CZĘŚĆ II
PART II

EKONOMIA
ECONOMY

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AN INFLUENCE OF DEEP LEARNING AND THE INTERNET OF THINGS ON DIRECTIONS OF DEVELOPMENT OF INTEGRATED FINANCIAL SYSTEMS SUPPORTING SMART CITIES FOR GREEN ECONOMY

Abstract

Digitalization is not only a continuation of the status quo at a higher technological level, but is changing the rules of the game in virtually all sectors of the economy, including financial and business. Digital business transformation is the process of using digital technologies to strengthen a company's ability to create robust new digital business models. The possibilities of applying digital technologies in enterprises of individual industries have gained great interest in global research. They are implemented primarily by significant scientific centers and consulting companies. According to Gartner study, 87% of senior executives say digitalization is a priority, and 79% of corporate strategists believe that digitalization is redefining their business in a completely new way, creating additional opportunities to generate profit. The aim of the work is to characterize the directions of financial system development supporting smart cities and green economy in the field of using modern information technologies based on cloud computing and deep neural networks. According to the author, the use of modern information technologies, based on the Internet of Things and deep neural networks in financial systems, in particular for the development of electronic forms of settlements creates a great chance to avoid a crisis due to the development of the pandemic consequences. 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 financial systems in smart city subject to an efficient development of green economy. Therefore, we discuss integrated financial system in smart city. Besides, we describe Internet of Things for green management of critical city resources. After discussing financial investment in green and smart technologies, issues related to deep learning for prediction in financial systems are characterized. Considerations on the special case of deep learning architecture based on artificial neural networks (ANNs) are presented, too. The Long Short Term Memory

ANNs are verified for stock market investment. Finally, conclusions and future work are presented.

Keywords: Financial Systems, Smart City, Green Economy, Deep Learning**.**

WPŁYW UCZENIA GŁĘBOKIEGO I INTERNETU RZECZY NA KIERUNKI ROZWOJU ZINTEGROWANYCH SYSTEMÓW FINANSOWYCH WSPIERAJĄCYCH INTELIGENTNE MIASTA W WARUNKACH EKOLOGICZNEJ GOSPODARKI

Streszczenie

Cyfryzacja to nie tylko kontynuacja status quo na wyższym poziomie technologicznym, ale również zmiana reguł konkurencyjności gospodarczej praktycznie wewszystkich sektorach gospodarki, w tym finansowym. Cyfrowa transformacja biznesowa to proces wykorzystujący technologie cyfrowe do wzmocnienia zdolności firmy w celu konstruowania nowych efektywnych modeli biznesowych. Możliwości zastosowania sztucznej inteligencji w przedsiębiorstwach większości branż zyskały duże zainteresowanie w światowych badaniach. Realizują je przede wszystkim znaczące ośrodki naukowe oraz firmy konsultingowe. Wg ekspertów z grupy Gartnera aż 87% menedżerów wyższego szczebla jest przekonanych, że cyfryzacja jest priorytetem, a 79% strategów korporacyjnych uważa, że cyfryzacja na nowo definiuje działalność przedsiębiorstw, tworząc dodatkowe możliwości generowania zysków. Celem pracy jest scharakteryzowanie kierunków rozwoju systemów finansowych, wspierających inteligentne miasta i ekologiczną gospodarkę, w zakresie wykorzystania nowoczesnych technologii informatycznych, opartych na Internecie Rzeczy i głębokich sztucznych sieciach neuronowych. Zdaniem Autorki wykorzystanie najnowszych osiągnięć sztucznej inteligencji w systemach finansowych, a w szczególności do rozwoju elektronicznych form rozliczeń, stanowi ogromny potencjał umożliwiający uniknięcie głębokiego kryzysu w związku z negatywnymi skutkami długotrwałej pandemii w gospodarce. Warto podkreślić, że istnieje luka w literaturze przedmiotu w tym zakresie, gdyż nie ma jasnych pomysłów, jak skutecznie wykorzystać sztuczną inteligencję w chmurze obliczeniowej do efektywnego wspomagania systemów finansowych w smaty city przy uwzględnieniu zrównoważonego rozwoju gospodarczego. Z powyższych względów w artykule rozważa się strategię, jak należy zwiększyć rolę zintegrowanego systemu finansowego w inteligentnym mieście. Ponadto charakteryzuje się Internet Rzeczy w odniesieniu do zarządzania krytycznymi zasobami miasta. Po omówieniu inwestycji finansowych w ekologiczne i inteligentne technologie scharakteryzowano zagadnienia związane z głębokimi sieciami neuronowymi do predykcji i klasyfikacji w systemach finansowych. Przedstawiono również rozważania dotyczące szczególnego przypadku architektury głębokiego uczenia opartej na sztucznych sieciach neuronowych (ANN). Rekurencyjne ANN klasy LSTM zweryfikowano pod kątem inwestycji finansowych na giełdzie. Na zakończenie przedstawiono wnioski i planowane przyszłe prace.

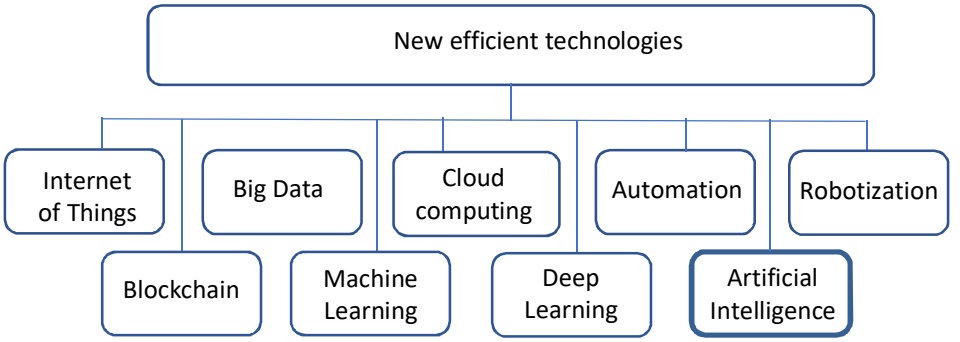
Słowa kluczowe: finanse, smart city, ekologiczna gospodarka, uczenie głębokie.

