 14, no. 2, 2000, p. 287.

Fig. 4. Diagram of a convolutional neural network to support stock market investments.



Source: Atsalakis G., Valavanis K.: Surveying stock market forecasting techniques – Part I: Conventional methods in Computation Optimization in Economics and Finance Research Compendium, New York, Nova Science Publishers, 2013, p. 35.

The analysis of quotations with an interval of one day seems more realistic, as the prices of shares and financial instruments at the opening and closing of the trading session stabilize. This is due to the characteristics of the trading session phases. Buy and sell orders can be placed and canceled in the pre-opening and pre-closing phase. Transactions are carried out only in the next phases - opening and closing. This makes the price of the stock at the close and opening less sensitive to fluctuations caused by investors' emotions.

In addition, the broker charges a commission of approximately 0.3% on each purchase and sale transaction. Consequently, in order to make a profit, the shares must be sold at a price at least 0.6% higher than the price at which they were purchased. Relatively high brokers' commissions exclude the profitability of very frequent market transactions for financial instruments with a stable exchange rate. For this reason, futures contracts solve the problem.

Prediction is also made difficult by the small amount of information in quotes. The quotes provided by the Warsaw Stock Exchange consist of five columns: opening price, highest price on a given day, lowest price on a given day, closing price and trading volume. The neural network has to be based on only five basic features, which in addition are highly dependent on random factors. The problem is difficult because, despite the potentially low degree of complexity resulting from a small number of features, the human mind is unable to solve it with high efficiency.

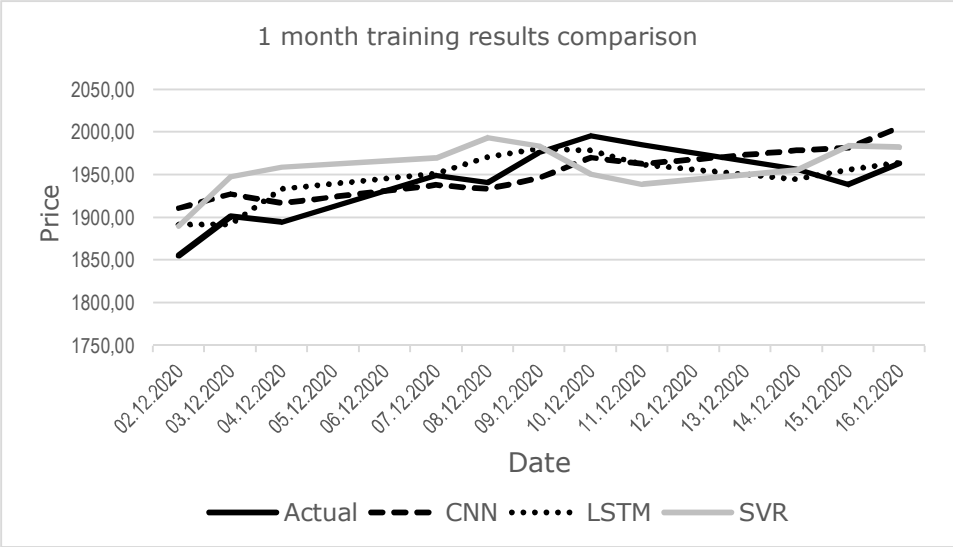
When trying to extract more information from the data, it needs to be preprocessed before it is used to train the network. The first step is to reduce the problem to time series analysis. In a single teaching example, there were percentage changes in the base values for a selected number of consecutive trading sessions. Then, the teaching examples should be expanded with the values of

stock market indicators. Indicators can be divided into two groups: lag-dependent or delay-independent indicators.

Figure 5 shows the simulated dependence of the achieved profit by the neural predictors CNN and LSTM. Besides, Support vector regression SVR is consider. The experiment was carried out in relation to the WIG20 stock.

Lag-dependent indicators are those for which the parameter is the number of consecutive values, and an example of such an indicator is a moving average. In its case, the delay value determines from which number of historical values the mean value is calculated. Such indicators allow to determine the direction of the trend, and also help to predict its change and aggregate information from a longer period. In the proposed model, indicators are calculated for each of the baseline values and for delays of 3, 7, 14 and 30 days. Other indicators are also determined: linear regression, direction of linear regression, rate of change, index of relative stability, and exponential moving average. In addition, lag-independent indices are calculated: the measure of convergence and divergence of moving averages, equilibrium price-stock index, and the Chaikin oscillator[57].

