Challenges of Application of Invisible Artificial Intelligence Technologies in the Industrial Internet of Things

Gennady Dik[1,2,5(✉)], Alexander Bogdanov[1], Aleksandr Dik[1,2,5], Jasur Kiyamov[1,3], Egor Savkov[4], Aleksandr Shchegolev[5], and Aleksandr Aleksandrov[6]

[1] St. Petersburg University, St. Petersburg, Russia
{a.dik,a.v.bogdanov,z.kiyamov}@spbu.ru, g.dick@systechnologies.ru
[2] St. Petersburg LLC "System Technologies", St. Petersburg, Russia
[3] Samarkand Branch of Tashkent University of Information Technologies, Samarkand, Uzbekistan
[4] Consern Avrora Scientific and Production Association JSC, St. Petersburg , Russia
[5] St. Petersburg State Marine Technical University, St. Petersburg , Russia
[6] JSC "Research Institute of Technical Sciences" "SINVENT", St. Petersburg , Russia

Abstract. The main problems and the possibilities of using artificial intelligence (AI) technologies in the industrial Internet of Things are considered, and the use of invisible intelligence technologies in an industrial environment (Industrial Invisible Intelligence, III) is analyzed. The article put forward the concept of building of an industrial framework in the form of a set of tools and libraries for fast and efficient software configuration, as well as the subsequent selection of the optimal composition of the AI models used in a particular production.

Keywords: artificial intelligence · Industrial Internet of Things (IIoT) · smart manufacturing · infrastructure of industrial smart systems · Technologies of invisible intelligence of the industrial environment · AI models

1 Introduction

Today, with the introduction of advances based on the Internet of Things (IoT), cloud technologies (Cloud), and Big Data (Big Data) in intelligent industrialization, the industrial Internet of Things is becoming an increasingly relevant topic for modern business, the public sector, and almost any manufacturing sector (Fig. 1). At the same time, the ever-growing volume of data, periodic changes in information processing methods, and an abrupt increase in the number of IIoTs in the "Smart Production" dictate the need to update the concept of building the infrastructure of modern industrial entities [1].

A modern enterprise is constantly facing a multitude of external and internal challenges. External challenges are primarily related to the ever-increasing competition, rapid changes in market conditions or new technological requirements.

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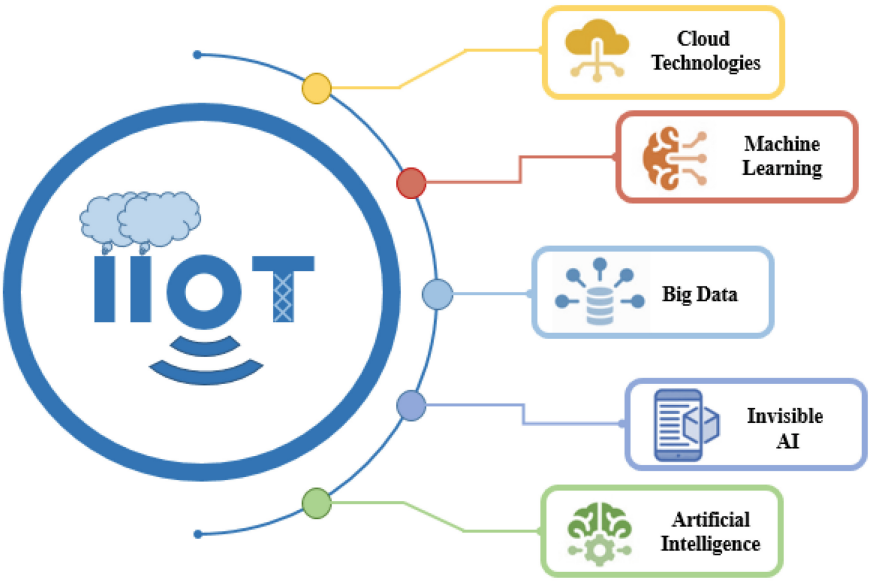


Fig. 1. New technologies in IIoT.

At the same time, internal problematic issues (hazardous production, lack of control over energy consumption and other resources, constant shortage of qualified personnel, suboptimal logistical movement, inadequate maintenance and repair, as well as insufficient automation of decision support, etc.) are dictated by increasingly complex production processes and, as a result, it is a big price of mistakes in any segment of industrial production [2,3].