Introduction

Digitalization is not only a continuation of the status quo at a higher technological level, but is changing the rules of the game in virtually all sectors of the economy, including financial and business. Digital business transformation is the process of using digital technologies to strengthen a company's ability to create robust new digital business models. The possibilities of applying digital technologies in enterprises of individual industries have gained great interest in global research. They are implemented primarily by significant scientific centers and consulting and consulting companies. According to a Gartner study, 87% of senior executives say digitalization is a priority, and 79% of corporate strategists believe that digitalization is redefining their business in a completely new way, creating additional opportunities to generate profit.

Modern technologies that cause digital transformation of business can be considered in two categories. The first category concerns the ability to keep the products and services currently offered alive and to survive in existing markets. The second category, on the other hand, encourages economic agents to engage in subversive activities. Figure 1 shows examples of new technologies that are subversive for business.

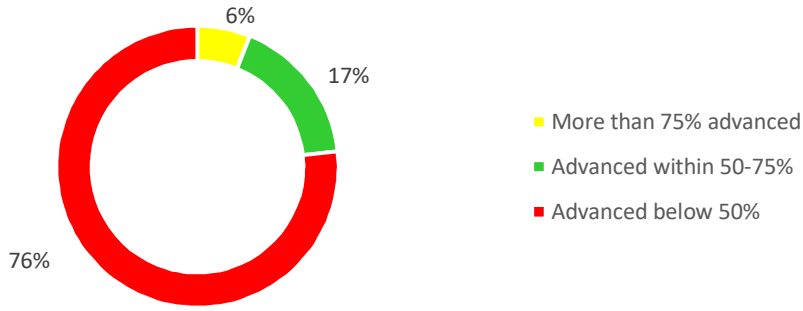
Fig. 1. New efficient technologies for business.



Source: Own study based on A. A. Rahman, U.Z.A. Hamid, T.A. Chin, *Emerging with Disruptive Effects*, A Review, „PERINTIS eJournal", vol. 7, no. 2, 2017, p. 112.

The technologies shown in Figure 1 are also referred to as technologies that intensify the fourth technological revolution, in which Enterprises 4.0, Industry 4.0 and Business 4.0 are developing. New efficient technologies for business are the backbone of the digital economy. The founding technologies, on the other hand, include the computer, the Internet, and the smartphone. Despite the rapid development of technology and its increasing availability for business, the digital transformation of business is characterized by a rather disappointing pace (Fig. 2).

Fig. 2. Digital transformation levels of business in the World.



Source: Gartner, Speed up Your Digital Business Transformation, https://www.gartner.com/smarterwithgart-ner/speed-up-your-digital-business-transformation/, 11.09.2021.

The economic crisis associated with a widespread pandemic could trigger a severe financial and even banking crisis. On the other hand, deep learning and modern technologies can support financial systems in smart cities towards green economy. Large cities have to cope with some open important issues like growing population, traffic congestion, air pollution and waste, an efficient planning of public space, and a lack of crucial resources such as water or energy. Therefore, an efficient management of resources is strongly recommended by using deep learning and The Internet of Things.

The aim of the work is to characterize the directions of financial system development supporting smart cities and green economy 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 crisis due to the development of the pandemic consequences. 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 financial systems in smart city subject to an efficient development of green economy.

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. In addition, intensive computational experiments related to the analysis of the quality of solutions were carried out, which determined using the proposed methods of deep learning with Short-Long Term Memory (LSTM) based artificial neural networks. The scientific study presented in this article was verified by simulation the feasibility of using deep learning. The results exceeded the estimates described in the literature on the subject. The mean error is estimated at less than 3% when

using LSTM networks. Therefore, it should be assumed that also the other deep learning paradigms will be an effective tool in financial systems.

In this serious situation, we should ask the following questions. How to effectively support the harmonious development of smart city? How to use modern technology, including artificial intelligence, sensor networks, Internet of Things, edge and cloud computing? How significant is an influence of deep learning and the Internet of Things on directions of development of integrated financial systems supporting smart cities for green economy? Perhaps we will be able to answer some of the above questions at the end of this paper.

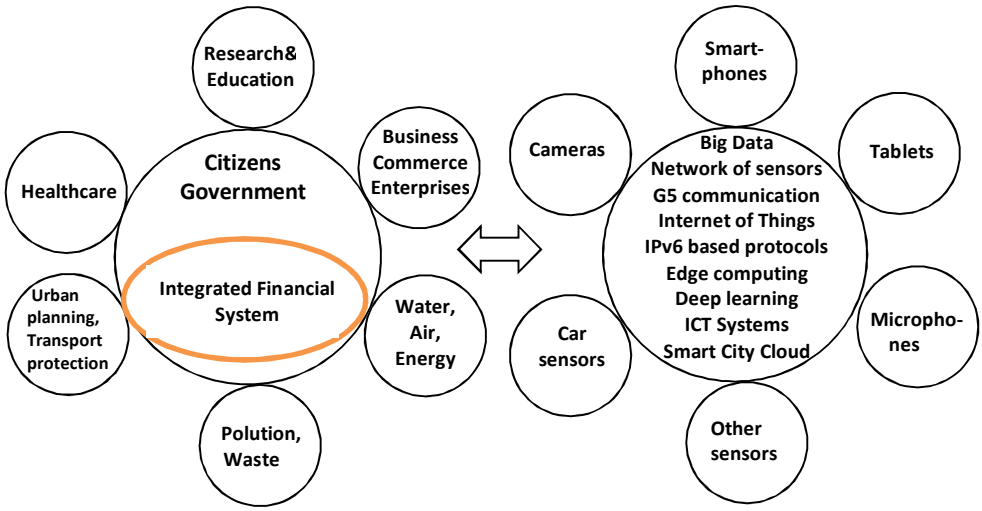
The rest of this paper is organized as follows. Section I discusses integrated financial system in smart city. The section II, in turn, describes Internet of Things for green management of critical city resources. After discussing financial investment in green and smart technologies in Section III, issues related to deep learning for prediction in financial systems will be characterized in Section IV. Considerations on Long Short Term Memory neural networks for stock market investment will be undertaken in Section V. Finally, conclusions and future work are presented.