Fig. 5. Simulation of achieving cumulative profit from the date of the transaction[58].



Source: Own study.

[57] Pietrzak E., Markiewicz M. (red.), *Finance, banking and financial markets*, University of Gdansk Press, Gdansk 2006, p. 27.

[58] Gis A., *A multi-threaded application that uses artificial neural networks and a swarm algorithm for prediction on the stock exchang, "*Master's thesis", Gdansk University of Technology, Gdansk 2015, p. 97.

Learning takes place on a set of 50 stock exchange sessions. It is worth emphasizing that it has not been possible to develop a strategy that will always win, and we can rather talk about winning networks in a certain (rather longer) period of time.

Deep neural networks are also used to optimize the stock portfolio, as they have proven themselves to optimize combinatorial NP-hard problems[59]. Tasks related to financial activities for which the support based on artificial neural networks was successfully applied include the analysis of the creditworthiness of bank customers[60], risk analysis related to granting a mortgage loan[61], building bid strategies, forecasting index values[62] and directions of trends on the stock exchange, determination of risk classes of stock exchange financial instruments, detection of regularities in changes in the prices of financial instruments and forecasting of bankruptcies and bankruptcies[63].

As a rule, an effective financial solution cannot be predicted by a mathematical model. The influence of the random factor - taken into account in many models - is usually too strong. Neural networks do not contain any a priori assumptions about the described phenomenon. For this reason, they can identify local market disturbances or dependencies occurring for a short time in financial markets[64].

An alternative way of using systems supporting stock exchange investments is the implementation of virtual brokers to automatically execute transactions on the market. Automated trading systems are used in high frequency trading (HFC) involving thousands of trades per session. Usually, in such systems, algorithms based on artificial neural networks are used. Until 1998, an investor could hold shares for several seconds and then sell them. Currently, on major exchanges, you can own shares for milli- or even microseconds.

However, the risk associated with very intensive investment activities is much greater. The Knight Capital Group, a broker on the US stock market, found

---

[59] Staniec I., *Application of artificial neural networks and selected statistical methods to support credit decisions. Applications of statistical methods in scientific research* II, StatSoft Poland, Cracow 2003, p. 20.

[60] Yobas M.B., Crook J.N., Ross P., *Credit scoring using neural and evolutionary techniques*, "IMA Journal of Mathematics Applied in Business and Industry", Vol. 11, 2000, p. 112.

[61] Zan H. et al.: *Credit rating analysis with support vector machines and neural networks: a market comparative study*, "Decision Support Systems", Vol. 37, 2004, p. 543.

[62] *German Credit dataset*, http://archive.ics.uci.edu/ml/datasets/Statlog+%28German+Credit+Data%29, [Access: 2.09.2015].

[63] Brown C., *Technical Analysis for the Trading Professional, Second Edition: Strategies and Techniques for Today's Turbulent Global Financial Markets*, The McGrawHill Companies, New York 2011, p. 226.

[64] Oet M., Eiben R., Bianco T., Gramlich D., Ong S., Wang J.: *SAFE: an early warning system for systemic banking risk*, "*Proc. of the 24th Australasian Finance and Banking Conference"*, SSRN, 2011, p. 243.

out about it and lost 440 million dollars in 30 minutes during the session on the New York Stock Exchange due to a bug in their HFC automatic trading system[65].

In order to forecast stock prices, information about companies is obtained in various ways. Modern methods use news about companies in an electronic text format that is available from many sources, including commercial providers such as Bloomberg, public news sites, and social networking sites such as Twitter. Applications can identify company names, keywords as well as message semantics. Ultimately, it is planned to use an approach based on the rules of operation of the IBM Watson supercomputer.

