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# ОСОБЛИВОСТІ ПОБУДОВИ МАСИВУ ДАНИХ НА ОСНОВІ НЕЙРОМЕРЕЖІ У СФЕРІ ІНТЕРНЕТУ РЕЧЕЙ ДЛЯ ГОТЕЛЬНО-РЕСТОРАННОГО БІЗНЕСУ

*У статті досліджено принципи формування масиву даних на основі нейронної мережі у сфері Інтернету речей для готельно-ресторанного бізнесу. Було виявлено, що Інтернет речей генерує величезну кількість неструктурованих даних, і аналітика великих даних є ключовим аспектом. Концепція Інтернету речей представляє особливу цінність для розвитку готельно-ресторанного бізнесу завдяки даним, які можна отримати з підключених елементів і гаджетів. Сформульовано дві теореми, які сприяють розкриттю принципу обміну знаннями, які можна взяти із взаємодії людини і комп'ютера. Визначено, що присвоєння назви суб'єкта господарювання має включати слова людською мовою, а не абревіатури, коди чи двійкові відображення. Їх можуть інтерпретувати лише машини, які є технічно більш ефективними з точки зору простору для зберігання даних або пропускної здатності мережі. Розкрито принципи теорії верифікаціонізму та описано шляхи адаптації структури масиву даних. Схематично запропоновано структуру машинних знань, яка представлена стосовно формування масиву даних на основі нейронної мережі у сфері Інтернету речей для готельно-ресторанного бізнесу. Описана структура має три бази знань: гіпотезу, онтологію та параметри. Визначено, що запропонована інтелектуальна база даних масиву може бути застосована в Інтернеті речей у сфері готельно-ресторанного бізнесу щодо автономного обміну та накопичення знань, а платформа, у свою чергу, може використовувати онтології для інтеграції пристрої IoT з інтелектуальними системами. Описано переваги та недоліки моделі. Зазначається, що перевага цієї моделі полягає в тому, що датчики IoT у хмарі можуть навчатися від віддалених датчиків у фоновому режимі, незалежно від затримки мережі підключення до віддаленої програми, а недолік полягає в тому, що затримка мережі може стати вузьким місцем, коли потрібно в режимі реального часу прийняття рішень зростає. Наголошується, що реалізація описаного алгоритму формування масиву даних, а також відповідного інтелектуального середовища дозволить знизити поріг входження розробників у сферу вирішення завдань за допомогою нейронної мережі.*

*Ключові слова: масив даних, штучний інтелект, нейронна мережа, Інтернет речей, датчик, інтелектуальна система, готельно-ресторанний бізнес*

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## FEATURES OF BUILDING A DATA ARRAY BASED ON A NEURAL NETWORK IN THE SPHERE OF THE INTERNET OF THINGS FOR THE HOTEL AND RESTAURANT BUSINESS

*The article examines the principles of forming a data array based on a neural network in the field of the Internet of Things for the hotel and restaurant business. It has been identified that the Internet of Things generates a huge amount of unstructured data, and big data analytics is a key aspect. The concept of the Internet of Things represents a special value for the development of the hotel and restaurant business thanks to the data that can be obtained from connected elements and gadgets. Two theorems have been formulated that contribute to the disclosure of the principle of knowledge exchange that can be taken from human-computer interaction. It is determined that the assignment of the name of the economic entity should include words in the human language, and not abbreviations, codes or binary mapping. They can only be interpreted by machines that are technically more efficient in terms of storage space or network bandwidth. The principles of the theory of verificationism are revealed and the ways of adapting the structure of the data array are described. The structure of machine knowledge is schematically proposed, which is presented in relation to the formation of an array of data based on a neural network in the field of the Internet of Things for the hotel and restaurant business. The described structure has three knowledge bases: hypothesis, ontology, and parameters. It was determined that the proposed intelligent database of the data array can be applied to the Internet of Things in the field of hotel and restaurant business, regarding the autonomous exchange and accumulation of knowledge, and the platform, in turn, can use ontologies to integrate IoT devices with intelligent systems. The advantages and disadvantages of the model are described. It is noted that the advantage of this model is that IoT sensors in the cloud can learn from remote sensors in the background,* *regardless of the network latency connecting to the remote application, and the disadvantage is that network latency can become a bottleneck when the need in real-time decision-making is growing. It is emphasized that the implementation of the described algorithm for the formation of the data array, as well as the appropriate intellectual environment, will allow to reduce the threshold for developers to enter the field of solving problems using a neural network.*

