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13. IMPROVING RELIABILITY OF DISTANCE EDUCATION INFRASTRUCTURE IN CRISIS SITUATIONS USING ARTIFICIAL INTELLIGENCE AND DEEP LEARNING APPLICATIONS

13.1. Introduction

The planning and development of smart cities involve the integration of various technologies and trends to improve the quality of life for residents, enhance sustainability, and optimize the use of resources. One of the key technologies and trends in smart city planning and development is Information and Communications Technology (ICT). Reliability is an extremely important practical aspect of practically any Information and Communications Technology (ICT) infrastructure in all conditions, with particular regard to a situation when a crisis occurs. We experienced this type of crisis quite recently, namely during the pandemic caused by the coronavirus. Since the beginning of 2020, nearly all countries have been battling a coronavirus pandemic with strict restrictions recommended by the World Health Organization to help minimize the number of infections. The restrictions also affect members of the academic community. Universities have suspended all teaching – except online classes. Most universities have put in place arrangements for remote education. However, organizing remote education requires adequate technological infrastructure. Providing adequate ICT infrastructure is not an easy challenge, as network devices and web servers are experiencing record peak loads during this time. There appear to be potentially many opportunities to use artificial intelligence to improve the performance of the distance education infostructure, information systems, and network infrastructure during this challenging time. Examples of such use of artificial intelligence applications are presented in this chapter. The chapter demonstrates that using artificial intelligence to improve the performance of distance education server infrastructure is possible in many areas. It is also worth noting that the

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use of artificial neural networks and deep learning techniques for this purpose seems very promising. The sample experiments presented in the chapter and the results obtained seem to confirm this thesis.

13.2. Artificial intelligence and deep learning application

Artificial Intelligence (AI) is a field of computer science that deals with the development of models of intelligent behaviours, programs and systems that simulate those behaviours[2]. It includes machine learning, fuzzy logic, evolutionary computing, neural networks, robotics, and artificial life. It is particularly interested in problems that are not effectively algorithmic. The term was coined by John McCarthy in 1956[3]. Andreas Kaplan and Michael Haenlein define artificial intelligence as "the ability of a system to correctly interpret external data, to learn from it, and to use this knowledge to perform specific tasks and achieve goals through flexible adaptation"[4]. Modern practical applications of AI are[5]: fuzzy logic technologies, expert systems, machine translation of texts, neural networks, machine learning, data mining, image recognition, speech and speaker recognition, handwriting recognition (OCR), artificial creativity, in economics, intelligent interfaces.

The most promising applications of artificial intelligence that could be used to solve the problems described in this chapter appear to be: expert systems – systems that use a knowledge base (stored declaratively) and inference mechanisms to solve problems[6]; neural networks - successfully used in many applications[7]; machine learning – a branch of artificial intelligence that deals with algorithms capable of learning to make decisions or acquire knowledge[8]; deep learning – as a subcategory of machine learning[9]; data mining – discusses areas, relationship to information needs, knowledge acquisition,

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[2] Poole D., Mackworth A., Mackworth A., Goebel R.: Computational Intelligence: A Logical Approach. Oxford University Press, 1998.
[3] Shannon C.E., McCarthy J.: Automata Studies. Princeton University Press, 1958; McCarthy J.: "Programs with common sense," Computation & intelligence, 1958.
[4] Kaplan A., Haenlein M.: "Siri, siri, in my hand: Who's the fairest in the land? on the interpretations, illustrations, and implications of artificial intelligence," Business Horizons, vol. 62, no. 1, 2019, pp. 15–25.
[5] Russell S., Norvig P.: Artificial Intelligence: A Modern Approach. Always learning, Pearson, 2016.
[6] Leondes C.: Expert Systems: The Technology of Knowledge Management and Decision Making for the 21st Century. Elsevier Science, 2001.
[7] Feldman J., Rojas R.: Neural Networks: A Systematic Introduction. Springer Berlin Heidelberg, 2013.
[8] Gori M.: Machine Learning: A Constraint-Based Approach. Elsevier Science, 2017.
[9] Goodfellow I., Bengio Y., Courville A.: Deep Learning. Adaptive Computation and Machine Learning series, MIT Press, 2016.

analysis techniques used, expected results[10]. These techniques include artificial neural networks. Some of the algorithms underpin deep learning, and also technologies such as image recognition and robot vision. Artificial neural networks are inspired by the neurons of the human brain. They consist of several artificial, interconnected neurons. The higher the number of neurons, the deeper the network. The adjective "deep" in deep learning refers to the use of multiple layers in a network. Early work showed that a linear perceptron cannot be a universal classifier, but a network with an uncountable activation function with a single hidden layer of unlimited width can. Deep learning is a contemporary variation that deals with an unlimited number of layers with limited size, which allows for practical application and optimized implementation while maintaining theoretical universality.

The issues addressed in this chapter relate to the use of artificial intelligence and deep learning techniques to improve the performance of ICT servers, which are part of the Distance Education Platform, during a period of the extremely intense load caused by the operation of distance education during a pandemic emergency.

