Development of the production monitoring system based on the Industrial Internet of Things platform

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Abstract. The article is devoted to the results of integrating the industrial Internet of things platform and industrial production into a digital environment. The architecture of a data collection system is shown and ready for its implementation on the PJSC Techpribor and the laboratory of ITMO University. Firstly, we prepared the methodology for modeling three-dimensional scenes and the methodology for generating equipment data models. These methodologies are for the Winnum Industrial Internet of Things (IIoT) platform. Secondly, we indicated the main stages of Winnum platform integration into the enterprise information system in the framework of the described methodology.

1. Introduction

Nowadays all the features of the Industrial Internet of Things (IIoT) platform helps to realize an idea of product tracking during the manufacturing process, as well as collecting data, which determines the transparency at all stages of manufacturing and monitoring processes [1]. Manufacturing management software allows users to control all processes at workshops in real-time. The resulting efficiency and accuracy of manufacturing lines help optimally use all the available resources [2]. Based on the current development of the issue, we have a number of already published ideas and the general definition of the concept has finally acquired specific features. The issue is a manufacture based on a continuous data analysis provided by the Industrial Internet of Things platform [3]. The concept of Industry 4.0 eventually is starting to change the way goods are produced. It combines IIoT technology with basic manufacturing technology and provides comprehensive support throughout the entire product life cycle [6, 8, 10].

Firstly, this paper describes a comprehensive description of the installed IIoT platform, while and shows complete platform integration sequence. Secondly, it suggests the methodology for modeling three-dimensional scenes, then proposes the methodology for generating equipment data models. Finally, the paper is wrapped up with Conclusion which discusses the results of the proposed methods.

2. Industrial Internet of Things platform

We use Winnum system as the Industrial Internet of Things platform. It is an important tool for manufacturers and management [5]. Winnum platform monitors, diagnoses, and optimizes industrial equipment operation modes (in our case, computer numerical control (CNC) machines and other devices) and manufacturing processes. It sequentially reduces release time, costs and risks associated with equipment breakdowns, unforeseen and planned downtime, defects, human factor and other
problems in manufacturing. Data collection goes on at every stage in real time without any human intervention. Further, the received information is analyzed by the overall equipment effectiveness methodology (OEE) [7]. Finally, we have a total modification of manufacturing technologies and processes and more rational use of the material and human resources which are based on monitoring results.

3. The process of integration the Industrial Internet of Things platform.

3.1 Architecture of the IIoT platform

At present, we prepared a platform that combines devices located at the Faculty of Control Systems and Robotics and coordinate-measuring machine with CNC machines at PJSC Techpribor.

The basic architecture of the IIoT platform at PJSC Techpribor and ITMO University you can see in Fig. 1. We install Winnum Platform, which is the main application, on the server at ITMO University. Also, we have there Winnum Cloud storage, based on Apache Cassandra which is storing all the data. Every user has the opportunity to work with the data remotely via the web (client application), which opens up wide possibilities, for example, distance education or working with the platform and all the connected devices. With this solution, students got an opportunity of using laboratory equipment: Adept Cobra i600 robot and Schneider Electric devices. But only authorized staff with the appropriate access, verified by the platform, are allowed to work with CNC machines at PJSC Techpribor. The existing internal firewall and security policies clearly distinguish between the users' rights. HAAS CNC machines, an injection molding machine and a coordinate-measuring machine are connected to the platform at Techpribor.

3.2 Installation and launching the IIoT platform

The stage of the IIoT platform deployment is a part of the global digitalization manufacturing processes. Further, we suggest key stages of Winnum platform deployment and development and the
tasks that are solved at each stage.

The first step is an installation Apache Cassandra on the server. This database management system provides data collection and storage of all the information received during the manufacturing process. Winnum accesses data through a database. Since the storage is a non-relational database, the speed of interaction between data, uploading data, building graphs is much higher than other types [5].

