ПРОБЛЕМИ ПРИЙНЯТТЯ РІШЕНЬ ТА УПРАВЛІННЯ В ЕКОНОМІЧНИХ, ТЕХНІЧНИХ, ЕКОЛОГІЧНИХ І СОЦІАЛЬНИХ СИСТЕМАХ

UDC 303.732.4, 519.816
DOI: 10.20535/SRIT.2308-8893.2020.1.03

ESTIMATION COMPUTATIONAL MODELS OF THE CYBER-PHYSICAL SYSTEMS FUNCTIONING

N.D. PANKRATOVA, Y.A. PTUKHA

Abstract. This paper reviews the use of computational models to support the functioning of cyber-physical systems (CPS) in the parallel world of the Internet of Things (IoT). Existing models, methods, techniques and their implementation in this direction are studied. The necessity of using machine learning methods due to inaccuracy, fuzziness, incompleteness of the transmitted data from sensors of physical systems is substantiated. The task is to make informed decisions in a timely manner to support the functioning of real objects of a particular cyber-physical system in real time conditions.

Keywords: cyber-physical systems, the Internet of Things, system methodology, machine learning, computer systems, sensors.

INTRODUCTION

A cyber-physical system (CPS) is a complex distributed system, managed and controlled by computer systems, tightly integrated with the Internet and its users. The main principle of the CPS is a deep relationship between its physical and computational elements to make decisions regarding the maintenance of the functioning of real objects.

The cyber-physical system was proposed for the study of complex systems consisting of various heterogeneous natural objects, artificial systems, controllers and distributed computing systems, including embedded real-time systems, automated control systems for technical processes and objects, wireless sensor networks, combined into a single whole [1]. The technological basis of CPS is the Internet of Things (IoT), which is the “brain” of a system in the form of artificial intelligence and other technologies for analysis, processing of data received from sensors in the real world [2].

The Internet of things becomes a modern tool that includes several stages of interaction with physical systems: collecting data from a specific physical system, bringing this information to the required format, performing calculations based on models, methods and techniques that allow you to make decisions based on information, obtained from physical models. In CPS, it becomes a fundamentally new fact that not only close communication and coordination between computational and physical resources must be ensured, but also the ability to effectively respond to emerging cyber-physical effects due to the interaction of physical objects and computational processes, and the ability to make adjustments to ensure the survivability of the functioning of physical systems.

Recently, the Internet of things has become quite popular due to its potential ability to be integrated into any complex system. So, on the market you can already find many ready-made software products, such as Blynk [3], Fracttal [4], PRG Network Monitor [5], IoT Analytics [6] etc. Even Google offers its Google Cloud IoT [7] solution on the market. Also, there are companies that offer their services to create products for IoT of the customer systems [8]. But most of them are only ready-made tools and algorithms for the field of study in question for collecting and processing information, and can offer customers forecasting and decision making support in the subject area. However, IoT involves the autonomous functioning and management of the system in cases of detecting threats of emergency situations. For example, according to the article [9] IoT is described as a network of connected embedded objects or devices with identifiers where control can occur without human intervention.

REVIEW OF IOT APPLICATION

The future of IoT is being determined. IoT provides decision-making options in all sectors, including manufacturing, fashion, restaurant, healthcare, education, etc.

IoT applications have already appeared in many aspects of the smart city. In the process of developing such applications, conflicting goals specific to the selected city are determined and their performance indicators are taken into account. For example, the government of Amsterdam is investing its financial resources in reducing transport, energy efficiency and improving the city safety [10], sensor technologies are implemented into new bus network in Barcelona [11], and Santa Cruz police use IoT technology to maximize their presence in the most criminal areas [12]. The Government of India has announced 100 cities that can be developed as “smart cities”, and also allocated 7,060 crore in the budget for 2015 [13].

Another equally common example of the use of the Internet of Things is the creation of a smart home. Smart home systems have gained great popularity in recent decades because they increase comfort and quality of life by making home appliances more intelligent, remotely controlled and interconnected. But it is also important that one of the basic functions of the system – the creation of thief warning technology, is developed in accordance with the environment and culture of the country [14, 15, 16].