13.3. Distance education infrastructure of the silesian university of technology

The Silesian University of Technology is a modern university, respected in the Polish and international scientific community, educating approximately 20,000 students, with long traditions and experience in the use of distance learning methods and techniques in the teaching process. Distance education or distance learning is a field of education that focuses on the pedagogy, technology, and instructional systems design that are effectively incorporated in delivering education to students who are not physically on-site to receive their education[11]. Instead, teachers and students may communicate asynchronously (at times of their choosing) by exchanging electronic media, or through technology that allows them to communicate in real-time (synchronously). Distance education courses that require a physical on-site presence for any reason including the taking of examinations are considered to be a hybrid or blended course or program[12]. Development research on creating an integrated distance education system for the Silesian University of Technology was started in 2001, but the Internet was practically

[10] Han J., Pei J., Kamber M.: Data Mining: Concepts and Techniques. The Morgan Kaufmann Series in Data Management Systems, Elsevier Science, 2011.
[11] Moore M.G., Diehl W.C.: Handbook of Distance Education, Reutledge, 2018.
[12] Lok J.: Classroom Teaching Problems. Independently Published, 2020.

been used in education since the nineties of the past century. Technical possibilities using the Internet in education are in existence since 1991, the year of connection of polish academic networks to the worldwide Internet. The Silesian University of Technology was one of several first polish universities connected to the Internet in 1991. For the next years, Internet application in education has been more and more popular, especially in the Faculty of Automatic Control, Electronics and Computer Science and other faculties, where using personal computers in education was necessary[13]. For many years, systematizing and regularising all activities in distance learning at the whole University are necessary. It was the main purpose of the Distance Education Platform at the Silesian University of Technology[14]. Development research on creating an integrated distance education platform for the Silesian University of Technology was started in 2001, at the Institute of Electronics, Faculty of Automatic Control, Electronics and Computer Science. Research on this area was based on: testing the most popular application useful for distance education, checking possibilities of adapting distance learning software to University requirements, and attempting to select one (several) of them to construct a distance education service for the whole University. Tested applications can be classified into 3 categories: authoring applications: the web authoring tools, course authoring tools, media editors, content creators - software to create and integrate e-learning content (courses, web pages, multimedia files); web servers, database servers, media servers – software to make e-learning products (courses) available over a network, hosting, administrating, maintaining, supporting; access applications: e-learning client applications, web browsers, media players, communication tools – software to locate and experience e-learning products.

Distance education systems usually use specialized software such as: Learning Management Systems (LMS), Learning Content Management Systems (LCMS) or Virtual Learning Environments (VLE)[15]. A Learning Management System is a software package that enables the management and delivery of online content to learners. LMS are web-based to facilitate "any time, any place, any pace" access to learning content and administration. The characteristics of LMS include[16]: managing users, roles, courses, instructors, and facilities and generating reports; course calendar; learner messaging and notifications; assessment/testing capable of handling student pre/post-testing; display scores and transcripts; grading of coursework and roster processing; web-based or

[13] Wegerif R.: Education for The Internet Age, Reutledge, 2013.
[14] Kłosowski P. and Doś P.: "Zdalna edukacja – pomoc dla studentów i szansa dla wykładowców," Biuletyn Politechniki Śląskiej, vol. nr 1/2016, 2016.
[15] Kats Y.: Learning Management System Technologies and Software Solutions for Online Teaching: Tools and Applications: Tools and Applications. IGI Global research collection, Information Science Reference, 2010.
[16] Kats Y.: Learning Management Systems and Instructional Design: Best Practices in Online Education. Premier reference source, IGI Global, 2013.

blended course delivery. As a result of provided research, the Distance Education Platform was created, as an effective, integrated e-learning service for all faculties of the Silesian University of Technology. A few virtual servers are integrated into one e-learning service for all educational units of the University. Currently on the Distance Education Platform at the Silesian University of Technology are available over 10000 online e-learning courses. The number of users exceeds 88000. In recent years, there has been a significant increase in the number of users and courses of the Distance Education Platform. This implies the need for mass distance education during the pandemic period. This trend was presented in Figures 13.1 and 13.2.

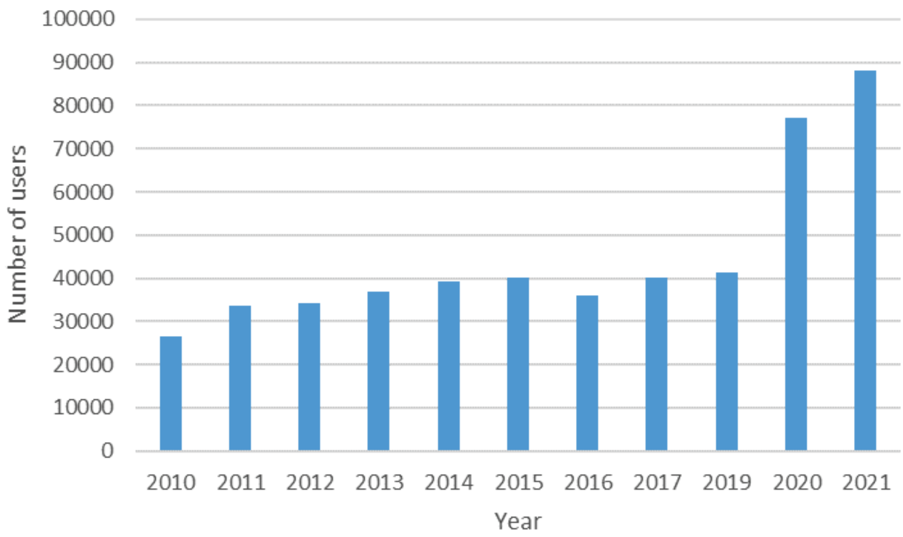

Fig. 13.1. Number of users on the Distance Education Platform in the years 2010–2021
Rys. 13.1. Liczba użytkowników Platformy Zdalnej Edukacji w latach 2010–2021
Source: own research.

