Service Innovation of Industrial Big Data Based on Industry 4.0 Architecture

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Abstract. The service innovation based on the cyber-physical system is a trend in the future manufacturing industry. In this article, the servicing functions involved in the manufacturing industry under the environment of industrial big data were analysed. In addition, the combination of the needs, environment and services of industrial big data were described. Furthermore, the intelligent forecasting tools to manage industrial big data, increase the transparency of industrial production, and improve work efficiency were proposed to adopt for the application of service innovation.

1. Introduction

With the development of informatization and networking, especially with the approach of the Industry 4.0 era, the high-tech enterprises are facing increasingly fierce business competition. To improve the production efficiency, many companies must face how to use industrial big data and how to manage industrial big data. A large number of software and intelligent integrated systems are embedded in the Industry 4.0 system based on the Cyber-Physical system by the promotion of the German government. These intelligent algorithms that connect electrification and intelligence are used for product performance prediction, independent management, and product service optimization [1].

Two key points of intelligent factory are the optimization and intellectualization of control center. Intelligence includes not only the performance of the machine itself, but also the interaction and integration. The peripheral system is directly related to the specific machine, so as to obtain more intelligence, transform ordinary equipment into intelligent machine with self-awareness and self-learning ability, and improve the overall performance. The problems of interaction between machine managers and operators need to be solved to transform ordinary industrial equipment into intelligent machines. The problem of data and information can be obtained by sensor and controller networks [2].

The data management and distribution in a big data environment is the key to realizing machine self-awareness and self-learning. Cloud computing can provide more flexible calculation methods. However, how to achieve the efficient management of big data requires further research and development of feasible forecasts and management algorithms. The current data processing services are far from meeting the modernization needs of Industry 4.0 factories under the environment of the upcoming big data. The establishment of self-perception and machine self-maintenance system based on industrial big data analysis, and the integration of the big data environment into the traditional manufacturing system will help realize the traditional manufacturing industry moving towards Industry 4.0.
2. The demand for industrial big data

The development of information automation promoted the early mechanical system to a high level of automation. In the concept of Industry 4.0, the information technology and social media networks determine product innovation, product quality, product type, delivery speed, and consumer perception. The main components of Industry 4.0 include timely adjustment of production, realization of self-awareness, self-prediction, self-comparison, self-reconstruction, and self-maintenance of machinery and equipment. The advantages of big data environment and cloud technology are integrated, forecasting functions are improved, and intelligent management of information are realized through service innovation and application [3].

At present, to maintain the manufacturing industry’s leading position in the world, the traditional manufacturing powers such as Germany and other advanced countries are trying to adjust their economic structure and reform the original manufacturing operation model to respond to the threats of emerging countries, emerging markets, and global supply chains. Some major manufacturing countries such as China and India that are catching up are also actively upgrading their traditional manufacturing industries to respond to the challenges brought by the technological revolution. Information-based manufacturing companies not only need to seek innovation in manufacturing technology, but also begin to pay attention to the service industry formed in the manufacturing industry chain. The fuzzy boundary between manufacturing and service industries will drive and stimulate the development of manufacturing towards service [4]. The traditional industry faced the problems of no cost advantage, difficult data resources, backward information technology [5]. Thus, the demand for industrial big data is urgent.

2.1. Difference between industrial big data and Internet big data

Industrial big data is the intersection of big data and intelligent manufacturing. Industrial big data refers to the data generated in the information application of the whole life cycle of industrial products. Based on the network interconnection and big data technology, the industrial big data runs through all aspects of industrial design, process, production, management, service, etc., making the industrial system have intelligent functions such as description, diagnosis, prediction, decision-making and control. Compared with internet big data, the industrial big data is more professional, relevant, process oriented, time-series and analytic. The differences between them are shown in Table 1.

| Classification | Industrial big data | Internet big data |
|----------------|---------------------|-------------------|
| Requirements   | Comprehensive sample data, high timeliness requirements. | A large number of sample data, low timeliness requirements. |
| Feature extraction | Pay attention to the physical meaning behind features and the mechanism logic of correlation between features. | Relying on statistical tools to mine the relationship between attributes, not to the specific meaning. |
| Means of analysis | Data modeling and analysis are more complex; algorithms in professional fields are needed, and algorithms in different industries and fields differ greatly. | Mature data mining algorithm; ignoring attribute meaning and values mining, and finding intrinsic value from seemingly unrelated attributes. |
| Application area | Health diagnosis, fault early warning, working condition identification, market forecast. | Image recognition, speech recognition, semantic analysis, preference recommendation. |

2.2. Sources of industrial big data

All the source of industrial big data, the use of equipment in various links, and industrial information are linked with market facilities, manufacturing, service manufacturing, etc. Each link has a large
amount of data, internal changes, customer demand, competitor national policy, important source of industrial province and a wide range of sources. Industrial big data is characterized by high data value density and various data types.