The selected deep learning methods presented in the article do not exhaust the enormous potential of using other methods of artificial intelligence in financial systems. For example, using the harmonic algorithm, it is possible to significantly shorten the response time of the online banking system, which enables a significant increase in efficiency, reduction of costs and increasing the system's resistance to hacker attacks. On the other hand, the improvement and increase of the security of internet transactions is influenced by the use of newer generations of contactless microprocessor cards. It is also worth emphasizing the importance of multi-processor graphics cards for the implementation of complex econometric models.

Remarks and Conclusions

The article proposes the use of virtual supercomputer infrastructure and deep learning models for intelligent computing in banking. In addition, the use of deep neural networks for stock exchange investments has been clarified.

An interesting direction for further research is the development of a support vector method for estimating the value of debt securities and assessing the risk of the banking sector. Building a national early warning system for banking based on advanced deep learning methods implemented on a supercomputer will increase the level of financial market security, and will also create the necessary area for decisions to mitigate the effects of banking crises in the future. Moreover, an important problem is the use of deep artificial neural networks not only for stock market investments, but also for testing the credibility of potential borrowers.

Bibliography

1. Abe Y. et al., *Power and performance analysis of GPU-accelerated systems*, "Proceedings of the 2012 USENIX Conf. on Power-Aware Computing and Systems (HotPower'12)", USENIX Association, Berkeley, USA, 2012.

[65]http://www.bloomberg.com/bw/articles/2012-08-02/knight-shows-how-to-lose-440-million-in-30-minutes. [Access: 20.01.2021].

2. Aldrich E., Fernández-Villaverde M., Gallant J.R., Rubio-Ramírez A., Juan F., *Tapping the supercomputer under your desk: Solving dynamic equilibrium models with graphics processors*, "Journal of Economic Dynamics and Control", Elsevier, vol. 35(3), 2011.

3. Baesens B., Setiono R., Mues C., Vanthien J., *Using neural network rule extraction and decision tables for credit-risk evaluation*, "Management Science", Vol. 49, No. 3, March 2003.

4. Balicka H., Balicki J., Korłub W., Paluszak J., Pastewski M., Przybyłek P., Zadroga M., Zakidalski M., *Artificial intelligence methods to support banking information systems,* In: K. Kreft, D. Wach, J. Winiarski (eds.): *Information systems in the economy*, University of Gdańsk Press, Gdańsk 2013.

5. Balicka H., Balicki J., Korłub W., Paluszak J., Zadroga M., *Supercomputers to support economic processes with particular emphasis on the banking sector*, "Contemporary Economy", Vol. 4, Issue 5, 2014.

6. Balicki J., Beringer M., Korłub W., Przybyłek P., Tyszka M., Zadroga M., *Collective citizens' behavior modelling with support of the Internet of Things and Big Data*, "Proceedings of the 8th International Conference on Human-System-Interaction HSI'2015", Warsaw, Poland, June 25-27, 2015.

7. Balicki J., Korłub W., Paluszak J., *Big data processing by volunteer computing supported by intelligent agents*, "Proceedings of 6th International Conference, PReMI 2015, Warsaw, Poland, June 30 - July 3, 2015, Lecture Notes in Computer Science", Vol. 9124.

8. Balicki J., Korłub W., Tyszka M., *Harmony search to self-configuration of fault-tolerant grids for big data*. In: Z. Kowalczuk: "Advances in Intelligent Systems and Computing", Vol. 386, 2016.

9. Balicki J., *Multi-criterion decision making by artificial intelligence techniques*, "Proceedings on the 8th Int. Con. on Artificial Intelligence, Knowledge Engineering and Data Bases", February 2009, Cambridge.

10. Balicki J., Przybyłek P., Zadroga M., Zakidalski M., *Artificial neural networks and the support vector method in banking information systems*, "Contemporary Economy", Vol. 4, 2013.

11. Balicki J., Szymański J., Kępa M., Draszawka K., Korłub W., *Improving effectiveness of svm classifier for large scale data*, "Proceedings on 14th International Conference", ICAISC 2015, Zakopane, Poland, June 14-18, 2015, "Part I, Lecture Notes in Computer Science", Vol. 9119.

12. Bandi N., Sun C., Agrawal D., El Abbadi A., *Hardware acceleration in commercial databases: A case study of spatial operations*, 2004.

13. Bechler A., *Comparison of the effectiveness of neural networks and econometric models in supporting credit decisions, "*Application of statistical methods in scientific research", StatSoft Poland, Cracow 2003.