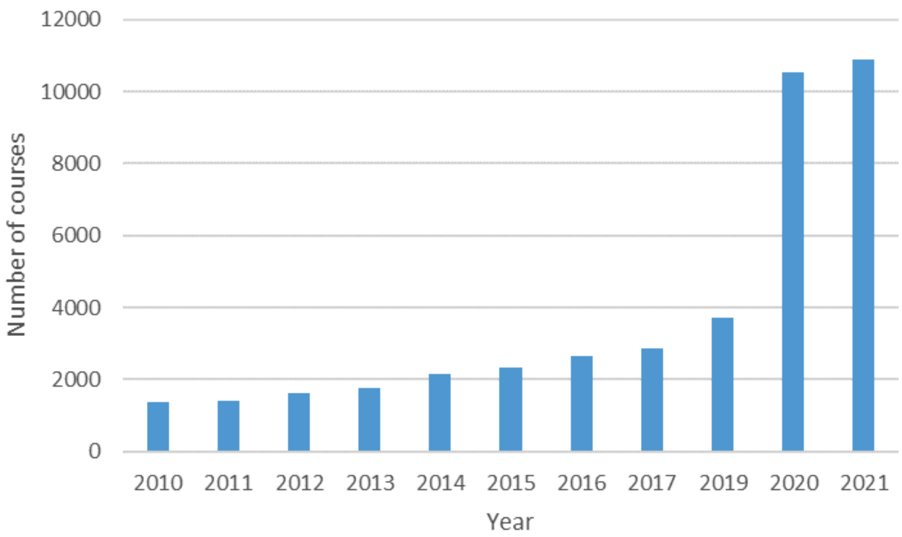

Fig. 13.2. Number of courses on the Distance Education Platform in the years 2010–2021
Rys. 13.2. Liczba kursów Platformy Zdalnej Edukacji w latach 2010–2021
Source: own research.

The Distance Education Platform works as a typically asynchronous e-learning service, but in the future, more synchronous e-learning services will be added. The exception to this is the pandemic period when most of the teaching process was done at a distance and synchronously. The most important features of the Distance Education Platform are: the easy creation of courses from existing resources, course content which can be re-used with different learners, including content from other vendors (Blackboard, WebCT etc.), a user-friendly environment, students enrolment and learner authentication are simple and secure, intuitive online learner and teacher management features. The Distance Education Platform is running on the following software configuration: FreeBSD operating system[17], Apache HTTP Server[18], PHP language interpreter[19], MySQL database server[20], Moodle learning management system[21]. The Distance Education Platform is based on a modular object-oriented dynamic learning environment named Moodle (www.moodle.org)[22], which represents LMS technology, a software package designed to help educators create high-quality online courses[23]. The Moodle software is an alternative to proprietary commercial online learning solutions and is distributed free under open source licensing[24]. The Silesian University of Technology has complete access to the source code and can make changes if needed. Moodle's modular design makes it easy to create new courses, adding content that will engage learners and to create courses for instructors. Students require only basic browser skills to begin learning. The Web front page of the Distance Education Platform of the Silesian University of Technology is presented in Figure 13.3.

The main advantages of Moodle LMS software are[25]: promotes a social constructionist pedagogy (collaboration, activities, critical reflection, etc.); suitable for 100% online classes as well as supplements face-to-face learning; simple, lightweight, efficient, compatible, low-tech browser interface; easy to install on almost any platform that supports PHP; requires only one database; full database abstraction supports all

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[17] Lucas M.: Absolute FreeBSD, 2nd Edition: The Complete Guide to FreeBSD. No Starch Press, 2013; The FreeBSD Documentation Project: FreeBSD Porter's Handbook, (https://docs.freebsd.org/en/books/porters-handbook), 2022.
[18] Apache HTTP Server Project: Apache HTTP Server 2.4 Reference Manual, (https://httpd.apache.org/docs/2.4, 2022.
[19] Nixon R.: Learning PHP, MySQL, JavaScript, and CSS: A Step-by-Step Guide to Creating Dynamic Websites. O'Reilly Media, 2012.
[20] Widenius M., Axmark D., Arno K.: MySQL Reference Manual: Documentation from the Source. O'Reilly Series, O'Reilly Media, Incorporated, 2002.
[21] Schinkten O.: Learning Moodle 3.7. linkedin.com, 2019.
[22] Cole J., Foster H.: Using Moodle. Content management, O'Reilly, 2008.
[23] Kłosowski P. and Doś P.: Zdalna edukacja – pomoc dla studentów i szansa dla wykładowców, Biuletyn Politechniki Śląskiej, vol. nr 1/2016, 2016.
[24] Rice W.: Moodle: E-learning Course Development: a Complete Guide to Successful Learning Using Moodle. From technologies to solutions, Packt Publishing, 2006.
[25] Rice W.: Moodle: E-learning Course Development: a Complete Guide to Successful Learning Using Moodle. From technologies to solutions, Packt Publishing, 2006.

major brands of a database; course listing shows descriptions for every course on the server, including accessibility to guests; courses can be categorized and searched – one distance education system can support thousands of courses; emphasis on strong security throughout. Forms are all checked, data validated, cookies encrypted etc.; most text entry areas (resources, forum postings, journal entries etc.) can be edited using an embedded WYSIWYG HTML editor.