At the same time, we have shown that by using of AI-based technologies, there is a real opportunity to obtain powerful tools for automating production processes, which will allow any enterprise from commercial to government to operate much faster, more accurately and reliably, and therefore more efficiently [4].

Thus, taking into account the relevance of the above-mentioned topics, we consider the issues of the introduction of AI technologies in the enterprise with a focus on the use of invisible intelligence technologies in an industrial environment with a wide range of IIoT applications [5].

2 The Relevance of the Use of AI as Part of the IIoT in the Enterprise

Automation in production is not just a trend today, but an urgent necessity for any organization seeking to maintain a competitive advantage and ensure sustainable growth. In the era of digitalization, when the speed of decision-making and their quality directly depend on the efficiency and accuracy of information

processing, automation is becoming a key factor in the success of any modern enterprise.

The main purpose of business process automation is to minimize manual labor, eliminate errors caused by the human factor, and accelerate production operations [6]. This is achieved through the widespread implementation of IIoT using specialized software as part of various kinds of "smart devices" that allow automating not only routine repetitive processes, but also optimizing project management, resources, customer bases, complex device assembly, and much more. As a result, the company gets the opportunity not only to reduce costs, but also to significantly improve the quality of its services or products [7].

The role of AI in automation issues lies in the fact that its application allows (Fig. 2):

1. Reduce decision-making time during production. The implementation of AI-based algorithmic solutions, including using trained mathematical models, will allow for rapid analysis and calculations on large amounts of data, which ultimately creates almost continuous real-time management.
2. Reduce the chance of errors. The presence of AI in automating decision-making and improving the accuracy of calculations leads to the partial elimination of the human factor and reduces the risk of errors in decision-making. In addition, interactive prompts generated by the invisible intelligence system will ensure the necessary level and correctness of work, compliance with safety requirements, especially when performing dangerous types of work, etc.
3. Improve the quality of production operations. Intelligent AI control will provide maximum assistance in the automated production of any type of work from an office to a large industrial enterprise, from design to construction, installation and commissioning, which as a result will improve the quality of both the production operations themselves and the decisions made.
4. Ensure consistency. AI in the automation of production operations helps to maintain uniform standards and approaches, which is especially important when performing related types of work.
5. Optimize resources. The use of AI in automating the management of production operations leads to the most efficient use of industrial and human resources, as well as reduces costs in the field of IIoT application.
6. Improve the safety of IIoT applications. The use of various methods for detecting anomalies in the behavior of IIoT during production operations makes it possible to bring both technical (emergency prevention) and information security (attempts to introduce malicious influence, theft of information, etc.) to the required level.

It should be noted that this is not a complete list of the possibilities of using AI as part of IoT in an enterprise. Further, we present the results of research on this topic, concerning the choice of AI models for the application of invisible intelligence technology in an industrial environment. In addition, the article will address problematic issues of technological security threats related to equipment failures, low technology, physical wear and tear of equipment, personnel

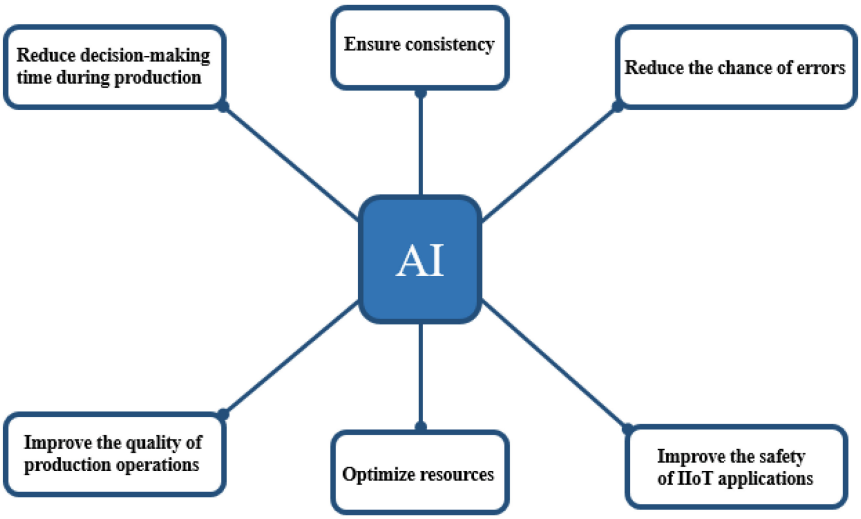


Fig. 2. Significance of AI in automation issues

errors, late or poor-quality maintenance, as well as problems with the use of new equipment and technologies, etc. [8].