2.3. Extremely complex relationship and correlation of data
At present, the core and key problem to be solved is to face the characteristics of big data and transform the ability of big data analysis. The available measures are to generate transformation, transformation diagnosis, industrial Internet, industrial analysis and supply chain analysis and optimization. The complex relationship and correlation mainly reflected in industrial R & D, design and manufacturing, operation and management, and the creation of intelligent engineering [6].

3. The environment of industrial big data
Big data has been widely used in many recent occasions as a buzzword. The big data currently used is mainly concentrated in the social and commercial fields including sales forecasting, user mining and clustering, opinion mining, etc. The big data involved mainly comes from "human-generated or human-related data" instead of "data generated by machines (industrial data)". The machine data involved comes from machine controllers, sensors, and manufacturing systems. In the Industry 4.0 era, the close integration of intelligent analysis and the Internet will transform the existing production management and equipment operation methods. A large amount of industrial data during the operation of the machine are stored and extracted in time by sensors and other devices, and it can also mine the historical data generated by the machine. All data are merged and integrated into "big data". The transformation platform converts massive amounts of big data into information. The transmission and integration platform, predictive analysis and visualization tools form a complete conversion platform. After a large amount of big data is intelligently refined, a small amount of information is transformed into useful actual processing information, which is the key to the Industry 4.0 factory [7].

With the deep integration of informatization and industrialization, information technology has penetrated into all aspects of the industrial chain of industrial enterprises. Bar code, two-dimensional code, RFID, industrial sensors, industrial automatic control system, industrial Internet, and other technologies have been widely used in industrial enterprises.

3.1. Acceleration of product innovation
The interaction and transaction behavior between customers and industrial enterprises will produce a large amount of data. Mining and analyzing these customer dynamic data can help customers participate in product demand analysis and product design and other innovative activities, which are contribute to product innovation.

3.2. Fault diagnosis and prediction of product
Fault diagnosis and prediction can be used for product after-sales service and product improvement. The introduction of ubiquitous sensors and Internet technology makes the real-time fault diagnosis of products becomes reality. While the application of big data, the modeling and simulation technology makes the prediction dynamic possible.

3.3. Big data application of industrial Internet
Thousands of small sensors are installed in modern industrial manufacturing lines to detect temperature, pressure, heat, vibration and noise. Because the data is collected every few seconds, many forms of analysis can be realized by using these data, including equipment diagnosis, power consumption analysis, energy consumption analysis, quality accident analysis (including violation of production regulations and parts failure), etc. In terms of production process improvement, the application of these big data in the production process can analyze the whole production process and understand how each link is implemented.
3.4. Optimization of industrial supply chain
At present, big data analysis has become an important means for many e-commerce enterprises to enhance the competitiveness of the supply chain. For example, Jingdong Mall, an e-commerce enterprise, analyzes and forecasts the demand for goods in various places in advance through big data to improve the efficiency of distribution and warehousing, and ensure the customer experience of the next day's delivery.

RFID and other product electronic identification technology, Internet technology and mobile Internet technology can help industrial enterprises to obtain the complete big data of product supply chain. The application of these data will bring about a substantial improvement in warehousing, distribution and sale efficiency and a substantial decrease in costs.

3.5. Sales forecast and demand management
The current demand change and combination form are analyzed through big data. Big data is a good sales analysis tool. Through the multi-dimensional combination of historical data, the proportion and change of regional demand, the market popularity of product categories, the most common combination form and the level of consumers are to adjust the product strategy and distribution strategy.

3.6. Production planning and scheduling
The refinement of data, automatic timely and convenient collection and variability lead to the dramatic increase of data under the condition of production mode of multi variety and small batch production. Big data can give us more detailed data information, discover the probability of deviation between historical forecast and actual situation, consider capacity constraint, personnel skill constraint, material availability constraint, tooling and mold constraint, formulate pre planning scheduling through intelligent optimization algorithm, monitor the deviation between plan and actual situation, and dynamically adjust planned production schedule.

3.7. Product quality management and analysis
The traditional manufacturing industry is facing the impact of big data. In product research and development, process design, quality management, production operation and other aspects, it is urgent to have innovative methods to meet the big data challenges under the industrial background. For example, in the semiconductor industry, chips will go through many complex processes such as doping, adding layers, photolithography and heat treatment in the production process. Each step must meet the extremely stringent physical characteristics requirements. The huge detection results are generated simultaneously while the processing products are highly automated equipment.