1. Integrated financial system in smart city

Artificial intelligence and modern technologies can support financial systems in smart cities towards green economy (Fig. 3). Cities, especially large cities, have to cope with some open important issues like growing population or traffic congestion. We expect that home and public space be supposed to be used in more efficient way. Even currently, there is a huge problem with a lack of crucial resources such as water or energy in many regions of the world. Therefore, an efficient management of resources is strongly required. Besides the cost accounting plays an important role. An efficient rules cost accounting should be applied in many domains including healthcare entities[1].

[1] Martyniuk T., Cygańska M., Żurawik A., Malinowska E., *Cost accounting in healthcare entities*, Wydawnictwo Uniwersytetu Gdańskiego, Gdańsk 2021 (in polish), p. 12.

Fig. 3. Integrated financial system in smart city.



Source: Own study.

What is more, it is predicted that global warming and carbon emissions will be probably considered as some critical factors for living conditions in cities. A vision of a smart city is related to better protection of natural environment. Sustainable homes and buildings should be planned and efficient use of city resources can be developed. Besides, the temperature in the streets can be controlled by building constructions. Citizens expect an efficient and sustainable transportation in livable city and better urban planning of ecological buildings[2].

To support a smart city towards green economy we can develop the latest technology, which permit us use a modern distributed computer system with various types of sensors that send streams of Big Data from homes, vehicular networks, parking, and air or water area. In smart city, we can consider a many-tier architecture including Internet of Things (IoT) sources to collect generated data. Moreover, various types of communication between sensors can be used for the data analysis and machine learning[3].

However, the challenges are enormous. For instance, Tokyo is the largest city in the world. Population is now estimated at 37 million, including metropolis with

[2] Amoruso F.M., Dietrich U., Schuetze T., *Development of a Building Information Modeling-Parametric Workflow Based Renovation Strategy for an Exemplary Apartment Building in Seoul, Korea*, Sustainability 2018, 10(12), 4494; https://doi.org/10.3390/su10124494, p. 2.

[3] 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, June 25–27, 2015, p. 33.

13 million. Japanese designers of the fastest supercomputer Fugaku HPL use it extensively for deep learning. In the Linpack AI computational test, Fugaku achieves a computing power of 2 Eflop/s based on TensorFlow or PyTorch deep learning software. Therefore, the possibilities of using supercomputers to carry out tasks in a smart city are huge.

The financial rule that applies in a smart city is *"The resident pays for the resources used, only"*. As this is not possible at the present stage of technological development of cities. That is why, we propose deep learning. Models of deep learning implemented in smart city infrastructure can effectively support many important tasks, as below:

- structural health in buildings, bridges and historical monuments;
- noise urban maps;
- smartphone detection;
- measurement of the energy radiated by cell stations and WiFi routers;
- smart parking: monitoring of parking spaces availability in the city.
- traffic congestion: monitoring of vehicles and pedestrian levels to optimize driving and walking routes;
- smart roads: intelligent highways with warning messages and diversions according to climate conditions and unexpected events such as accidents or traffic jams;
- smart lighting: intelligent and weather adaptive lighting in street lights;
- waste management.

The production and supply of energy for the city are of key importance. A green solution is based on light sensors on solar panels that track sunrays to ensure power is gathered in a more efficient manner. Distribution of energy is by the smart grids, which are highly complex systems technically integrating digital and non-digital technologies. Smart grids are characterized by more efficient energy routing (reduces excess capacity), better monitoring, and improved data capture and measurement. The resident's charges for energy consumption are charged with using smart devices and metering at the city, building, and home levels.

Another important task is related to smart buildings with sensors technology used in buildings for monitoring and control. Smart buildings increase energy efficiency, user comfort, and security. Artificial intelligence is developed for supporting heating, ventilation and air conditioning systems. In addition, lighting and shading is modified due to the preferences of citizens. Windows can be controlled regarding air quality. Systems can switch off devices and metering is performed. To increase a level of security, an access control is carried out. In such an integrated system, it is very easy to charge for resource consumption. Thus, the resident does not pay a lump sum or for the availability of infrastructure, but only for the actual consumption of resources: energy, water, gas and waste production. In this way, you can minimize the consumption of critical resources based on reliable data.

The headquarters of the New York Times is an example of how different smart building technologies can be combined to reduce energy consumption and to increase user comfort. Overall, the building consumes 30% less energy than traditional office skyscrapers. Equipped with lighting and shading control systems based on ICT technologies. The lighting system ensures that electrical light is only used when required. Further daylighting measures include a garden in the center of the ground floor, which is open to the sky as well as a large area skylight. The electrical ballasts in the lighting system are equipped with chips that allow each ballast to be controlled separately. The shading system tracks the position of the sun and relies on a sensor network to automatically actuate the raising and lowering of the shades.