*Keywords: data array, artificial intelligence, neural network, Internet of Things, sensor, intelligent system, hotel and restaurant business*

## Formulation of the problem

Despite the prevalence of Internet of Things (IoT) devices, the lack of adaptive learning machines is becoming an obstacle to the adoption of intelligent IoT systems in the hotel and restaurant business. Currently, there is a lack of research on the principle of forming an array of IoT data that machines can autonomously share when data comes from different industries or case studies. Thus, the question of how machines can autonomously share knowledge from a dataset, create new knowledge and adaptively learn from this knowledge so that it can become applicable in the field of hotel and restaurant business or case studies is relevant.

## Analysis of recent sources

Both domestic and foreign scientists pay a lot of attention to the issue of development, implementation and implementation of the Internet of Things in all spheres of life of modern humanity. In particular, A. Semenog [1] carried out an analysis of the main technologies used in the conditions of the formation of the digital economy, determined their essence, types and methods of practical application. He studied the properties, potential advantages and risks of block chain technology, gave examples of companies that use it. Defined the main elements and hierarchy of the Internet of Things.

Prospects for the development of the Internet of Things and the industrial Internet of Things were cited by I. Sotnyk and K. Zavrazhnyi. The authors proved that the deterioration of the information security of enterprises and organizations is one of the important problems accompanying the development of the industrial Internet of Things. N. Aksak disclosed the methods and models of distributed intelligent processing of big data in specialized computer systems. Describes the basic breakthrough technologies of the modern stage of society's development: artificial intelligence, the Internet of Things, additive technologies using a 3D printer, virtual and augmented reality, new materials, "cloud" technologies, etc. Possible positive and negative effects of the implementation of the mentioned breakthrough technologies are analyzed. K. Balakleets and A. Kvitka paid attention to the relevance of technological trends that have a seismic impact on the economy, values, identity and opportunities for future generations [2-5].

Among foreign authors, it is worth noting the works of such scientists as: Zhang, Weiping & Kumar, Mohit & Liu, Jingqing, Cui, Dan & Liu, Fei, Xiao, Han & Li, Yuanjiang, Changsheng Xiang, ZiYing Zhou, Han Xiao, Yuanjiang Li, Ren Fang, Ma Jian-Feng, Naveen, Dr & Raina, Rohini, Li Hinwu and others. However, in view of the described scientific achievements on the topic, the question of revealing the principles of forming a data array based on a neural network in the field of the Internet of Things remains open and needs to be worked out in detail. Setting objectives. The goal is to investigate the principles of forming a data array based on a neural network in the field of the Internet of Things. Presentation of the main research material. Research that has used big data analytics to solve IoT problems using machine learning techniques can be grouped into four areas, such as: smart city, manufacturing (i.e., agriculture and industrial production), building management, and healthcare [6-21].

## Presenting main material

The domain of smart cities is interested in creating efficient and comfortable daily activities. Some examples include providing optimal traffic routing, predicting the filling pattern of garbage bins for collection, recommending products based on their location, and predicting energy consumption in smart meters. In the case of energy prediction, support vector machines were used to analyze past energy consumption and building environmental data such as temperature and humidity, resulting in predicted energy consumption with a difference of 1.7 kWh between actual and predicted consumption in the time window.