To implement the above-mentioned innovative features, it is necessary to include them in the automation infrastructure (an application option for "Smart Manufacturing" is being considered) separate software components and modules that implement the corresponding functionality. At the same time, various types of automation systems should be taken into account, from ERP (enterprise resource planning) to MES (manufacturing execution system, production process management system) with the inclusion of IIoT devices in the control loop for collecting, transmitting and processing information (Fig. 3) [9,10].

3 Application of Invisible Intelligence Technology in an Industrial Environment

Ambient Invisible Intelligence (AII) is increasingly effectively and imperceptibly entering our lives. It is known that a number of technologies used to operate in the background ("invisible" to external manifestation) mode. This new paradigm is referred to by the term "ambient invisible intelligence", in which the intelligent infrastructure on IoT devices is built in such a way as to provide functionality with maximum convenience and minimal staff intervention. Unlike traditional technologies, AII does not require interaction with a tangible interface (voice commands, screen, keyboard, graphic manipulator, etc.), and it shows how such innovations can empower people while remaining virtually invisible and proactive

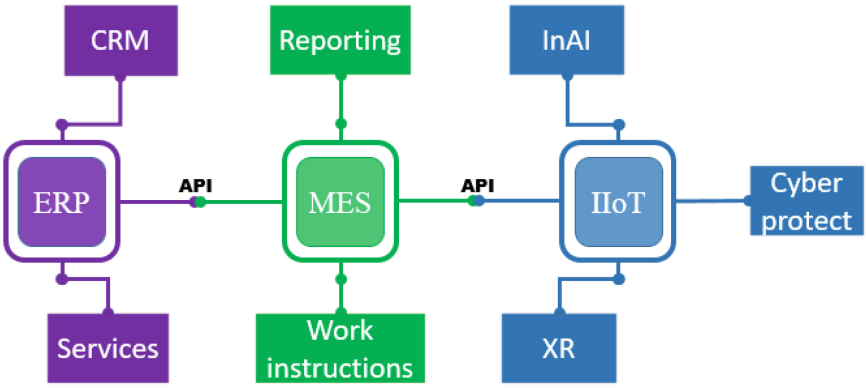


Fig. 3. Interaction of various types of automation with IIoT

Currently, AII form the basis of environments and systems that seem natural, end-user-oriented, and easily integrated into everyday life [11]. At the same time, the basic principle of construction should be simplicity, when devices are designed in such a way that they work without distracting attention, making interaction easy and intuitive. This paradigm paves the way for transformative innovations in areas such as smart living, education, healthcare, industry, etc., demonstrating the potential for optimizing and improving everyday production processes. Therefore, a wide practical application of AII can be found in climate control or Smart Home lighting. The most common example is the control of a thermostat, which adapts to the user's habits, remembers the preferred temperature settings and automatically determines the climatic conditions, thus eliminating the need for periodic manual data entry. Another everyday use case is adaptive lighting systems that adjust brightness and turn on (off) depending on movement and natural light, while there is no need for traditional switches and, as a result, the energy efficiency of the facility increases

Ensuring the continuity of operation and economical power consumption of IIoT devices as part of the AII is possible due to:

1. **Organization of information transmission** via low-power wireless communication such as Bluetooth, 5G, LoRaWAN, (widely used for switching various IIoT) and Wi-Fi (transmission of large amounts of data such as high-resolution images or video streams). In addition, the use of wireless Backscatter communication with backscatter is becoming more promising. This innovative technology allows devices to receive energy from radio waves (in particular, Wi-Fi) as a power source, providing long-term and energy-efficient communication.
2. **Energy storage** through the use of energy from external sources such as light, vibration, or radio frequencies (without recharging), which helps to extend service life, reduce maintenance costs, and improve environmental friendliness.