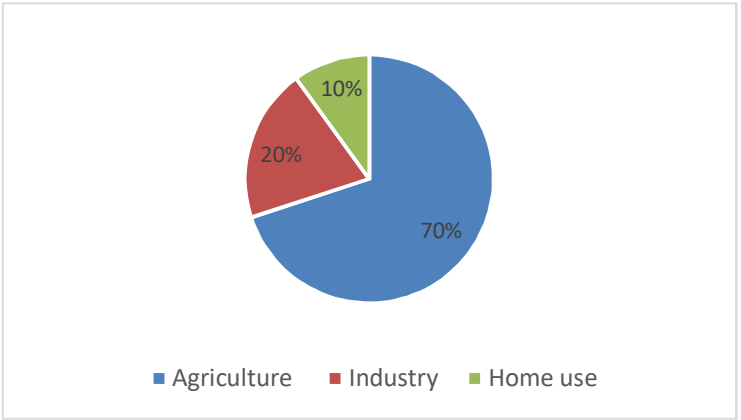
2. Internet of Things for green management of critical city resources

The environmental impact of industry is becoming more and more evident, especially in large cities. As early as the 1990s, many investors began to invest relatively large funds in companies that minimize environmental degradation for a truly sustainable urban society. Besides, exploring determinants of enterprise system for an adoption success are very crucial in light of an ageing workforce, too.[4]

Activities in the field of water management affect the quality of life of the inhabitants (Fig. 4). Adequate examples are drinking water monitoring or detecting chemical spills in rivers. In estuary cities such as Gdańsk, it is important to control leakages into the sea in real time. It is equally important to track pressure changes in the plumbing and to check the quality of the water in the pools. Water scarcity already covers about 40% of the world's population and will continue to worsen. More than 80% of man-made wastewater is discharged into rivers or the sea without removing pollutants. What is the threat of this? It is estimated that about 1,000 children die daily from diarrheal diseases related to water and sanitation. In addition, floods and other water-related disasters account for 70% of all deaths related to natural disasters. It is also worth noting that about 70% of all water obtained from rivers, lakes and aquifers is used for irrigation. A modern solution that can be used is the Internet of Things. In addition, deep learning enables intelligent implementation of the above tasks and reduction of negative effects.

[4] Soja E., Soja P., Exploring determinants of enterprise system adoption success in light of an ageing workforce, In: Themistocleous M., Rupino da Cunha P. (eds) Information Systems, EMCIS 2018, Lecture Notes in Business Information Processing, vol .341, 2019, Springer, Cham. https://doi.org/10.1007/978-3-030-11395-7_32, p. 419.

Fig. 4. World water usage distribution.



Source: Libelium.org, https://www.libelium.com/, [Access: 10.09.2021].

Water demand is expected to increase by 1/3 in 2050. IoT for water management monitors water quality, including surface waters: rivers, lakes and coastal waters. In addition, groundwater is also monitored. Ecological control uses biological, hydro morphological and physicochemical indicators. This is possible with sensor networks, the Internet of Things, deep learning, and cloud computing, which require financial investments.

In addition to water, energy, especially renewable energy, is an important resource. For this reason, financial investment in companies that build solar panels or wind turbines is crucial. The Internet of Things also plays a key role in this class of systems. Financial investment in the services that will be developed to develop these technologies is also important, such as fuel cells in hybrid vehicles, biofuels, and the production of algae, maize or wood waste for fuel production.

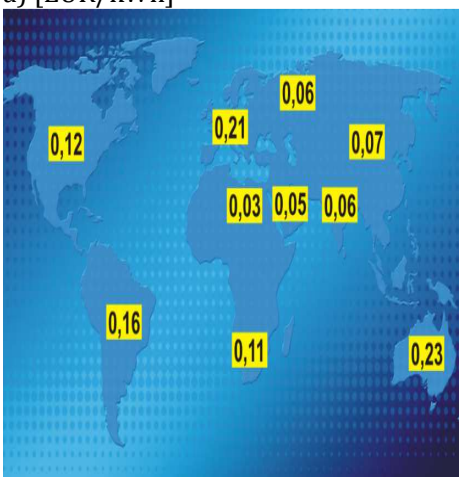
Figure 5 shows electricity prices for households. The highest prices are in Australia and Europe (Fig. 5a). Electricity prices in the US are almost twice as low as in Europe. Europe is even worse compared to China, where energy is three times lower than in Europe. The cheapest energy is in Africa – seven times less than in Europe. Investing in renewable energy sources is therefore the most profitable in Europe and Australia. It is also recommended to introduce technological solutions such as smart grids, which minimize losses related to the transmission of energy from producers to consumers.

In Europe, the highest electricity prices are in Germany, which are twice as high as in Poland and five times in Belarus (Fig. 5b). In Poland, on the other hand, energy prices are usually slightly higher in the north than in the south (Fig. 5c). Although energy prices in Poland are not yet among the highest, it is worth investing in new renewable energy sources and new technologies. Figure 6 shows the principle of operation of IoT in a smart city. On the one hand, there is

a network of sensors (only a few are shown in the figure) that monitor key spheres affecting the quality of life in the city, including the state of water. On the other hand, renewable electricity and storage facilities are essential. It is therefore worth emphasizing that investing in a smart city must be accompanied by investing in new information technologies, including computers, routers, switches, smartphones, and sensors[5].