3.8. Industrial pollution and environmental protection
The value potential of industrial big data is huge in application. However, much remains to be done to realize these values. One is the establishment of big data awareness. In the past, there were also big data. But due to the lack of awareness of big data and the lack of data analysis methods, many real-time data were discarded or put on the shelf. And the potential value of a large number of data was buried. Another important issue is data islands. The data of many industrial enterprises are distributed in the isolated islands of enterprises, especially in large multinational companies. It is very difficult to extract these data in the whole enterprise. Therefore, an important topic of industrial big data is the application of integration.

4. Self-consciousness and self-maintenance of machines
In the environment of industrial big data, the development of the Internet and sensing technology closely connects the system and human beings. A large amount of data generated by the interaction between things and people belongs to the big data environment of manufacturing industry. In the future, the industry will realize the information system transmission and calculation within the scope of a machine set. The emergence of advanced analysis technology (cloud computing and cyber physical systems)
helps the machine to gain self-awareness and prevents potential performance problems. A system with self-awareness and self-sustaining machine is defined as a complete system. The system can self-assess its own health and operation. In addition, the system can make optimized decisions based on similar intelligent information of other peers through intelligent analysis to avoid potential problems. The above self-assessment process belongs to the intelligent process of the machine, which needs to use intelligent analysis in the individual and the unit. Under the premise of data-driven algorithm analysis and the control of self-awareness, the mechanical system can evaluate the current and past health status of the machine, output the response to the evaluation results, and feedback the real-time status of the machine to the machine controller to realize adaptive control. This step is conducive to the maintenance of the machine administrator. However, in most industrial applications, the self-conscious machines are far from being realized. The diagnosis or prediction algorithms are usually only for specific machines or applications [8].

Why a self-conscious machine is not fully implemented? The main reasons are: (1) the lack of close coupling between human and computer interaction. At present, the machine can only passively obey the command, and the assigned tasks are often not the most suitable state. The intelligent machine system can arrange tasks according to the provided suggestions, adjust the operation parameters in time, and maximize the production efficiency and product quality; (2) lack of adaptive learning and make full use of information. In most cases, the data of industrial 4.0 system algorithm is only obtained from the actual monitoring data of machines because the real-time data collected by machines is usually multiple machines [9].

4.1. Self-awareness
Self-awareness means that the robot will be able to carry out actions in accordance with the new environment. These new environments and new actions are not the programs that the researchers have written in advance, that is to say, they are not the physical actions set by the programmers in advance. If robots can work in real time and actively guide their body behavior with consciousness, then more obstacles may be broken through. There may be such a scene in the future: robots can act as our private drivers.

4.2. Autonomous robots
Autonomous robots need to perceive the surrounding environment like human beings, and then make a comprehensive judgment according to the information of the surrounding environment, and make a reasonable decision on its own motion. Therefore, autonomous robot is mainly composed of detection system, communication system, decision-making system and bottom control system. Communication system is a necessary means of all information exchange, such as remote human-computer interaction, communication between robots, robot controller and central controller. It can be used for remote control test, parameter setting, start and end of control tasks and task operation intervention. The bottom control system is the executive control component of motion mechanism and operating mechanism, and is the most important basic structure of robot. Decision system is the most important technology in autonomous robot. By receiving the data and identification results of the detection system, the environmental status and operating objects are analyzed and processed. After a reasonable decision was made, the command to the underlying control system is sent.

4.3. Autonomous decision-making
In the decision-making system, the ordinary decision-making is difficult to save the wrong decision-making. Usually, the task can only be terminated artificially to avoid the expansion of danger. The self-conscious decision-making is repeatedly adjusted and gradually optimized, and there will be no serious deterioration. The decision-making with self-awareness is multiple. It doesn't need more than a set of specific programs that can meet various environmental conditions. Only program modules that can complete various basic operations can be combined to complete complex operations, which greatly reduces the storage capacity requirements.
Since autonomous robots are mostly used in harsh environments, although the first task of the robot is to complete the task. It is necessary to protect the robot body under this premise to work better. The robot with self-awareness can meet this requirement. The improvement effect of robot self-consciousness on robot performance is measured by task completion rate and robot survival rate. Both the task effect and robot safety are taken into account and difficult for general decision-making scheme to achieve.

4.4. Simulation technology
The robot with self-awareness can make more intelligent behavior decisions by the simulation technology, and enhance its survival ability while improving its adaptability. This method has great theoretical significance and practical application value for improving the survival ability and autonomous decision-making ability of autonomous robot in harsh environment. Of course, the current research is the basic theory, there is still a big gap from the actual application and still a need for physical experiments. With the deepening of the related theoretical research, the combination of human emotional intelligence and robot cognitive intelligence is bound to be a research hotspot in the field of artificial intelligence in the future.