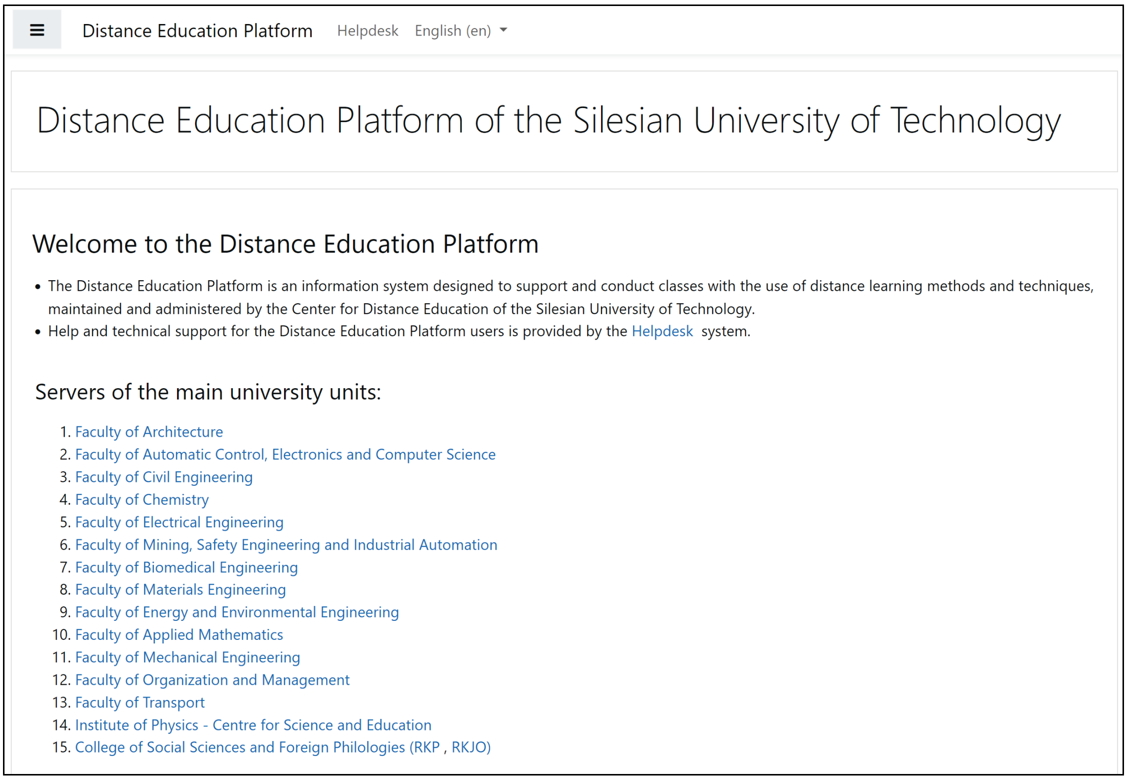

Fig. 13.3. The Web front page of the Distance Education Platform of the Silesian University of Technology
Rys. 13.3. Strona główna WWW Platformy Zdalnej Edukacji Politechniki Śląskiej
Source: https://platforma.polsl.pl/?lang=en

13.4. Preventing distance education infrastructure overload in crisis situation

Poland has fought the coronavirus pandemic with strict restrictions recommended by the World Health Organization to limit the number of infections as much as possible. The restrictions also affect members of the Polish academic community. Universities have suspended classes: lectures, exercises, laboratories and others – with the exception of online classes. Most universities, for the time of suspension of classes, have introduced solutions allowing for distance education. The organization of distance education requires universities to provide adequate technological infrastructure and support in the use of information and communication technologies and e-learning tools by students. Ensuring adequate IT infrastructure is not an easy challenge as network devices and web servers experience record peak loads during the pandemic period. It can be seen that during this period, the load on servers increased more than 20 times compared to months of normal operation. This situation is presented in Figures 13.4, 13.5 and 13.6. Figures 13.4 and 13.5 show the monthly statistics of the Distance Education Platform in the months of the academic years 2019/20 and 2020/21 (Figure 13.4) and in individual months of September 2019 to February 2022 (Figure 13.5), expressed as the monthly number of distance education server references. The 24-hours server statistics during the period of increased load are presented in Figure 13.6, which shows the average daily number of server accesses in each hour of the day.

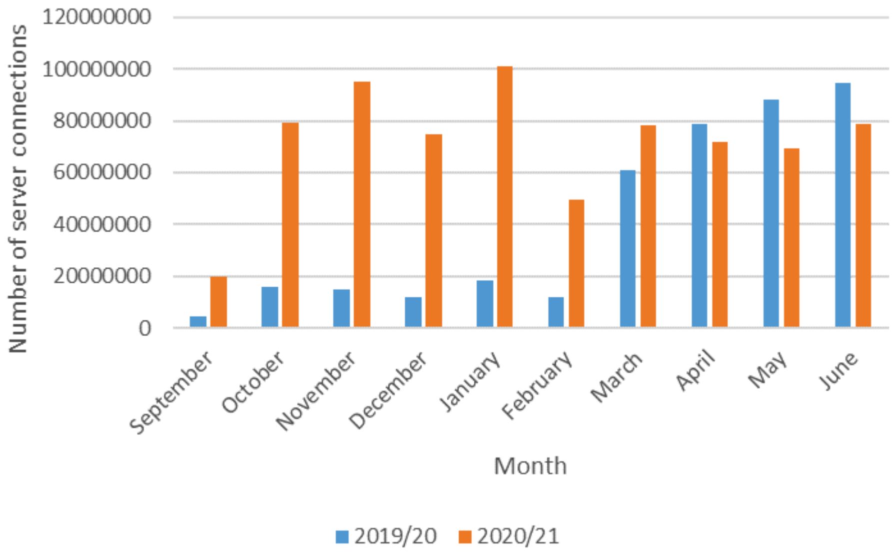

Fig. 13.4. Monthly statistics of the Distance Education Platform in the months of the academic years 2019/20 and 2020/21

Rys. 13.4. Miesięczne statystyki Platformy Zdalnej Edukacji w miesiącach roku akademickiego 2019/20 oraz 2020/21

Source: own research.