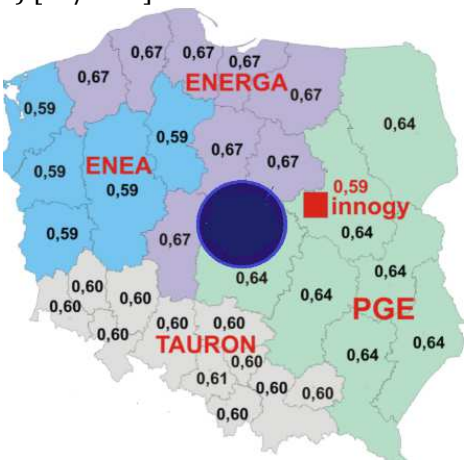
Fig. 5. Electricity prices for households [EUR/kWh].

a) [EUR/kWh]



b) [EUR/kWh]

c) [PL/kWh]



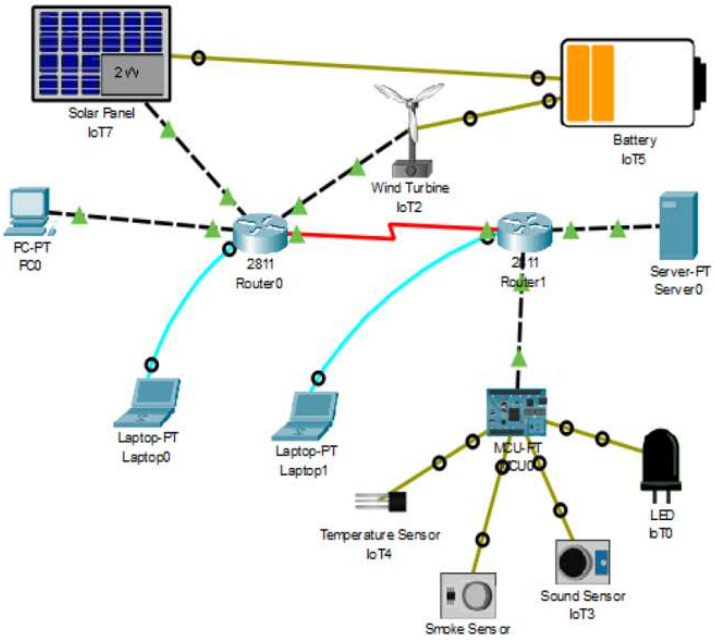
Source: http://cena-pradu.pl/mapa.html, [Access: 10.09.2021].

[5] Balicki J., Balicka H., Dryja P., *Big Data from Sensor Network via Internet of Things to Edge Deep Learning for Smart City*, [In]: Saeed K., Dvorský J. (eds) *Computer Information Systems and Industrial Management*, CISIM 2021, Lecture Notes in Computer Science, vol 12883. Springer, Cham 2021 p. 1034.

3. Financial investment in green and smart technologies

Investing in green and smart technologies can be directed to universities for student education or research. It may concern financial support for start-ups or advanced organizations. It can also refer to investing in the stock market in companies offering this class of products.

Fig. 6. Internet of Things supporting the production and storage of renewable energy (wind and solar) and monitoring of pollution and weather conditions.



Source: Own study by using Cisco Packet Tracer software, https://www.netacad.com/courses/packet-tracer, [Access: 10.09.2021].

Let us consider some of the most interesting applications of deep learning in a smart city. Imagine being able to predict when and where a crime will happen. In addition, we can receive information on how to prevent crime in a crowded city. In the fight against lawlessness, deep learning algorithms can help us, which will indicate the areas with the highest intensity of crime. This kind of products are constantly updated, improved and developed to offer the greatest efficiency[6].

[6] 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, p. 342.

Deep learning is useful in virtually every aspect of our lives. Solutions that assist selected residents in their daily activities are tested. In particular, they recommend what to eat, when to sleep, with whom to talk to, and even where to live. This class of algorithms decide how much we pay for the ticket, whether we get a loan and what we will see in the news of our smartphone. Usually, specialized companies integrate the best deep learning models in the market. The most important advantage of deep learning algorithms is not only controlling the present, but also insight into the future, i.e. predicting future events with high efficiency. More and more US police departments are using deep learning to improve the prosecution of criminals, including predicting where a crime will occur. This problem has not been solved for centuries, although a number of statistical methods have been used.

In the early 19th century, Guerry discovered that some parts of France had more crimes than others. He developed choropleth maps showing the average value of a given phenomenon in spatial units. Such a choropleth map may concern other phenomena, such as electricity prices in Europe (Fig. 5b). From the cartograms of the level and type of crime, you can immediately see where and when the crime is most likely to occur. As people predicted it, the estimates were not very accurate. Today, security risk maps are prepared with a precision that exceeds the capabilities of human teams. The HunchLab app does this almost flawlessly. It serves not only to predict when and where crime is likely to occur, but also to regulate police work. It calculates equivalence ratios, distributing security across the territory based on multiple cost and social justice criteria[7]. Another application PredPol offers a method that highlights the economic aspect of police action. To do this, the platform assesses the value of the patrol using a classical formula for calculating return on investment[8]:

$$ROI = (Gains - InvestmentCosts)/InvestmentCosts \quad (1)$$

This ratio, which is theoretically simple to specify, implies an evaluation of police work in accounting terms through the establishment of an equivalence between avoided costs (gains) and police action. To evaluate this measurable ROI, a monetary estimation of the "cost of crime" Is develop. This provides a single summary value allowing the police to measure its predictive action in investment terms, expressing the prediction as a monetary value. Both systems are supported by IoT to maintain interoperability with using a wireless technology including LPWAN communications important for smart cities projects. Data is collected in cloud data centers that are compatible with city council platforms. The PredPol is solar powered and uses long life batteries. What is more, minimal maintenance costs can be achieved, too.

[7] Benbouzid B., *To predict and to manage. Predictive policing in the United States*. Big Data & Society January–June 2019, p. 7.
[8] Ibid., p. 8.