3. **The use of an IoT element** based on advanced chips/microprocessors with low power consumption, low-power cost-effective sensors and energy-efficient memory.

The study noted an increase in the degree of application of III (AII in the industrial sector) in such areas of industrial production as data analytics, resource optimization, preventive maintenance, ensuring various types of safety, proactive monitoring, emergency response, management through cognitive digital counterparts of objects and devices, as well as optimizing the movement of machines and mechanisms on the territory of the enterprise, including ensuring their interconnection.

Below are examples confirming the active use of III in the composition of IIoT:

1. Intellectual protection in the hazardous area of production by tags in clothing items (determining the location of employees and warning of danger).For example, clothing manufactured by the British company Eleksen for railway workers is capable of sending signals about the movement of trains, monitoring the health indicators of employees and allowing them to signal for help, as well as their location in transport movement zones (ElekTex technologies).
2. The built-in voice assistants integrated with system III can manage schedules or coordination of work of both employees and several IIoT devices, responding to commands in a conversation. The built-in speech recognition functionality at "NOVATEK STC" allows you to transform oral speech into written speech and enter text into a database; generate reports and send them to specified email addresses; open other corporate applications by voice request, etc.
3. In smart buildings, III-devices monitor energy consumption and regulate lighting, air conditioning, and RM employees to reduce the consumption of electrical resources, as well as costs and environmental impacts. An example worth mentioning is the SRR3 industrial building (Bangalore, India) - a shining example of intelligent synchronicity that ensures employee satisfaction. The integrated smart system controls air conditioning, ventilation, improves comfort and prioritizes renewable sources in the background.
4. Sensors installed in industrial or public premises can detect environmental hazards such as gas leaks, temperature fluctuations, or unauthorized access. Intelligent systems invisible in the environment can automatically manage alerts and initiate corrective actions. "Arm" (NASDAQ: ARM) develops and deploys innovative security foundations that enable seamless and personalized remediation in the environment.
5. In emergency situations (fire evacuation, warning and evacuation management systems, etc.), external invisible intelligence systems analyze real-time data to guide evacuation efforts, notify authorities and provide updated information about the situation, ensuring a quick and effective response. Google's Crisis Response: Google's Crisis Response team leverages AI to provide real-time information during disasters. Their AI-powered tools, such as SOS Alerts

and Crisis Maps, aggregate data from various sources to offer timely updates and resources to affected populations.

6. Virtual copies of real objects or processes, called digital twins, which use data from sensors and sensors installed, for example, on complex technical devices such as an airplane, helicopter, electric train, and others, will allow you to monitor a system or object in real time and predict its behavior. Sensors on such a real object collect data on the condition of individual devices, complexes, and systems (engine, motion and braking control systems, electrical systems, fuel systems, and other systems). This information is transmitted to its computer model or the digital twin of the object, where, using machine learning and predictive analytics algorithms, they predict how the parameters change under different conditions, external influences or the internal state of the devices. For example, Structon's predictive maintenance and fault diagnostics system allows manufacturers to identify conditions that could cause failure and intervene before it happens.
7. In real time, based on data from IIoT, the III-based software system calculates the optimal use of resources and routes for the movement of goods and mechanisms on the territory and inside the warehouses of an industrial enterprise. This direct interaction between vehicles replaces the traditional centralized concept of logistics organization by the teamwork of machines. For example, the AI Team Logistics software, as part of automated enterprise systems, optimizes the movement of vehicles in a warehouse to ensure their interaction.

Similar supporting examples can be continued (various examples together with specific technologies for implementing AI algorithms are given in Appendix 1), but a more detailed examination of production processes shows that the invisible intelligence in the IIoT plays a key role in collecting and analyzing data that was previously quite difficult or expensive to obtain, and given the development of technology, it is now possible to predict equipment breakdowns, optimize production lines, plan resources, and more., as mentioned earlier [12]. At the same time, it is obvious that these technologies are not some kind of new innovative solution for digital production, but the transfer of these technologies to the level of background or invisible intelligence is a new application of AI in IIoT. As a result, the analysis of the prospects for using AII in the industrial sphere carried out by the authors of the article made it possible to form the concept of building a software system using technology invisible industrial intelligence (SST III) for various use cases of IIoT [13–15].