14. Bosse T., Siddiqui G.F., Treur J., *Supporting financial decision making by an intelligent agent estimating greed and risk*, "Proceedings the IEEE/WIC/ACM Int. Conf. on Web Intelligence and Intelligent Agent Technology", Vol. 3, Aug. 31-Sept. 3 2010.

15. Brown C., *Technical analysis for the trading professional, Second Edition: Strategies and techniques for today's turbulent global financial markets*, The McGrawHill Companies, New York 2011.

16. Chaveesuk R., Srivaree-Ratana C., Smith A.E., *Alternative neural network approaches to corporate bond rating*, "Journal of Engineering Valuation and Cost Analysis", Vol. 2, 1999.

17. Chen S.-H., Kuoand T.-W. Hoi K.-M.: *Genetic programming and financial trading: How much about "What we Know".* In: "4th NTU International Conference on Economics, Finance and Accounting", April 2006.

18. Davis E. P., Karim D., *Comparing early warning systems for banking crises*, "Journal of Financial Stability", Vol. 4, no. 2, 2008.

19. Demirguc-Kunt A., Detragiache E., *Monitoring banking sector fragility: a multivariate logit approach*, "World Bank Economic Review", Vol. 14, no. 2, 2000.

20. Dziubinski M.P., Grassi S., *Heterogeneous computing in economics: A Simplified approach*, "CREATES Research Papers 2012-15", School of Economics and Management, University of Aarhus, 2012.

21. Frankel J. A., Rose A. K., *Currency crashes in emerging markets: an empirical treatment,* "Journal of International Economics", Vol. 41, no. 3-4, 1996.

22. Gately E., *Neural networks. Financial forecasting and design of transaction systems*, WIG-Press, Warsaw 1999.

23. Gis A., *A multi-threaded application that uses artificial neural networks and a swarm algorithm for prediction on the stock exchange, "*Master's thesis", Gdansk University of Technology, Gdansk 2015.

24. Govindaraju N. K., Lloyd B., Wang W., Lin M., Manocha D.: *Fast computation of database operations using graphics processors,* "Proceedings of the 2004 ACM SIGMOD Int. Conf. on Management of Data", June 2004.

25. Hanschel E., Monnin P.: *Measuring and forecasting stress in the banking sector: evidence from Switzerland*, "Investigating the Relationship between the Financial and Real Economy", BIS Papers, no. 22, 2005.

26. Henley W.E., Hand D.J., *A k-nearest-neighbour classifier for assessing consumer credit risk*, "The Statistician", Vol. 45, Issue 1, 1996.

27. Kaminsky G. L., Reinhart C. M., *The twin crises: the causes of banking and balance-of-payments problems*, "American Economic Review", Vol. 89, no. 3.

28. Leyton-Brown K., Shoham Y., *Multiagent systems: algorithmic, game- theoretic, and logical Foundations*. "Cambridge University Press", 2008.

29. Majer I.: *Application scoring: logit model approach and the divergence method compared,* Department of Applied Econometrics, Working Paper, No. 10-06, 2006.

30. Mylonakis J., Diacogiannis G., *Evaluating the likelihood of using linear discriminant analysis as a commercial bank card owners credit scoring model*, International Business Research, Vol. 3, No. 2, 2010.

31. Nazari M., Alidadi M., *Measuring credit risk of bank customers using artificial neural network*, "Journal of Management Research", Vol. 5, No. 2, 2013.

32. Oet M., Eiben R., Bianco T., Gramlich D., Ong S., Wang J., *SAFE: an early warning system for systemic banking risk*, "Proceedings of the 24th Australasian Finance and Banking Conference", SSRN, 2011.

33. Pandey V., Wee-Keong Ng, Ee-Peng Lim, *Financial advisor agent in a multiagent financial trading system,* "Proceedings 11th Int. Workshop on Database and Expert Systems Applications", 2000.

34. Pietrzak E., Markiewicz M. (red.), *Finance, banking and financial markets.* Publishing House of the University of Gdańsk, Gdansk 2006.