The use of the HunchLab deep learning application has resulted in a reduction in crime in Philadelphia about 31% as well as an increase in confidence in the police. Safe city life increases the comfort of the inhabitants. The system uses more than just crime statistics from the past. In addition, it analyzes data about the weather, ATM locations and planned events. Dangerous areas are designated, the type of crime, the timing of the crime, and a patrol that works best. As a result, citizens work better, trade develops, the amount of taxes paid grows, and the amount of outstanding loans decreases.

In a smart city, the fight against crime goes hand in hand with the fight against a traffic congestion, a lack of electric energy, or the high level of pollution. IoT and deep learning may enable quick data collection and predict changes in air pollution hazards in the future. High accuracy sensors (Fig. 6) such as calibrated gases sensors are useful to measure the exact value in PPM's of a gas concentration. They support applications that require accurate readings and exact concentrations. For instance, Particle Matter Sensors allows to measure intensity of several particles like PM1, PM2.5, and PM10. Deep learning makes it possible to predict in which areas the air pollution will be highest. Citizens should be informed about the temporary zones to make the adequate decisions. Another important information is related to what the concentrations of individual pollutants will be. It can prevent the unnecessary pollution in the centers of a city. In addition, it is crucial whether there will be rare phenomena that are particularly dangerous. For example, both sulfur dioxide cloud from volcano or acid rain with a high concentration of sulfuric acid can be recognized. It is worth emphasizing that clean air means a longer life of inhabitants and a lower intensity of diseases.

4. Deep learning for prediction in financial systems

Forecasting trends in finance can be predicted with the help of parallel deep learning algorithms, which are characterized by high requirements for the computing power of computers[9]. This kind of financial forecasting can therefore be made with the use of computing clouds[10]. In addition, country banking sector crises can be anticipated by trained deep learning models[11]. This task is extremely difficult due to the small amount of data because about 100 partial

[9] 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.

[10] Balicki J., Balicka H., Dryja P. *Big Data from Sensor Network via Internet of Things to Edge Deep Learning for Smart City*. In: Saeed K., Dvorský J. (eds) Computer Information Systems and Industrial Management. CISIM 2021. Lecture Notes in Computer Science, vol 12883. Springer, Cham 2021 p. 127.

[11] Pietrzak E., Markiewicz M. (red.), *Finance, banking and financial markets. Publishing House of the University of Gdańsk*, Gdansk 2006 (in Polish), p. 23.

banking crises in the world have been observed in the last fifty years, only[12]. For instance, the banking crisis in Poland in 2009 trembled the country economy, which caused the annual GDP deterioration by 14%. Thanks to EU funds, already in 2010, GDP returned to the level of EUR 360 billion, and in 2020 the value of GDP reached EUR 524 billion[13]. Much more crises were in Czech Republic, Hungary, Italy, and Spain that returned to the previous values of GDPs after five years. Remarkably, US GDP cut to EUR 1.001 trillion in 2008[14]. In Greece, GDP was reduced to level of 2003 year. In general, two-year period of slow decline of GDP precedes the banking crisis, and then it becomes an actual crisis with a significant decline in GDP (over ten percent) for the next two years. Machine learning models such as artificial neural networks or support vector machines can be developed for early warning of banking failures[15].

The crisis related to the Covid-19 pandemic can trigger a much more severe economic crisis, including financial and banking crisis. Compared with the same quarter of 2019, seasonally adjusted GDP decreased by 14.1% in the EU in the second quarter of 2020, after -3.1% and -2.5% respectively in the previous quarters. These were also by far the sharpest declines since time series started in 1995. 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). In 2020, GDP of Poland decreased by 2.7%. Spain, United Kingdom, Italy, Greece and Portugal were most affected by this crisis, as illustrated by a decline in GDP ranging from 7 to 11%. In Europe, Ireland's economy is developing the best, with a growth of 3.4% in 2020. In addition, Denmark, Lithuania and Switzerland obtained the growth of GDP. A legitimate question can therefore be asked, was such a pandemic economic crisis foreseeable? Probably it would be possible, if deep learning models were applied earlier.

Deep learning models for classification of the credibility of borrowers are important to decrease an amount of unpaid loans. Too liberal lending and 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 trade-off is needed between the liberal lending strategy in order to stimulate the economy and the upward trend of irregularly repaid loans emerging with a delay of several years.

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[12] 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.

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

[14] Ibid.

[15] 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).

Avoiding innovation in financial systems, in particular, may lead to the uncontrolled development of a new currency system, as was the case with bitcoin, where the financial transaction approval process adds a new entry to the blockchain. Searching for *evidence* is based on the principle of competition, after which the winner receives an amount for finding the proof. After finding the proof, the system moves to the next challenge. As a result, the complexity needed to set the challenge also grows. Deep learning models can predict the course of Bitcoin. Bitcoin is enjoying a growing interest in emerging markets, where there is a lack of developed payment systems. Several companies allow payments with bitcoin, e.g. Microsoft accepts such payment for its products. Unfortunately, anonymity carries the risk of interest in this currency by criminal groups[16]. Bitcoin is being rolled out nationally in El Salvador, where Bitcoin Law granting the currency legal tender status went into effect. Remarkably, in just October 2021, there were more Salvadorans with bitcoin wallets than traditional bank accounts. Three million people have downloaded the Chivo bitcoin wallet, amounting to 46 percent of the population. By contrast, as of 2017, only 29 percent of Salvadorans had bank accounts[17].

The US economy is believed to be successful because of the aggressive absorption of high technology. It is worth noting that Asian manufacturers are also supporting their activities with artificial intelligence to develop products. In addition, several problems with climate modeling has made great impact on the development of deep learning models. The Competitiveness Council in Washington recommended the dissemination of computing cloud in economic applications. In addition, the US defense industry, which develops "dual-use" technologies, was called to make deep learning and IoT available to manufacturers, innovators and entrepreneurs.