The versatility of IoT makes it an attractive option for so many businesses, organizations and government agencies so there is no doubt about using this. However, organizations face many challenges when integrating IoT devices into outdated ecosystems. So, when the IoT is implemented, all devices work simultaneously and the question of data collection and its potential problems arises. IoT works through remote sensors that can make enterprise privacy public [17]. And a separate issue is the big risk of hacking company data on IoT devices. Therefore the Internet of Things is part of Industry 4.0’s modern strategy, which connects information systems and big data to form a single digital device [18]. As part of this strategy, modern researchers are developing various frameworks for IoT systems management solutions [19, 20, 21].

For example, in article [22], the authors propose an IoT infrastructure that focuses on security and reducing complexity, regardless of industry. While researchers of the Department of Technology Management developed an IoT framework to monitor all the conditions and results of smart agriculture in Thailand, which also accompanies developers in improving various processes in the industry [23].

Other scientists from Lancaster University are exploring the challenges of the widespread service-oriented architecture (SOA) of IoT software, such as integration, scaling and sustainability in IoT systems [24]. The development of frameworks in IoT has become so popular that companies even rank the highest quality solutions [25, 26] .

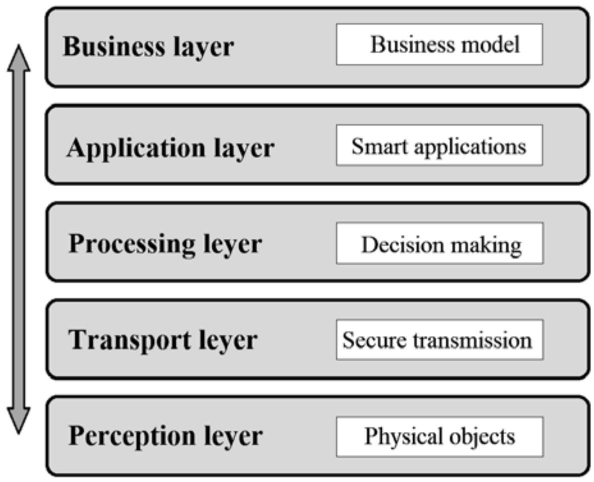
Smart city, smart homes, pollution control, energy saving, smart transportation, smart industries — modern development due to the Internet of things. Many important studies have been conducted to improve technology using IoT. However, there are still many problems that need to be solved in order to fully realize the potential of IoT. The main ones that most scientists put emphasis on can be determined by the following list:

- security and privacy issues related to threats, cyber-attacks, risks and vulnerabilities;
- compatibility issues that arise due to the heterogeneous nature of the various technologies and solutions used to develop IoT;
- ethics, law and regulatory rights to comply with quality standards and prevent illegal use of people;
- scalability, availability and reliability to support a large number of devices with different memory, processing, storage capacity and bandwidth;
- compliance with quality of service (QoS) standards.

It means that improving existing solutions in the above areas can improve the quality and safety of human life at the highest possible level for IoT systems [27].

APPLICATION OF MACHINE LEARNING METHODS

Despite great progress, developing IoT applications is still a complex and time-consuming task. Basically, there are 5 main stages of developing such solutions [28–31] (Figure).



Architecture of IoT

1. Perception stage is the physical layer that is responsible for collecting environmental information. It defines some physical parameters or identifies other intelligent objects in the environment.
2. The transport phase transfers sensor data from the perception level to the processing level and vice versa through networks such as wireless networks, 3G, LAN, Bluetooth, RFID and NFC.
3. The processing layer stores, analyzes and processes huge volumes of data (Big Data) coming from the transport layer, using technologies such as databases and cloud computing.
4. The application layer is responsible for providing the user with application-specific services. It identifies various applications where the Internet of Things can be deployed, such as smart homes, smart cities, and smart health.
5. The business layer manages the entire IoT system, including applications, business models and profit models, as well as user privacy.

In this study, we consider 3–4 steps, which involve processing the data received and supporting timely decision making.

The existing IoT network architecture allows you to extract, convert, delete and consolidate structured data from existing databases and unstructured data from sensors, various transmitting devices. Such data is analyzed using software services that run on a virtual machine for advanced analysis using various machine learning (ML) methods. Most aspects such as managing a smart city, home or business, forecasting water demand, or detecting anomalies are solved directly using ML methods [32, 33].