As far as the progress is concerned, the artificial intelligence is still some time away from self-consciousness. What people are more afraid of seems to be the "Superman" ability of artificial intelligence, but they are not alert to the self-consciousness of artificial intelligence, and even are very interested in robots that can "communicate with people". This is a mistake. The danger of any intelligence lies not in its ability, but in its consciousness. Since man is the only intelligent life with self-consciousness to create artificial intelligence with self-consciousness, we can only take human self-consciousness as a model.

5. Serve of industrial big data
The application of big data in industry 4.0 system includes: (1) define data and information, record and manage information collected from physical space; (2) cyberspace is designed as accumulated knowledge, which is applied to machine health assessment under the intelligent control; (3) the results of health assessment are fed back to physical space, and the corresponding actions are taken to realize intelligent operation.

5.1. Self-assessment of machine health
In industry 4.0 system, according to the obtained big data and related algorithms, machines can evaluate their own health level and their performance in the physical world. On the basis of adaptive learning and data mining algorithms, machine health self-assessment can feedback machine performance and machine health level in real time. The big data of machine health is also growing synchronously, and its fidelity and ability to cope with complex work in reality are also improved with the rapid growth of new data. After the collection of the data sent by the machine, the appropriate data mining algorithm is used to compare the horizontal data (machine equipment to machine equipment) and vertical data (time to time) to realize the self-assessment of machine health. Based on the preset prediction algorithm, it is very important to evaluate the health information of a specific machine. The intelligent control will extract the necessary information from its database, and then carry out the health assessment of the corresponding machine [10].

5.2. Decision analysis of self-maintenance
The main objective of machine design, control and decision is to meet its production objectives, as well as efficient production planning, equipment maintenance and production scheduling. In real production, equipment downtime and machine failure are mostly caused by system performance, which reduces the production efficiency and operation efficiency. Two key factors affecting the performance of the machine system are: (1) reducing the unplanned downtime and improving the operational efficiency of
the machine; (2) detecting the bottleneck components that affect the production, making efficient use of the limited resources of the system and improving the application efficiency of the machine [11].

5.3. CPS architecture
Cyber physical systems (CPS Architecture) realize self-awareness and self-maintenance by combining sensor data and machine information data. The strategy of CPS architecture can mine useful information hidden in big data. The characteristics of CPS architecture under industrial big data mainly include: (1) the unity of architecture. The data involved in CPS in industry 4.0 not only comes from a single machine, but also comes from machine combination and manual operation. The system under CPS architecture collects information and data from specific machines, closely related other machines, and the surrounding environment of operators. The machine under intelligent control can also analyze the past historical data of other machines, and evaluate the operation status of its own machine by comparing with its own data. (2) self-awareness and self-maintenance are mainly realized by self-learning PHM algorithm. The low-intensity and invalid processing are the main obstacles to the application of PHM algorithm. (3) the intelligent decision-making system maintenance maximizes the performance of the machine through the balance and compensation work load and other measures according to the health condition of each machine body [12].

5.4. Industrial big data monitoring system
The monitoring system serves the intelligent manufacturing and industrial big data environment. The prediction of the machine operation status by the monitoring system can reduce the downtime. The information support ERP system has the functions of optimizing production management, maintenance scheduling and ensuring machine safety. The monitoring system is applied to the information flow and supply chain management of production line, which makes the industrialized operation of enterprises more transparent and organized. In addition, the monitoring system helps to reduce labour costs and provides a better working environment for operators and managers. The monitoring system can also reduce the cost through energy-saving measures and optimize the maintenance plan and supply chain management.

6. Conclusions
The fourth generation of industrial revolution Industry 4.0 is the development direction of the future industry. All machines in the entire industrial chain form a cooperative team through network and intelligent control. The machines are interconnected and closely connected to realize intelligent operation. In the face of the huge data generated by the machine, it is necessary to use prediction tools to make a large number of disorderly data systematically processed into available information. The method can be used to explain some uncertainties, so as to make more "informed" decisions and realize the intelligent control of the machine. With the coming industrial 4.0 era, the manufacturing industry not only includes single mechanical equipment or production line, but also includes manufacturing service, which will change the value of the whole manufacturer.

The rapid growth of industrial big data makes the service industry of manufacturing analysis more important than in the past. In addition, machine self-awareness and self-maintenance are also implemented on the basis of industrial big data service industry. CPS architecture includes cyber physical systems and decision support system. As an effective means of service industry implementation based on industrial big data, CPS architecture strategy can mine hidden big data information and extract useful information.

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