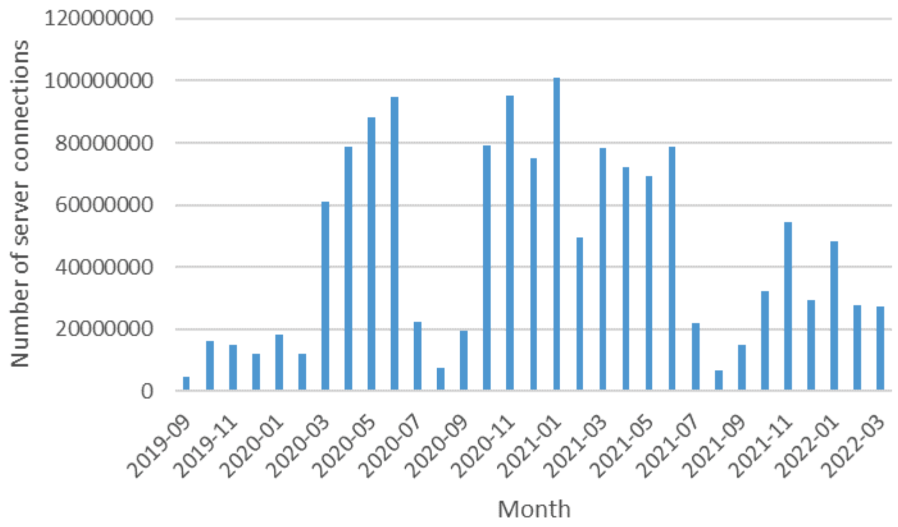

Fig. 13.5. Monthly statistics of the Distance Education Platform in the months of September 2019 to February 2022
Rys. 13.5. Miesięczne statystyki Platformy Zdalnej Edukacji w miesiącach od września 2019 r. do lutego 2022 r.
Source: own research.

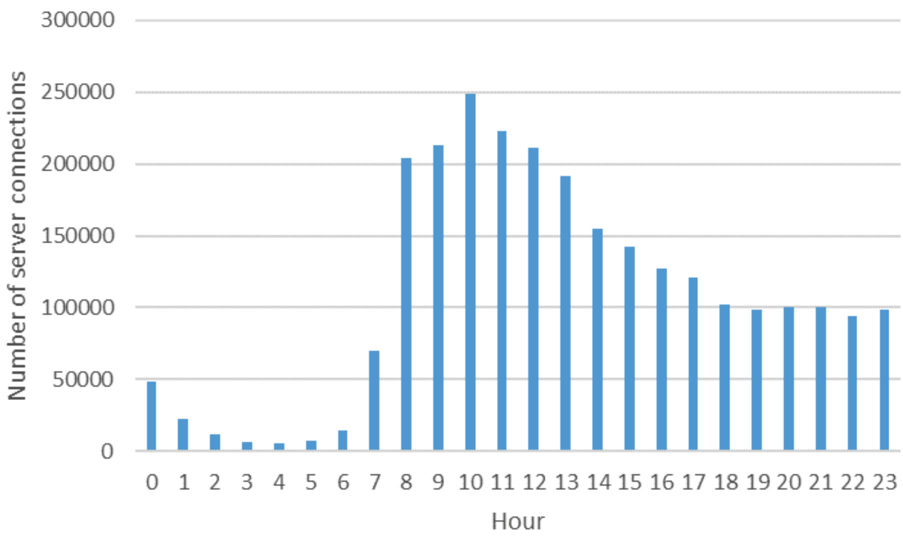

Fig. 13.6. Hourly average statistics of the Distance Education Platform
Rys. 13.6. Średnia dobowa statystyka Platformy Zdalnej Edukacji
Source: own research.

It seems that there are potentially great possibilities for using artificial intelligence to improve the performance of information systems and infrastructure in this difficult and demanding period. The use of artificial intelligence to improve the operation of the Distance Education Platform servers is potentially possible in the following areas: analysis and control of the current server operating parameters: server load, server resource utilization, data transfer rate, network utilization, energy consumption and operating temperature, etc.; analysis of the server operating parameters in the past; analysis of a current server load; analysis of a server load in the past; prediction of the highest server load: monthly, weekly, daily, hourly; reserving server resources during a period of higher load; moving selected server tasks from periods of higher server load to periods of lower load; server load equalization: monthly, weekly, daily, hourly; balancing a daily server load and avoiding overloads; controlling of security and stability of server operation; improvement of back-end operations; improvement of front-end operations and user interface operation responsiveness.