It is also necessary to consider the issue of processing a large amount of data generated by the IoT system, especially possible approaches to creating state control algorithms that can operate on client devices or nodes with low computational performance [34]. However, in each specific case, in order to create real systems, it is necessary to analyze the most effective algorithms for forming a fuzzy knowledge base and draw fuzzy inference, as well as pre-train systems during the formation of a fuzzy knowledge base and when choosing algorithms for fuzzy inference [35].

An additional problem that we face in the process of studying existing IoT applications is the lack of formalization of the methods described in materials available for research. The main part of the works mentioned above offers only descriptive materials of architecture, selected methods and obtained application results.

CONCLUSION

Based on the above review of the development and application of IoT, in this paper, it is proposed to use the IoT concept where, in real-time, data obtained from physical systems will come to a parallel world and a decision will be formed in a timely manner to ensure the survivability of their functioning based on the analysis and processing of these data. A feature of the application of ML methods in IoT systems is that these methods must control the operation of devices or form decisions on the behavior of the system in emergency and critical situations. In other words, they must accompany the work of physical systems in real time.

As an example of the implementation of the system strategy of guaranteed survivability of the functioning of the system, it is proposed to consider a real closed deep water supply system [36]. The main purpose of the system is to provide the indicated level of water consumption for consumers, provided that the priority is the cooling process of an environmentally hazardous technological installation.

In order to achieve the goal of timely identification of the causes of potentially possible emergency situations and to ensure the survivability of its operation in real time, monitoring is carried out in the form of technical diagnostics and indicators are taken at key points in the water supply system, which are transmitted to the IoT to develop a solution to support the functioning of the system. It is assumed that the implementation of a water management system can be accomplished by using hybrid neural networks, which is planned to be presented in further works.

REFERENCES

1. *Vyatkin V.* Cyber-physical engineering as a way of applying the theory of cyber-physical systems / Valeriy Vyatkin, Dmitry Drozdov, Yulia A. Golub // SAEC. — 2019. — No. 1.
2. *Xia F.* Internet of things / F. Xia // International Journal of Communication Systems. — 2012. — Vol. 25. — No. 9. — P. 1101.
3. https://blynk.io/
4. https://www.fracttal.com/en/fracttal-box
5. https://www.paessler.com/prtg
6. https://iot-analytics.com/
7. https://cloud.google.com/solutions/iot
8. https://www.analyticsinsight.net/top-iot-companies/
9. *Gubbi J.* Internet of things (IoT): A vision, architectural elements, and future directions / J. Gubbi, R. Buyya, S. Marusic, M. Palaniswami // Future Generation Computer Systems. — 2013. — Vol. 29. — No. 7. — P. 1645–1660.
10. *Mora L.* How to Become a Smart City: Learning from Amsterdam / L. Mora, R. Bolici // In: Bisello A., Vettorato D., Stephens R., Elisei P. (eds) Smart and Sustainable Planning for Cities and Regions. SSPCR 2015. Green Energy and Technology. — Springer, Cham. — 10.1007/978-3-319-44899-2_15
11. *Madakam S.* Barcelona Smart City: The Heaven on Earth (Internet of Things: Technological God) / S. Madakam, R. Ramaswamy. — An International ICT R&D Journal Sponsored by ZTE Corporation. — 2015. — Vol. 13. — N 4.
12. *Baxter S.* Modest gains in first six months of Santa Cruz's predictive police program / S. Baxter // Santa Cruz Sentinel. — 2012. — Retrieved 2015-05-26.
13. *Chatterjee S.* Success of IoT in Smart Cities of India: An empirical analysis / S. Chatterjee, A. Kar, MP. Gupta // Government Information Quarterly. — 2018. — 10.1016/j.giq.2018.05.002.
14. *Tran A. Thuan.* SmartHome IoT Application Development / Tran A. Thuan, T. Huy, D. Hoang et al. — 2019.
15. *Alaa M.*. A Review of Smart Home Applications based on Internet of Things / M. Alaa, A. Zaidan, B. Bahaa et al. // Journal of Network and Computer Applications. — 2017. — 97. 10.1016/j.jnca. 2017.08.017.
16. *Yang H.* IoT Smart Home Adoption: The Importance of Proper Level Automation / H. Yang , L. Wonji, L.Hwansoo // Journal of Sensors. — 2018. — P. 1–11. — 10.1155/2018/6464036.
17. *Khan A.* The Role of IoT in Digital Governance / A. Khan, N. Zaman, M. Humayun. — 2020. — 10.4018/978-1-7998-1851-9.ch007.
18. *Koman G.* Advantages of IoT implementation in enterprise process management / G. Koman, M. Kubina, D. Šulyová. — 2020.