In the field of industrial agriculture, in [14] the authors proposed to identify the symptoms of lameness in dairy cows. Sick cows affect milk production, symptoms of the disease are usually manifested through inactive behavior, for example, lying down for a long time. behaviors such as active, normal and dormant in cows. Random sampling gave an accuracy of 91%, detected 1 day before some visual signs could be observed; and k-nearest neighbors gave an accuracy of 81%, detected 3 days before their symptoms were visible through visual cues. Thus, IoT sensors were placed on cows to collect data on their activity such as lying time and number of steps .

In the field of production, maintenance of machines is of great importance for minimization of production interruptions due to engine malfunctions. Thus, a study [15] proposed a mechanism where 3-axis accelerometers were placed on factory engines to collect vibration data such as the amplitude and frequency of the engines. With the help of neural networks, it was possible to identify malfunctions in normal driving conditions with a level of confidence with 100% accuracy from 80 to 99 percent.

Building management can be seen as a domain connecting the smart city and production domain, as their solutions can be applied to both domains. A study [16] predicted building occupancy levels by observing temperature, $CO_2$, air volume and air conditioning data. Random sampling was used to classify the data and gave 95% accuracy in predicting the occupancy rate of the rooms in the building.

The health domain may be the most common application as IoT devices are attached to individuals. Applications predict sugar levels to treat diabetes, assess the level of thermal comfort in the workplace, and detect falls at home. Also, deep learning is used to detect such cases of ambulation as abnormal walking patterns, sleeping habits and visits to the toilet. The app offers a real-time solution to detect abnormal health risks using devices such as heart rate, respiration rate, etc., and has given an accuracy of 94%. Such a solution can be considered as a smart home application, as it also helps to increase the efficiency of daily activities (for example, providing a cyber guardian for the elderly).

How humans can interact with websites can show how machines should interact with other machines. The most important property of a website is that its presentation can be understood by people. Users can semantically navigate websites to achieve the goals necessary to complete a task. Websites are made up of words in a language that users understand. In addition, website layouts are arranged in a meaningful structure that reflects their "informational slant," so users can navigate naturally to find the information they're looking for.

There are two characteristics of knowledge sharing that can be taken from human interaction – computer:

Theorem 1. Naming the entity (that is, the object, properties, relations and services) must use words that are understandable to a person.

Theorem 2. Information should be arranged semantically in such a way that so that it allows a person to derive meaning by following its structure.

The assignment of the name of the business entity must use words in human language, not abbreviations, codes or binary representation that can interpret only machines, despite the fact that the latter are technically efficient niches in terms of data storage space or network bandwidth.

In the organization of information, the semantic use of ontologies is the very model.

It allows people to get information based on semantic queries. Philosophy of knowledge, or epistemology, provides a breakdown of how a person acquires knowledge. Fundamental in this field is "a priori" and "a posteriori" knowledge. A priori is obtained through definitions such as the classification: apples are fruits. And the a posteriori is obtained thanks to experience and observations, for example, apples are red.

Deviations from the above definition are also used for description of ideas and human understanding. A priori and a posteriori description of knowledge is parallel to primary and secondary quality in human understanding. A primary quality includes properties of an object that are independent of the observer, such as an apple having weight, size, and color. A secondary quality refers to some property of the object according to the observer, for example apples are red.

Primary knowledge is embedded in ontologies, such as the definition "If the soil is moist, the crops will flourish." Secondary knowledge is derived from IoT sensors such as “soil dry”. The resulting knowledge builds upon the findings, assuming what else serves as an indicator for crop prosperity, such as sunlight and fertilizer. Secondary knowledge can become primary knowledge when the quality it describes can be generalized. Similarly, when inventive knowledge (such as a hypothesis) has been scientifically proven, the parameters it describes become secondary knowledge. This is consistent with the theory of verificationism [17], which serves as the basis for the proposed system of machine knowledge regarding the formation of a data array.