An interesting example of combining deep learning and parallel computing is the supercomputer IBM Watson that is helpful in making decisions, including medical diagnostics. It is equipped with artificial intelligence enables correct diagnostics in 90% of lung cancer cases[18]. Nuance Communications Inc. uses Watson with speech recognition skills and medical knowledge in medical diagnostics. IBM is also exploring the use of Watson as a lawyer assistant. Finance predictions are also be an important planning application of the system[19].

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[16] 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.

[17] Roy A., *In El Salvador, more people have bitcoin wallets than traditional bank accounts*, Forbes, 7 October, 2021, https://www.forbes.com/sites/theapothecary/2021/10/07/, [Access: 20.10.2021].

[18] 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.

[19] 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.

French company ARIA Technologies performs calculations to predict flood risk for insurance companies by simulating extreme rainfalls. In addition, the impact of climate change on natural hazards is simulated. It is worth mentioning one more interesting project is IBM Blue Brain that try to simulate the human brain, one should reckon with modeling 100 billion neurons and 1 trillion neural connections. 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. 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[20].

An area where the effective use of graphics cards has been documented is the analysis of econometric models. Aldrich et al. show that GPUs estimated 200 times faster computing than CPUs when analyzing business cycles in markets[21]. Genetic programming is an alternative to classic stock exchange applications based on technical analysis, such as the CRISMA system, which determine a positive return on investment within 10 years with transaction costs of 2%. Data from the stock market for a certain period, divided into three intervals, is usually used to learn and test programs[22]. Frequently, program performance is compared with business strategies such as a "buy and hold" strategy[23] and more advanced autoregressive methods[24].

Genetic programming may produce decision-making rules during dynamically changing conditions on the stock market. 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

[20] 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; 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.

[21] 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.

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[24] 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.

long period of time and sells when it makes a profit[25]. In results, genetic programming produces buy and sell rules that can be triggered when certain conditions are met. Perceptibly, 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 trade-off between the dynamics of profit and the risk incurred.

5. Long Short Term Memory based neural networks for stock market investment

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. Models uniquely fit into the requirements of capital market analysis, making this approach particularly effective[26]. 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.

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. 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[27].

On the other hand, simulating the market situation allows you to predict trends and make recommendations for transactions. Moreover, agents can be intro-

[25] 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.
[26] 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.
[27] 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.

duced into the real system to automatically execute operations on behalf of investors based on recommendations. 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[28].

However, Long Short Term Memory artificial neural networks are the most efficient approach for stock market investments[29]. ANNs are learned based on historical data of time series that is available through technical analysis. Multilayer networks make it possible to predict the value of the studied features[30]. 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. In the context of stock market prediction, we are dealing with a specific problem of predicting time series[31]. A training algorithm allows adjusting the synaptic weights[32]. 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.

Feature of LSTM network to remember the state is reached by a memory cell that passing through the cell information, and then is accepted or removed from the cell state by valves. The block of LSTM consists of three valves or gates (input, forget, and output), a block input, a memory cell, and output activation function. All these elements are connected[33]. Figure seven shows LSTM, where circles pointwise operations take place. In rectangles, past information is saved that was learned in previous steps. Line joining another line means concatenation and line that is diverging means that the content that is duplicated going to two different locations. Three sigmoid functions (valves) learn how to protect linear block from false signals. As such, the first valve protects block from insignificant input events. This is reached by sigmoid function to which a previous state and current input is passed. After then, *tanh function* transforms the

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[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.

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

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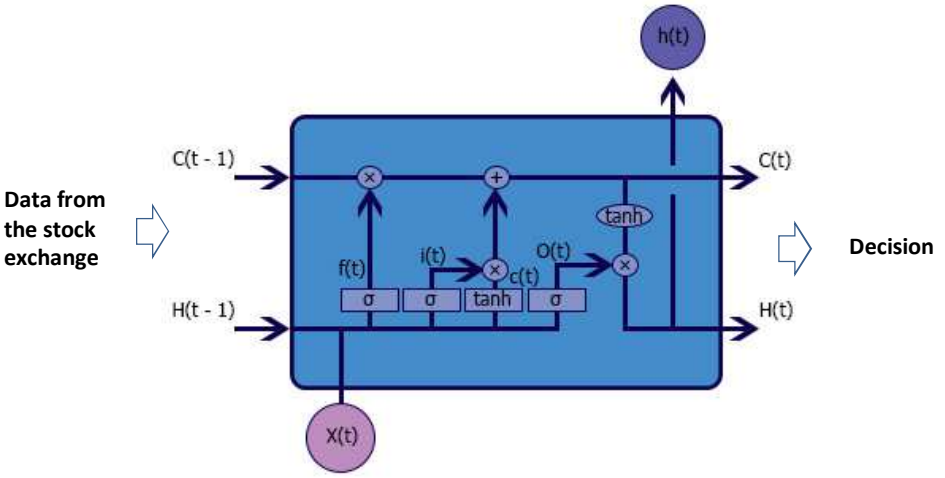
same input values between -1 and 1. Then, both outputs are multiplied by one another and sigmoid function decides which values to keep from *tanh* function.

Fig. 7. Diagram of LSTM ANN 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 second sigmoid function makes a block to be able to forget previous content of memory. Through sigmoid function are passed the previous state and information from the current input. The output of the function are values from 0 to 1 determining which information if important and which is not. The third sigmoid function presents the content of memory in output. Then, the modified state is passed to the *tanh* function. Both outputs are multiplied to determine what information to pass further to the next time step[34].