19. *Mohapatra S.* A Solution Framework for Managing Internet of Things (IoT) / S. Mohapatra, J. Bhuyan // International journal of Computer Networks & Communications. — 2016. — 8. — P. 73–87. — 10.5121/ijcnc.2016.8606.
20. *Ando B.* Editorial: Hot I&M topics in the IoT framework / B. Ando // IEEE Instrumentation & Measurement Magazine. — 2019. — 22.2-2. 10.1109/MIM.2019.8917895.
21. *Vranken C.* Combination of IoT framework with liquid software. — 2018.
22. *Cheruvu S.* IoT Frameworks and Complexity / S. Cheruvu, A. Kumar, N. Smith, D. Wheeler— 2020. — 10.1007/978-1-4842-2896-8_2.
23. *Krongthong T.* Modeling and Simulink of Smart Agriculture Using IoT Framework / T. Krongthong, B. Muangmeesri. — 2019. — P. 185–188. — 10.1109/ICORIS.2019. 8874914.
24. *Onoriode U.* IoT Architectural Framework: Connection and Integration Framework for IoT Systems / U. Onoriode, G. Kotonya // Electronic Proceedings in Theoretical Computer Science. — 2018. — 264. — P. 1–17. — 10.4204/EPTCS.264.1.
25. https://www.byteant.com/blog/5-best-open-source-iot-frameworks/
26. https://www.techtic.com/blog/top-10-open-source-iot-frameworks/
27. *Kumar S.* Internet of Things is a revolutionary approach for future technology enhancement: a review / S. Kumar et al. // Journal of Big Data. — 2019. — 6. — P. 1–21.
28. *Mashal I.* Choices for interaction with things on Internet and underlying issues / I. Mashal, O. Alsaryrah, T.-Y. Chung et al. — Ad Hoc Networks. — 2015. — Vol. 28. — P. 68–90.
29. *Wu M.* Research on the architecture of internet of things / M. Wu, T.-J. Lu, F.-Y. Ling et al. // in Proceedings of the 3rd International Conference on Advanced Computer Theory and Engineering (ICACTE '10). — Vol. 5. — P. 484–487. — IEEE, Chengdu, China, August 2010.
30. *Khan R.* Future internet: the internet of things architecture, possible applications and key challenges / R. Khan, S.U. Khan, R. Zaheer, S. Khan // in Proceedings of the 10th International Conference on Frontiers of Information Technology (FIT '12). — 2012. — P. 257–260.
31. *Sethi P.* Internet of Things: Architectures, Protocols, and Applications / P. Sethi, S. Sarangi // Journal of Electrical and Computer Engineering. — 2017. — P. 1–25. — 10.1155/2017/9324035.
32. *Vijai P.* Design of IoT Systems and Analytics in the Context of Smart City Initiatives / P. Vijai, P. Sivakumar // India. Procedia Computer Science. — 2016. — 92. — P. 583–588. — 10.1016/j.procs.2016.07.386.
33. *Zantalis F.* A Review of Machine Learning and IoT in Smart Transportation / F. Zantalis, G. Koulouras, S. Karabetsos // Future Internet. — 2019. — 11. 10.3390/fi11040094.
34. *Luntovskyy A.* Performance, Reliability and Scalability for IoT / A. Luntovskyy, L. Globa. — 2019. — P. 316–321. — 10.1109/DT.2019.8813679.
35. *Globa L.* Fuzzy logic usage for the data processing in the Internet of Things networks / L. Globa et al. // Open Semantic Technologies for Intelligent Systems (OSTIS-2018): International scientific and technical conference proceedings (Minsk, February 15–17, 2018) / V. V. Golenkov, Ed. — Minsk: BGUIR, 2018.
36. *Pankratova N.D.* System analysis: Theory and applications: textbook / N.D. Pankratova; NASU, NTUU "KPI", IASA NASU. — K.: Naukova Dumka, 2018. — 347 p.

Received 20.03.2020

From the Editorial Board: the article corresponds completely to submitted manuscript.