4 The Concept of Building a SST III

Conceptually, SST III is a fragment of an industry framework in the form of a set of tools and libraries for fast and efficient software configuration, as well as determining the optimal composition of the AI models used to solve tasks in production [16].

According to this statement, the version of the framework being developed is designed to solve the following tasks:

1. Formation of the digital twin of the enterprise.
2. Identification of typical production process patterns.
3. Identification of unusual situations, artifacts, anomalies and deviations during various types of work in a digital enterprise.
4. Forecasting based on data (events) collected from the IIoT distributed environment.
5. Identification of explicit and hidden dependencies and correlations.
6. Forecasting taking into account various additional factors of possible external and internal impact.

As a prototype of the SST III, in accordance with the set of tasks to be solved, the authors selected a structure with typical options, consisting of the following software components (SCs) (Fig. 4):

1. SC "MIDDLE Layer" is an inter-platform (middleware) software that includes technological software for implementing and supporting interaction between various applications, systems and software modules (receiving packets or data streams, buffering, validation, normalization, etc.).
2. SC "Creating and editing digital the double of the enterprise".
3. SC "Identification and prevention of emergency situations".
4. SC "Formation of corrective actions".
5. SC "Monitoring and dispatching".
6. SC "Control of reactive, preventive and predictive maintenance".
7. SC "Recommendation generation (voice notification and management)".
8. SC "Ensuring information and technological security of IIoT". The use of various methods for detecting anomalies in the behavior of IIoT during production operations makes it possible to bring both technical (emergency prevention) and information security (attempts to introduce malicious influence, theft of information, etc.) to the required level.
9. DBMS storage of input and processed data and AII models.

The SST III input receives data from various IIoT sensors, digital production automation systems, computerized maintenance management systems (CMMS) and other industrial smart systems in JSON, CSV, PROTOBUF, XML and other exchange protocols supported by the MIDDLE Layer PC.

The input of input PCs for the industry framework is organized through the endpoints of the FastAPI framework.

The developed industry framework uses the following software tools:

- PYTHON, the main programming language of the PC framework, provides the necessary support for AI creation and training methods.
- UVICORN is a library for running a web server in PYTHON.
- FastAPI is a web framework for creating fast HTTP API servers with built-in validation, serialization, and asynchrony.

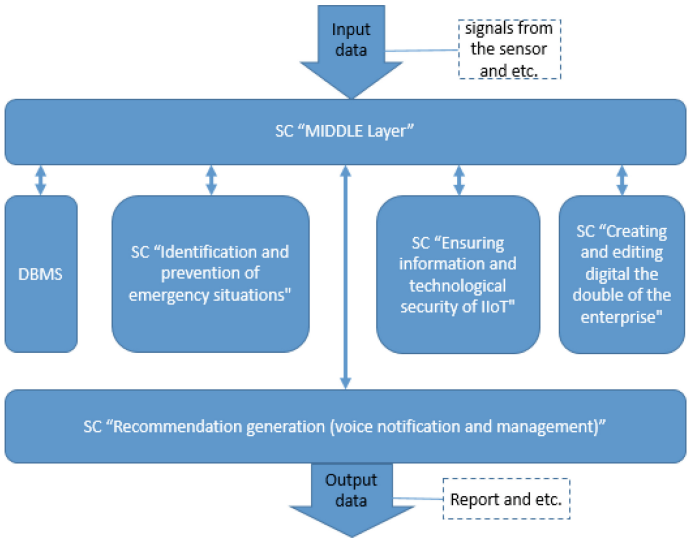


Fig. 4. The block diagram of the SST III prototype

- OpenAPI is a REST web services framework that allows you to test and manage a project without an interface.
- PostgreSQL is an objectâĂŞrelational database management system based on POSTGRES, v.4.2. with the ability to provide a packaging tool and add-ons for the database (DB).