35. Potvin J.-Y., Soriano P., Vall M., *Generating trading rules on the stock markets with genetic programming*. Computers & Operations Research, Vol. 31, 2004.

36. Pruitt SW, White RE, *The CRISMA trading system: who says technical analysis can't beat the market?,* "Journal of Portfolio Management", 1988;14:55–8.

37. Schwaerzel R., *Financial time series prediction and evaluation by genetic programming with trigonometric functions and high-order statistics,* "Ph.D. Dissertation", The University of Texas at San Antonio, Advisor(s) Tom Bylander 2006.

38. Shouwei L., Mingliang W., Jianmin H., *Prediction of banking systemic risk based on support vector machine*, "Mathematical Problems in Engineering", Vol. 2013, April 2013.

39. Solomon S., *Option pricing on the GPU*, High Performance Computing and Communications, 2010.

40. Srivastava R. P., *Automating judgmental decisions using neural networks: a model for processing business loan applications*, "Proceedings of the 1992 ACM annual conference on Communications".

41. Staniec I., *Application of artificial neural networks and selected statistical methods to support credit decisions. Applications of statistical methods in scientific research* II, StatSoft Poland, Cracow 2003.

42. Svangard N., Nordin P., Lloyd S., Wihlborg C., *Evolving short-term trading strategies using genetic programming*, "Proceedings of the Congress on Evolutionary Computation", Vol. 2, 2002.

43. Wooldridge M., *Introduction to multiagent systems*, John Wiley & Sons, June 2002.

44. Yobas M.B., Crook J.N., Ross P.: *Credit scoring using neural and evolutionary technique,"*IMA Journal of Mathematics Applied in Business and Industry", Vol. 11, 2000.

45. Zan H. et al., *Credit rating analysis with support vector machines and neural networks: a market comparative study*, "Decision Support Systems", Vol. 37, 2004.

46. Benchmark German Credit dataset, http://archive.ics.uci.edu/ml/datasets/Statlog+%28German+Credit+Data%29, [Access: 20.08.2020].

47. Bitcoin.org, https://bitcoin.org/en/, [Access: 20.08.2020].

48. *Bitcoin: A Peer-to-Peer Electronic Cash System*, https://bitcoin.org/bitcoin.pdf, [Access: 20.08.2020].

49. *EBA warns consumers on virtual currencies*, http://www.eba.europa.eu/-/eba-warns-consumers-on-virtual-currencies, [Access: 20.01.2021].

50. *Eurostat.* http://ec.europa.eu/eurostat/, [Access: 20.01.2021].

51. *Forbes*, http://www.forbes.com/sites/techonomy/2014/08/07/bitcoin-momentum-grows-in-emerging-markets/, [Access: 20.01.2021].

52. *How do Bitcoin Transactions Work*. http://www.coindesk.com/information/how-do-bitcoin-transactions-work/,[Access: 11.02.2015].

53. *How does Bitcoin work*, https://bitcoin.org/en/how-it-works, [Access: 20.01.2021].

54. Knight shows how to lose 440 million in 30 minutes, http://www.bloomberg.com/bw/articles/2012-08-02/knight-shows-how-to-lose-440-million-in-30-minutes, [Access: 20.01.2021].

55. *Mining hardware comparison*, https://litecoin.info/Mining_hardware_comparison, [Access: 20.01.2021].

56. NBP: *Report on Poland's full participation in the third stage of the Economic and Monetary Union,* http://www.nbp.pl/Publikacje/O_Euro/RE1.pdf, [Access: 20.08.2020].

57. NUMTECH: *GPGPU and financial business,* http://www.numtech.co.jp/files/documents/seminar/20101019/20101019E.pdf, [Access: 20.01.2021].

58. NVIDIA: *Computational Finance*, http://www.nvidia.com/object/computational_finance.html, [Access: 20.01.2021].
59. *Bitcoin specification,* http://nakamotoinstitute.org/bitcoin/, [Access: 20.01.2021].
60. *TOP 500 The List*, http://www.top500.org/, [Access: 20.01.2021].

Informacje o autorze

Honorata Balicka, Ph.D.
Assistant Professor
Sopot University of Applied Sciences,
Faculty of Economics and Finance, Poland
e-mail: HBalicka@ssw.sopot.pl