The next step is an installation Winnum Cloud on the server. The application allows managing data stored in the database. The data cloud is the most important component of the system, where data arrives and then is processed. There is unified software required for recording and reading data and interaction with the cloud. However, the key problem, in this case, is a large variety of communication protocols, so we can see incomplete unification. Therefore, partial unification is achieved through the using unified algorithm interacting when connecting devices.

The third step is an installation Winnum Platform on the server. The application generates a data model, interacts with the users and the database. Only after that, we have to install Winnum Connector. The software is a connector and interacts with devices and external applications. It is important to know when we work with heterogeneous devices, one of the most important tasks is to bring different signals into one standard for further analysis, as well as for generating graphs and reports. Then we need to connect CNC machines, devices and equipment for signal transmission to Winnum Connector for further conversion (depending on the communication protocol) and transfer to the database. Winnum supports the following CNC: Siemens, Heidenhain, Fanuc, HAAS, Mazak, Mitsubishi, Balt-System. An adapter converter is added to the platform for compatibility if necessary. The connection is via Ethernet or RS-232/485, MPI / PROFIBUS interfaces with conversion to Ethernet. Also supports communication protocols: ModBus RTU / ASCII / TCP, OPC DA / UA.

The next step is the development of control and visualization interfaces in Winnum Platform for employees who will use the platform. Interfaces are created in various versions according to the needs of specialists and access rights. The platform is equipped with a standard set of functions for data analysis and equipment operation reports. There is also the ability to write and running diagnostic algorithms for any type of equipment.

Only after finishing these stages, we can move to modelling 3D scenes which are the three-dimensional models of the workshops with CNC machines and equipment. All the information of the current state of CNC machine can be displayed in real time on three-dimensional models, increasing the visibility and information content of ongoing processes.

3.3 The methodology for modeling three-dimensional scenes
The three-dimensional modeling technology is especially emphasized as part of the digitalization of manufacturing enterprises. Obviously, the Industrial Internet of Things development leads to supplement 3D models of workshops and equipment with relevant information in real time. Three-dimensional visualization of the workshop takes production analytics to a new level of data visualization since the added three-dimensional models of factory sites change the perception and time of information analysis by specialists. The advantages of three-dimensional representation are obvious: a high degree of visibility, information content, as well as ease of understanding, regardless of specialist competence.

The subsection presents the methodology of modeling three-dimensional scenes of workshops in the Industrial Internet of Things platform. We use both simplified and detailed scenes, which allow us to reflect a wide range of characteristics, both of the product itself, and technological and manufacturing processes. Obviously, three-dimensional scenes are the most informative when they accurately receive the real state of their prototype. In real life, as a rule, processes always proceed somewhat differently than is specified in the documentation, but it is three-dimensional visualization that conveys information about the actual operation of CNC machines.

Let’s introduce the methodology for modeling three-dimensional scenes and list the steps we go through. Firstly, we add or create 3D objects and do it in several ways. We can create geometric primitives, to create geometric objects by programming, to load geometry in a neutral format (STL,
VRML, OBJ, Blender, Collada and JSON) from the other computer-aided design (CAD) software. As a rule, we develop 3d models of CNC machine with CAD. The example in Figure 2 was made in Siemens NX 10 and then imported to the platform.

![Figure 2. Willemin Macodel 508MT (a) and a 3D model of Willemin Macodel 508MT at the Winnum scene (b).](image)

At the next step, according to the methodology, we have to receive data from the CNC machines transmitted in the signals and make a connection between the three-dimensional model and the equipment. We write codes in Javascript which arrange and change objects on the three-dimensional scene. These codes are used for modeling behaviour of all the available three-dimensional objects of the scene. It is worth mentioning that anywhere in the code there are global functions: start, stop, init, update; and global variables: renderer, scene, appid.

We show the color indication on the scene as a result of combining the developed 3D models with the scripts for them. The color indication conveys a visual image of the current state of the CNC machine. It shows a dependence of the functions responsible for certain parameters of the machine to a certain color, tied to a three-dimensional model on the scene. For example, green means “working”, yellow means “on”, red means “accident” showed in Figure 3.