In addition to the above software tools, the developed industry framework uses special software tools âĂŞ libraries of AI methods, which are later used in SST III. In accordance with the capabilities of the framework, the composition of libraries of methods can be supplemented and adjusted depending on the purpose and complex of tasks of the digital enterprise to be solved. Tables 1, 2, 3, 4, 5, 6, 7 and 8 contains a number of algorithms for the framework in question.

The composition of the SST III can be supplemented and expanded depending on the functionality and class of tasks to be solved both in production and in the household sphere.

As a result, among the many possibilities of using artificial intelligence technologies, it is proposed to emphasize the prospect of using invisible intelligence in the industrial sphere. With the help of available libraries and tools, it is easy to set up the environment and create the most optimal solution for the enterprise.

An example of a real implementation of the presented methodology is the implemented prototype of the "Zeus" software system. This software system solves current unification problems in order to improve the management of heterogeneous types (different manufacturers) and devices (different functionality) as part of technical security systems, active use of AI methods to solve problems of ensuring the safety of industrial facilities, as well as maintaining the software

Table 1. Structon's POSS preventive Maintenance and Fault diagnosis system

Tasks	identifies conditions that could cause a breakdown and intervenes before it occurs
Algorithms	Predictive maintenance that uses models to predict failures of specific unit components
Links	https://www.altexsoft.com/blog/predictive-maintenance/
Justification of the choice of algorithms	Speaking of industry, it is necessary to mention the high cost of suspending production, especially in large enterprises. Predictive maintenance eliminates the need to suspend production processes, as it helps to recognize even those minor changes in the condition of equipment that are not detected during a typical inspection. AI-based diagnostic tools allow manufacturers to identify conditions that could cause a breakdown and intervene before it occurs. With the help of machine learning models, manufacturers can predict the remaining service life of equipment and prepare for repairs.

Table 2. Robotic Process Automation Working for Schneider Electric's Global Supply Chain

Tasks	Automation of document preparation
Algorithms	RPA is a robotic process automation software designed to simulate human actions when performing repetitive business tasks
Links	https://www.uipath.com/resources/automation-case-studies/schneider-electric-manufacturing-rpa https://www.altexsoft.com/blog/robotic-process-automation
Justification of the choice of algorithms	The operators responsible for the installation of electrical panels on the territory of customers had to deal with monotonous and voluminous documentation processing, for example, marking electrical circuits or production specifications of electrical panels. To complete this long and tedious task, an AI bot was introduced, freeing up operators' time for more valuable and complex production work.

Table 3. Google Cloud Visual Inspection AI

Tasks	Quality control (QA) and verification of the condition of manufactured products
Algorithms	Google Cloud Visual Inspection AI
Links	https://cloud.google.com/vertex-ai/generative-ai/docs/model-garden/explore-models https://www.altexsoft.com/blog/image-recognition-neural-networks-use-cases
Justification of the choice of algorithms	Human vision has obvious disadvantages (fatigue and bias), therefore, thanks to computer vision control, QA becomes more reliable and accurate. Visual Inspection AI automates the QA process and identifies defects even before products leave the assembly line

Table 4. AI Team Logistics

Tasks	Warehouse automation
Algorithms	Optimizing the movement of all trucks in the warehouse and ensuring their interconnection
Links	https://toyota-forklifts.eu/about-toyota/news-and-editorials/toyotas-a.i.teamlogistics-concept-presented-at-cemat-2018/
Justification of the choice of algorithms	very second, an AI-based software system calculates the optimal use of resources and routes for carriers. This direct interaction between vehicles replaces the traditional centralized warehouse concept with the teamwork of machines. The AI Team Logistics concept transforms redundant warehouse management into productive teamwork

Table 5. Arkellis Technologies

Tasks	A framework for industrial applications.
Algorithms	Development tools for various use cases: training, repair, maintenance, visualization, job introduction, etc.
Links	https://arkellis.com/, https://innovanews.ru/info/innovations/top-10-sovremennykh-tendentsijj-i-innovatsijj-promyshlennojj-revoljutsii-40/
Justification of the choice of algorithms	The framework accelerates production processes by integrating ready-made solutions with data. This allows you to bring a product to market faster and not develop them from scratch on your own

Table 6. SECOM class imbalance âĂŞ solutions to the problem of class imbalance are presented (in data on semiconductor production lines)