In recent years, mass data analysis applications have been developed to improve the performance of cloud computing and network server infrastructure[26]. The most common methods of predicting performance are essentially divided into two categories: one of them focuses on building the relationship between performance and time, e.g. neural network (MLP), and the other linear[27], weighted multifactorial linear regression (MVLR)[28], and recursive neural network (RNN)[29] are even used long short-term memory (LSTM)[30]. Recently, deep neural networks are beginning to show their great potential in language processing and modelling[31]. Currently, the field of language modelling is shifting from statistical methods to neural networks and deep learning methods. Recent studies show that the neural network does not realize popular statistical algorithms to a small extent[32]. As a particular type of RNN, the LSTM neural network[33] has proved effective in modelling sequential data such as speech and text[34].

[26] Buyya R., Ramamohanarao K., Leckie C., Calheiros R.N., Dastjerdi A.V., Versteeg S.: "Big data analytics-enhanced cloud computing: Challenges, architectural elements, and future directions," in Proceedings of the 21st IEEE International Conference on Parallel and Distributed Systems, ICPADS 2015, pp. 75–84.

[27] Islam S., Keung J., Lee K., Liu A.: "Empirical prediction models for adaptive resource provisioning in the cloud," Future Generation Computer Systems vol. 28 no. 1, 2012, pp. 155–162.

[28] Davis I., Hemmati H., Holt R.C., Godfrey M., Neuse D., Mankovskii S.: "Storm prediction in a cloud," in Proceedings of the 2013 5th International Workshop on Principles of Engineering Service-Oriented Systems, PESOS 2013, pp. 37–40.

[29] Luo B., Ye S.: "Server performance prediction using recurrent neural network," Computer Engineering and Design, vol. 8, 2005, p. 57.

[30] Song B., Yu Y., Wang Y.Z.Z., Du S.: "Host load prediction with long short-term memory in cloud computing," The Journal of Supercomputing, 2017, p. 1–15.

[31] Kłosowski P.: "Deep learning for natural language processing and language modelling," in Proceedings of the 22nd IEEE International Conference Signal Processing Algorithms, Architectures, Arrangements, and Applications, September 19–21, 2018, Poznan, Poland, 2018, pp. 223–228; Kłosowski P.: "Polish language modelling based on deep learning methods and techniques," in Proceedings of the 23rd IEEE International Conference Signal Processing Algorithms, Architectures, Arrangements, and Applications, September 18–20, 2019, Poznan, Poland, 2019, pp. 223–228; Auli M., Galley M., Quirk C. and Zweig G.: "Joint language and translation modeling with recurrent neural networks," Proceedings of the 2013 Conference on Empirical Methods in Natural Language Processing, 2013, pp. 1044–1054.

[32] Osawa M., Yamakawa H., Imai M.: "In implementation of working memory using stacked half restricted Boltzmann machine: Toward to restricted Boltzmann machine-based cognitive architecture," in Neural Information Processing – 23rd International Conference, ICONIP 2016, Proceedings, vol. 9947 LNCS, (Germany), pp. 342–350, Springer Verlag, 2016. 23rd International Conference on Neural Information Processing, ICONIP 2016 ; Conference date: 16-10-2016 Through 21-10-2016.

[33] Hochreiter S., Schmidhuber J.: "Long short-term memory," Neural Computation, vol. 9, no. 8, 1997, p. 1735–1780.

These previous studies have inspired us to use LSTMs in these predictive tasks, as the user's query data is quantifiable. To improve the predictive performance of the webserver and workload can be used RNN-LSTM with vector queries for this task.

The following sample experiments and results show that it is possible to use artificial intelligence to improve distance education server performance. The purpose of the first experiment is to predict the distance education server load. The obtained results allow providing the second experiment which aims at balancing the daily distance education server load and avoiding overloads. The purpose of the first experiment was to try to predict the hourly load distribution of distance education servers based on load statistics recorded in the past. In the last few months, admins have collected website access logs and server uptime logs and processed these two files, combining transactions and average load that occur at the same interval. The collected data were then used as training samples. Each line of the sample training file contains information about time, number of unique IP addresses, total content size, protocol and average load of the last 1, 5 and 15 minutes. The main goal of the experiment was to predict the distance education server load based on time. The problem of predicting server load based on time alone would be extremely difficult to solve. So we decided to divide this problem into two parts, one designed to predict server load, and the other to predict user activity based on time. The output we tested was selected as a 1-minute average server load because the uptime command was run on the server every 1 minute. Figure 13.7 presents the predicted and real average server load at each hour of a day, calculated based on the experiment results. On the vertical axis, the values of server load are marked and on the horizontal axis the individual hours of server operation.

[34] Sundermeyer M., Ney H., Schluter R.: "From feedforward to recurrent LSTM neural networks for language modeling," IEEE Transactions on Audio, Speech and Language Processing, vol. 23, no. 3, 2015, p. 517–529.