![Figure 3. Color indication of the three-dimensional scenes.](image)

### 3.4 The methodology for generating equipment data models

It is important to provide the data models of equipment (equipment templates) to the platform. After that signals coming from equipment will be processed and displayed by the platform. The data model describes all of the components of the CNC machine and signals associated with them. The platform library is not able to describe all available existing equipment, such as, for example, Schneider Electric equipment. Therefore, there was an issue to develop the methodology to simplify and formalize the process of creating templates for Winnum platform.

The data model consists of a hardware template, patterns of individual components of the
equipment, and patterns of data objects and signals. The top level of the data model is a hardware template that describes a real or virtual device and displays objects in the user interface. The data object template is included in the equipment template and describes one or more interconnected signals. The signal is associated with the template of the data object and is used to describe the real signal. When we finished with templates, we link templates of data objects with the parent equipment templates. As a result, we generate the data model.

It is necessary to highlight all the key stages of the methodology. The first step is creation of the equipment data model (template) structure and also of device templates, data objects and signals. For example, we have several types of signal: regular signals which are using for standard data types; irregular signals which are using for memory; files are using to receive and to transmit binary data streams. The second step is creation a virtual image of the equipment and setting the parameter value: setting the serial number, location folder, description of the model. The third step is the connection to the existing equipment and setting up equipment connected via a connector corresponding to this type of device. As result, we provide equipment connected to the cloud: we select encryption algorithm for data; we note IPv4, IPv6 – IP address of the equipment and the interval of data transmission from the equipment to the cloud. The last step is distribution the equipment between applications of the IIoT platform: Winnum OEE – automatic control and tracking, Winnum CNC – remote monitoring and diagnostics of CNC equipment, Winnum MSE - remote monitoring of assembly, measurement and test production equipment.

4. Conclusion

As result, we finally approved and tested the methodology for modeling three-dimensional scenes [13]. Then, based on the proposed methodology, we modeled scenes of three workshops with CNC machines for two instrument-making plants in St. Petersburg and Krasnogorsk. Based on the results, we suggest the main conclusion that the methodology for modeling three-dimensional scenes based on Winnum platform is applicable in practice and can be the next step to integrated manufacturing digitalization in order to create smart digital production. Also, we introduced the methodology for generating equipment data models.

We concluded that implementation of the industrial Internet of things in practice is necessary to comprehensively change the existing approaches to the development and operation of automated information management systems. Winnum platform functions at PJSC Techpribor and ITMO University. However, morally obsolete manufacturing lines as a whole are not upgradeable, and therefore must be replaced by new, robotic and automated equipment. During the installation of the platform, we encountered many problems related to old equipment. The problems were old equipment without modern communication protocols, unable to connect interfaces. Moreover, we consider that in the transition to the ecosystem of the industrial Internet of things, a complex transformation of manufacturing (companies) from isolated systems is needed into open cross-industrial systems based on the cloud services principle.

As a recommendation, it is also necessary for the IIoT to create functioning ecosystems that could cover not only retrofitting and modernization of equipment, as well as installation of modern management systems but also optimization of manufacturing processes, training and retraining of personnel, close work with suppliers, customers and other participants in the production process [11, 12].

Returning the topic of cloud storage, we can get all the necessary information about the current state of all the available resources at the company, such as electricity, machine tools and industrial equipment, raw materials and vehicles, was available, both: to the company and the partners. Such a relationship scheme can be implemented by cloud technologies, by connecting all the devices and systems to protected cloud storage; it can be implemented through the mechanism of open application interfaces – Application Programming Interface (API) [10, 11, 12].

An effective strategy for building an industrial Internet of things should be based on the consolidation of data in cloud storage received from existing but disparate systems using high-level
analytics algorithms. And we accept that decisions based on predictive analytics allow transforming the workflow, such as replacing a manual start (which faced only when the problem diagnosed) with an automatic start warning a dangerous situation [7]. This approach avoids downtime, and also increasing safety and productivity. Moreover, it becomes possible to monitor what happens at the manufacturing lines, regardless of their remoteness.

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