The structure is adapted from the theory of verificationism, which provides a breakdown of scientific methods. This is a school of thought where knowledge is obtained as a result of experimentally verified observations. Since society developed by of this scientific path, its framework for acquiring knowledge through observation can be borrowed for the design of autonomous machines for learning.

The framework describes how IoT sensors can autonomously exchange knowledge with other sensors. It consists of three databases, namely the Ontology, Parameters and Hypotheses databases. When sending data from IoT sensor databases, services are labeled according to primary, secondary, or invented knowledge levels. IoT sensors share knowledge through advertising and service discovery with other IoT sensors.

The Ontology database contains inference rules. It takes rules either directly from other sensors of the Internet of Things as Primary Knowledge, or from an established ontology definition, or from its parameter database.

The Parameters database contains name-value data pairs. It accepts values either from IoT devices as secondary knowledge or from its database of hypotheses. Secondary knowledge can become primary knowledge after checking the rules in the database through some inductive learning. A family of machine learning techniques such as rule learning, classification, and Bayesian inference can be used for inductive learning.

The Hypothesis database contains untested inference rules. It takes rules either directly from other IoT sensors, such as Invented Knowledge, or from any Ontology definition or from its Ontology database. Invented knowledge can become secondary knowledge after some observations of values conforming to a distribution or pattern. Statistics can be used to observe the distribution of data.

The Hypothesis database also learns from the Ontology database. The original knowledge from the Ontology database can become the invented knowledge after generating the rules using abduction techniques. For example, given the rule "apples are red," the rule attempts to infer whether an object is an "apple" when "red" is observed. In this system, abduction is triggered when the observed chewable quantity (ie red) does not yield a class result (ie apple).

When creating rules, the system implements the two theorems discussed earlier. First, it uses natural language processing to understand human speech. Natural language can find synonyms, homonyms and word categories. In "apples are red", natural language reveals that "red" is a color and "apple" is a noun. So she wants to find other nouns, so she creates a rule like "(noun) is red." The use of natural language in this process implements Theorem 1.

Second, the platform exchanges ontologies with other IoT sensors. Ontologies are built in such a way that the rules of inference are understandable to humans. Although IoT sensors are machines, the structure of ontologies must convey meaning.

The proposed intelligent database can be applied to various IoT industries (i.e., smart home, farming, smart city, and healthcare) for autonomous knowledge sharing and accumulation. However, the proposed framework does not address how IoT devices can learn adaptively in a constrained environment.

The platform can use ontologies to integrate IoT devices with intelligent systems. Choosing any model involves evaluating how critical the application is. For example, when considering the right model for a remote, mission-critical application, one can accept the availability of resources in the cloud, provided that network latency and network availability requirements are optimized for the remote application. The advantage of this model is that IoT sensors in the cloud can learn from remote sensors in the background, regardless of the latency of the network connecting to the remote application. The downside is that network latency can become a bottleneck when the need for real-time decision making increases.

The framework addresses the current gap in the reuse of ontologies across domains by requiring the use of human language to name entities and relationships. Despite the fact that the system solves the current problem of reusing ontologies, it accepts an imperfect definition of intelligent systems. The intelligent objects in the case study are aware of and respond to changes in their environment, actively make decisions and communicate with other intelligent objects, and help others. In addition to this, strong artificial intelligence includes the manifestation of emotions and desires, the formation of a personal character when it gets into different situations. However, there is little debate as to whether IoT systems should exhibit a strong AI character, or whether this could be counterproductive. Hence, holistic frameworks offer new insights into intelligent IoT systems.

The convergence of IoT and big data analytics has created enormous opportunities. Machine intelligence based on IoT data has brought the cyber and physical worlds together and greatly improved to explore real-world problems from a cyber-physical perspective. The efficiency and reliability of processes and systems have improved significantly. System operators now have better monitoring and control over their systems and processes, and business intelligence people better understand their challenges and make informed decisions. While the convergence of machine intelligence and the Internet of Things has opened up many opportunities, there are several challenges that are holding back their growth.