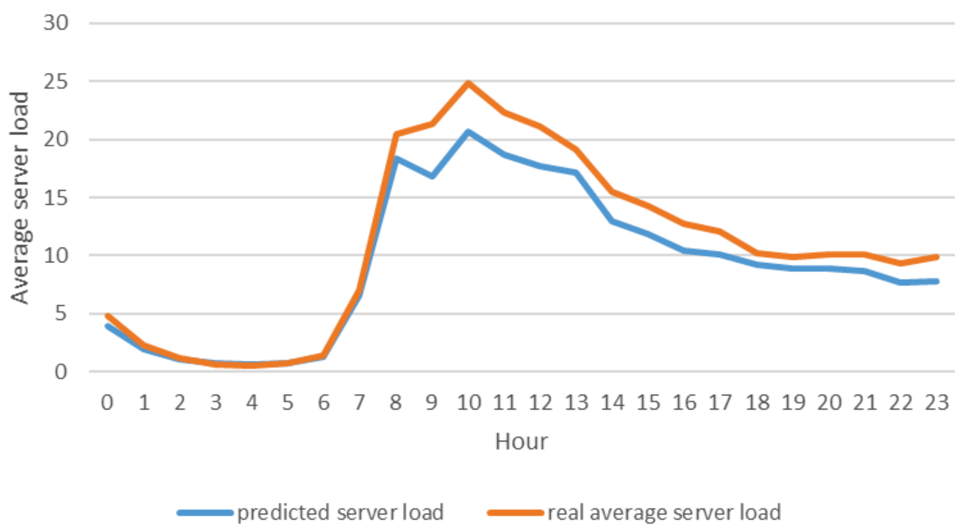

Fig. 13.7. Hourly distance education server load prediction results
Rys. 13.7. Prognozowanie dobowego rozkładu obciążenia serwera zdalnej edukacji
Source: own research.

As can be seen in Figure 13.7, the shape of the server load distribution was predicted correctly, but the real average server load values were higher than expected. The reason is that the real average server load in the tested month was much higher than in the training months. However, it is noteworthy that the server load distribution curve was predicted correctly, and this fact allowed for further actions to be taken using artificial intelligence to improve the performance and better operation of the server during individual hours of the day. An attempt to do so was made in the next experiment described below.

The second experiment part aimed to equalize daily server load to avoid overloads. The experiment involves using artificial intelligence techniques to decide which tasks performed by the server can be postponed and performed when the server is less loaded. This will reduce the probability of server overload and make the load on the server more evenly distributed all day. The basic and essential thing is to choose the time and date of the postponed server tasks. The data obtained in the previous experiment, i.e. prediction of the server load at home, is here necessary and crucial. The results of the following experiment were presented in Figures 13.8 and 13.9. On the vertical axis, the values of server load are marked and on the horizontal axis the individual hours of server operation.

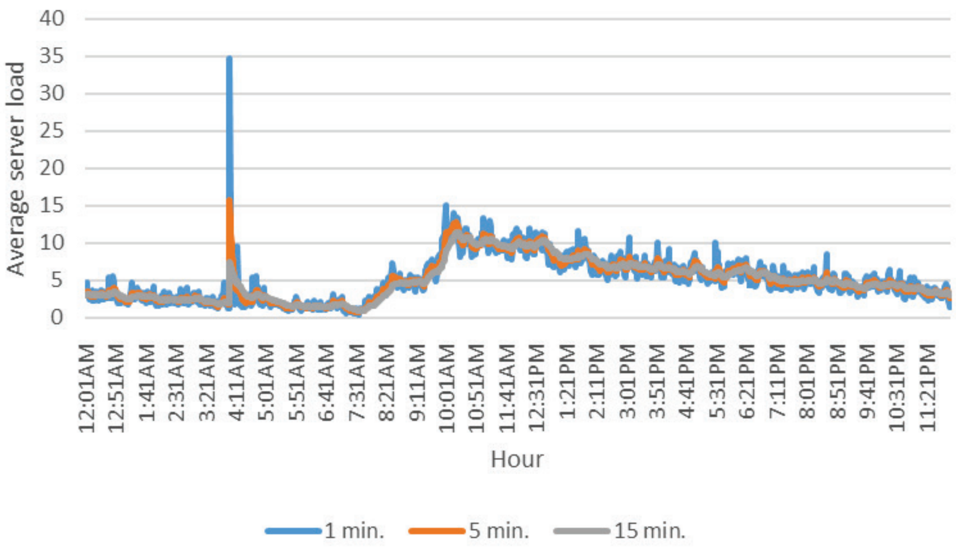

Fig. 13.8. Hourly distance education server load before improvements
Rys. 13.8. Dobowy rozkład obciążenia serwera zdalnej edukacji przed wprowadzeniem usprawnień
Source: own research.

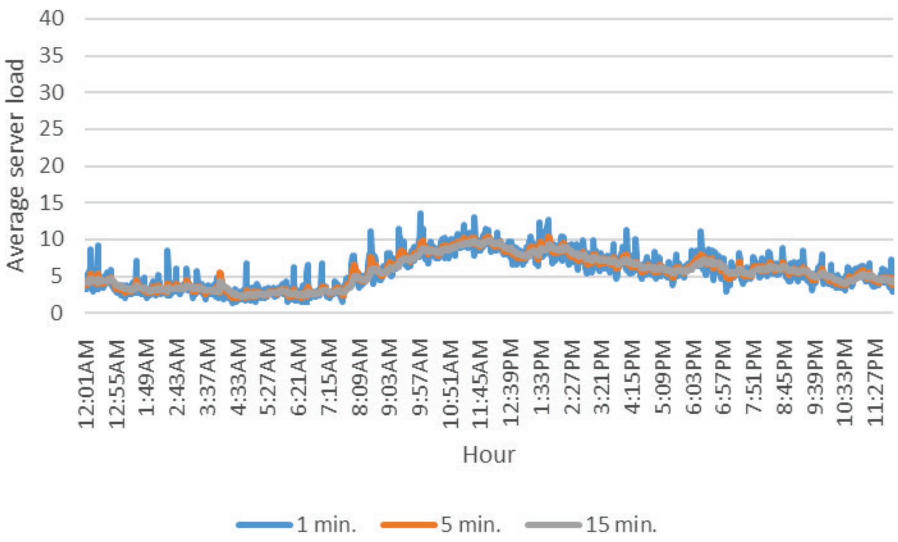

Fig. 13.9. Hourly distance education server load after improvements
Rys. 13.9. Dobowy rozkład obciążenia serwera zdalnej edukacji po wprowadzeniu usprawnień
Source: own research.