Tasks	Working with distorted data and selecting features, focusing on the problem of class imbalance and the ability to successfully predict failures
Algorithms	Random Forest is a machine learning algorithm that uses an ensemble of decision trees. Single—class support vector machines (SVMs) are a type of outlier detection method. SMOTE - synthetic data generation. Gradient Boosting Machine (GBM) is a machine learning method for regression and classification problems that creates a predictive model in the form of an ensemble of forecasting algorithms, usually decision trees.
Links	https://github.com/Meena-Mani/SECOM_class_imbalance?tab=readme-ov-file.
Justification of the choice of algorithms	Random Forest is an algorithm capable of efficiently processing data with a large number of features and classes and containing methods for estimating the significance of individual features in a model

Table 7. Predictive-maintenance

Tasks	Improve maintenance operations and time-based preventive maintenance planning by using data processing techniques and machine learning algorithms to more accurately predict maintenance needs
Algorithms	The sklearn Library: – regression modeling – binary classification – multiclass classification algorithms
Links	https://github.com/Samimust/predictive-maintenance.
Justification of the choice of algorithms	Regression modeling - algorithms for predicting the number of cycles remaining before engine failure. Binary classification algorithms were used to predict whether an engine would fail within a certain number of cycles or not. Multiclass classification algorithms were used to predict in which cycle or period the engine would fail.

Table 8. Iot-predictive-analytics

Tasks	Predicting equipment failures using Internet of Things sensor data
Algorithms	TLogistic regression is a statistical model used to predict the probability of an event occurring
Links	https://github.com/IBM/iot-predictive-analytics.
Justification of the choice of algorithms	Advantages of logistic regression: - simplicity in the implementation and interpretation of the results of the algorithm - high speed operation - relatively good accuracy

used in the current state) due to the capabilities of the built-in framework and rule designer. At the same time, the main attention is paid to the fulfillment of requirements for security and fire measures, control of water leaks and gas leaks, as well as identifying anomalies in electricity consumption using AI (predictive analytics, forecasting and development of recommendations) with the active use of IoT and IIoT at facilities.

At the core of "Zeus" is a framework designed to analyze big data collected from the environment of technical security systems (for example, from distributed sensors) in order to identify patterns, typical data patterns, implicit dependencies, unusual behavior of the system as a whole and, ultimately, to generate forecasts of the state of a given object. It should be noted that the implemented AI-based software tools operate in the background (use option III) to receive data from end devices in order to determine emergency and critical situations (incidents), since the enterprise has a large number of false positives due to the use of classic threshold algorithms.

5 Conclusion

Our task was to show the possibility for a customer from industry or a government structure to choose and create the most suitable option for "Smart Production", while setting up the use of IOT based on III in the background. At the same time, the main problematic issues of the enterprise were considered, to which it is advisable to apply the III.

In addition, in this paper, we propose a version of the methodology for implementing an industry framework using III in an industrial enterprise:

1. Analysis of the infrastructure of a "digital enterprise", identification of production processes for automation, assessment of the availability and capabilities of IIoT, as well as identification of needs for their use.
2. Building a digital twin of the enterprise.
3. The formation of an industry framework as part of a set of AI libraries that can be connected depending on the tasks being solved in the enterprise.
4. Training of the III models included in the industry framework.
5. Installation of trained models into the existing infrastructure of the "digital enterprise", conducting testing and determining the optimal options for further trial operation.

The proposed methodology depends on the purpose, composition, complex of tasks to be solved, the degree of equipment with IIoT tools and other factors related to the planned automation in the digital enterprise under consideration.

The application of the methodology proposed by the authors depends on various parameters of the digital enterprise (purpose, composition, set of tasks to be solved, degree of equipment with IIoT tools and other factors related to the planned automation).

Calculation of the increase in efficiency when implementing the proposed technology is beyond the scope of this article. At the same time, it should be noted that the increasingly widespread implementation of this concept demonstrates the efficiency of the functioning of the components of the Internet of Things due to the automation of routine tasks and optimization of processes in an industrial enterprise, savings due to waste reduction and improved resource management in production, as well as improving various aspects of safety (improving safety protocols, reducing the influence of the human factor, etc.).

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