Machine learning algorithms rely heavily on IoT data generated and transmitted from IoT devices to improve decision-making. Within IoT, different layers of IoT, such as perception layer, transport layer, and application layer, are vulnerable to cyber attacks. For example, malicious code injection, node spoofing, impersonation, speech-in-service attacks, routing attacks, and data transit attacks are some examples of cyber attacks in the IoT system model. To protect an IoT system from these cyber threats, it is important to have a proper trust management system in place. IoT devices themselves require proper attention as most devices do not have adequate security mechanisms.

First, users can add security solutions at any time in a traditional IT scenario; however, most IoT devices do not have security solutions, while others have built-in security solutions, and most devices do not support additional security patches, solutions, or updates later after the devices are manufactured.

Second, due to low memory and processing limitations, only simplified algorithms.

Third, a wide variety of devices are used in an IoT environment. Because of this heterogeneous nature, security risk is increased by the integration of different device types, technologies, and vendors.

Fourth, the IoT application layer suffers from privacy issues. Leakage data and data eavesdropping can have potential consequences. Fifth, IoT communication protocols are also vulnerable to cyberattacks and threats, including data-in-transit attacks, routing and DoS attacks, key management issues, high computational cost, and lack of user control over privacy.

IoT applications will require faster processing and decision-making, bringing data processing closer to the consumer. Sending data to the cloud takes time and a lot of bandwidth. Analytics at the IoT edge has therefore opened up the possibility for future impacts.

One of the reasons for this trend is that the use of sensors is widespread in many areas of life and business, such as vehicles, manufacturing and healthcare, creating continuous streams of data. This large amount of data becomes the raw material for businesses and governments to gain insights and new knowledge using machine learning techniques. The motivation includes competing or creating better policies when there is enough data, which gives rise to the urgency of learning from data.

Another driver is the convergence between IoT and critical infrastructure due to their demand for mission-critical applications. Data is processed closer to the consumer when low latency is critical. The current trend is that trivial programs tend to become critical or can be redesigned to support critical programs.

The challenge against this trend is that edge devices (such as mobile devices) tend to have lower computing capabilities than the cloud data center. On the other hand, machine learning data analysis requires high computing power and storage. In this context, the proposed machine learning system in the IoT environment can solve this problem. Her future work may include exploring a federation of knowledge-sharing edge devices. An edge device equipped with the highest computing performance can handle data processing tasks. The edge device that has the most bandwidth can communicate with the cloud to offload its computing tasks.

IoT technologies have enabled the platform to communicate between a large number of connected sensors and sensors. When mission-critical applications and end users require a large number of interconnections, scalability becomes an issue that must be addressed. For example, large amounts of data need to be distributed across multiple end devices, where the devices simultaneously solve computational problems. So, distributed machine learning algorithms with edge computing are a potential solution. This enables computational decisions to be made at the edge, which is closer to IoT devices.

Advances in human language research will help improve machine learning tasks in a distributed system. Human language puts context behind data values, allowing connected IoT devices to collaboratively label their data, learn from other devices, thereby introducing distributed machine learning to solve computational problems.

In hyperconvergence, storage is shared among a large number of distributed nodes, and their combined performance helps solve the problem of resource sharing.

## Conclusions

The paper examines the principles of forming a data array based on a neural network in the field of the Internet of Things. IoT devices are limited in computing and communication resources, which is a bottleneck in the development of adaptive intelligent solutions using machine learning techniques. The formation of a data array based on a neural network is based on taking into account the semantics of the tasks being solved, which makes it possible to make the solution of these tasks more structured and transparent for the user, as well as to make additional adjustments to the process of learning the neural network and solving tasks. The implementation of the described algorithm for the formation of the data array, as well as the corresponding intellectual environment, will allow to reduce the threshold for developers to enter the field of solving problems using a neural network.

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