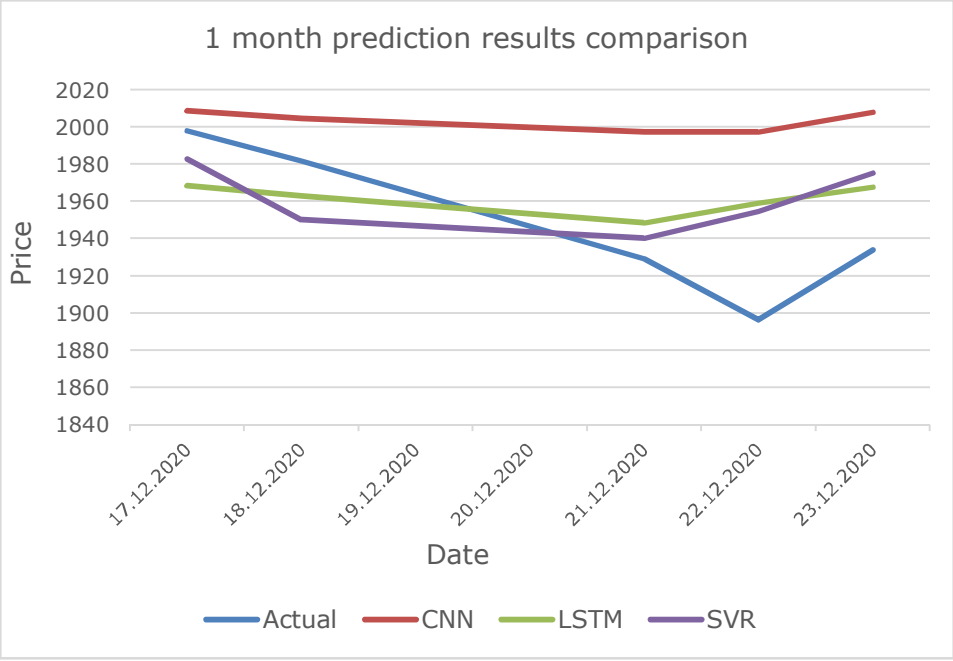
Prediction is also made difficult by the small amount of information in quotes. The quotes provided by the Warsaw Stock Exchange consist of five columns: opening price, highest price on a given day, lowest price on a given day, closing price and trading volume. The neural network has to be based on only 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

[34] Aslam S., Rasool A., Jiang Q., Qu Q., *LSTM based Model for Real-time Stock Market Prediction on Unexpected Incidents*. RCAR 2021, p. 1149.

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 8 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. LSTM was trained 16 December 2020 based on the history of one-month time series of data from 17 November to 16 December. Then, the predictions have been done for the period in the future from 17 December to 23 December. Concurrently, two other predictions have been prepared by Support Vector Regression (SVR)[35] and Convolutional Neural Networks (CNN)[36]. During seven days, the actual values of WIG20 were collected, and they are on Figure 8. We can observe that prediction by LSTM (green line) are very close to the actual values of WIG20 (blue line).

Fig. 8. Simulation of achieving cumulative profit from the date of the transaction.



Source: Own study.

[35] Awad M., Khanna R., *Support Vector Regression: Efficient learning machines*. Apress, Berkeley, CA, 2015, p. 223.
[36] 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, p. 322.

Deep neural networks are also used to optimize the stock portfolio, as they have proven themselves to optimize combinatorial NP-hard problems[37]. 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[38], risk analysis related to granting a mortgage loan[39], building bid strategies, forecasting index values[40] 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[41].

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.

An alternative way of 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, we can own shares for mille- or even microseconds.

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

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[37] 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.

[38] 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.

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[41] 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.

complex econometric models. Modern IT systems should have properly adapted accounting charts so that their use in the distributed computing environment is not only effective, but also very safe. [42] To minimize the likelihood of an attack in cyberspace, the optimal chart of accounts should be dispersed into the areas where payments are most intensively made.

Remarks and conclusions

The use of modern information technologies based on the Internet of Things and deep learning methods, with particular emphasis on neural networks in financial systems, creates a great chance to avoid a deep crisis due to the negative effects of the pandemic in the economy. The article presents, in particular, the methods of deep neural networks implemented on supercomputers or computing clouds, with the help of which you can develop modern and effective methods of cashless settlements, predict the exchange rate, symptoms of corporate bankruptcy, and banking crises.

The article discusses integrated financial system in smart city. Besides, it describes Internet of Things for green management of critical city resources. After discussing financial investment in green and smart technologies, we characterize issues related to deep learning for prediction in financial systems. Finally, Long Short Term Memory artificial neural networks are proposed for stock market investment.

Answering the questions we asked at the beginning of the article, it is worth emphasizing that the harmonious development of smart city can be effectively supported by carefully investing significant funds in the development of modern technologies such as deep learning, Internet of Things and cloud computing. To support this hypothesis, many examples were studied. Therefore, it will be important to finance the construction of an intelligent urban computer infrastructure, which will enable a more complete picture of the complex decision-making situation in the city. It will also ensure the synergy effect resulting from the balanced interaction of key domain systems.

Also in the paper, we tried to answer the question, how to use modern technology, including artificial intelligence, sensor networks, Internet of Things, edge and cloud computing. Complex smart city deep learning models require high computing power for training. On the other hand, prediction, classification and decision support by a trained model require much less resources and can therefore be implemented at the edge of a computer network. Summing up, we can emphasize that we observe a very significant influence of deep learning and the Internet of Things on directions of development of integrated financial systems supporting smart cities for green economy.

[42] Gierusz J., Koleśnik K., Chart of accounts with comment, ODDK, Gdańsk 2021 (in polish), p. 27.

An interesting direction for further research is the development of the other deep learning models such as Convolutional Neural Networks for estimating the risk of the banking sector. Moreover, an important problem is the use of deep artificial neural networks for testing the credibility of potential borrowers.

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