Figures 13.8 and 13.9 show the hourly load distribution of the server for the whole day before and after improvements. It is easy to see that the application of the improvements resulted in a more even distribution of the server load during the day and a sudden increase in the server load could have been avoided, even though on the day when the improvements were applied the server load was much higher than on the day without the improvements. This is evidenced by the data presented in Figures 13.10 and 13.11. Figure 13.10 presents the values of maximum distance education server load before and after improvements, and Figure 13.11 presents average values.

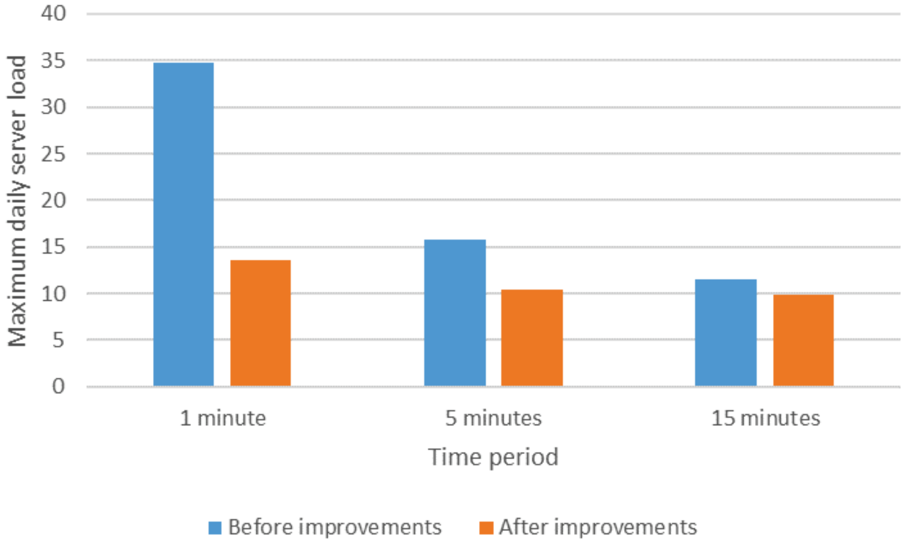

Fig. 13.10. Maximum distance education server load before and after improvements
Rys. 13.10. Maksymalne obciążenie serwera zdalnej edukacji przed i po wprowadzeniu usprawnień
Source: own research.

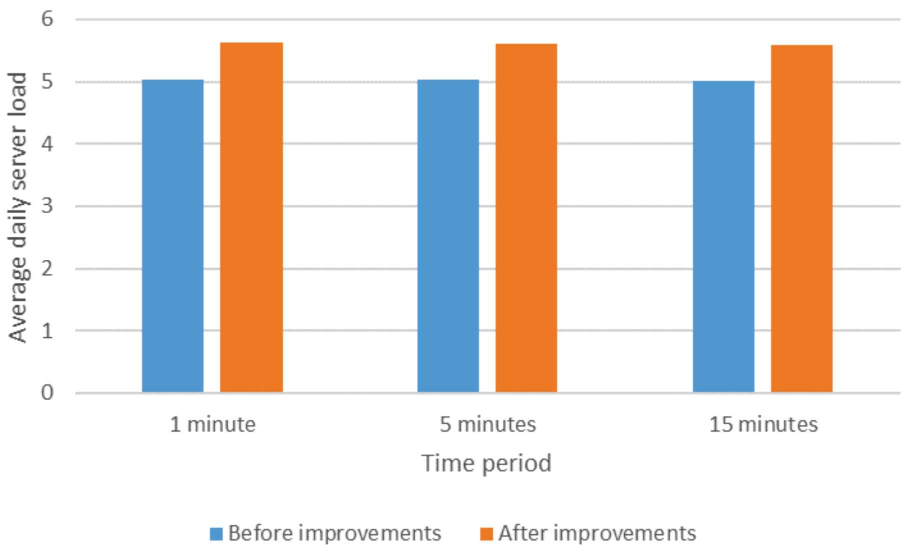

Fig. 13.11. Average distance education server load before and after improvements
Rys. 13.11. Średnie obciążenie serwera zdalnej edukacji przed i po wprowadzeniu usprawnień
Source: own research.

13.5. Conclusions

The efficient provision of network services for a large number of users, as is the case in distance education, depends closely on the performance and reliability of the network and server infrastructure. The situation becomes more complicated when the demand for services increases significantly, as was the case during the coronavirus pandemic. The issues described in the article show that improving server operation and performance, especially in a period of extreme loads, is a complex problem and very difficult to solve effectively. The problem is further compounded by the fact that daily demands for computing power and server resources are a random variable and are not known. The examples of experiments presented in the article show that the use of artificial intelligence techniques helps not only to predict the daily demand for computing power and resources of the distance education server but can also effectively contribute to improving the security of distance education server operation by reserving the computing power of the server and server resources and making them available when necessary. The obtained results are very promising and give the prospect of further research and can be applied in improving the functioning of the ICT infrastructure as a key technology in the development of a smart city. Therefore the research will continue particularly in the area of the use of artificial neural networks and deep learning to model server load and performance prediction of network servers to improve the reliability of ICT infrastructure and the operation of network servers.

13.6. Acknowledgements

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