A Data-Driven Industrial Internet Operating System for Lean Production and Its Implementation Method

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ABSTRACT

Through the comprehensive interconnection of people, machines and things, the Industrial Internet realizes the comprehensive connection of all elements, the entire industrial chain, and the entire value chain (MIIT 2021). At present, the precipitation of industrial knowledge is relatively difficult. At this stage, there is still a certain threshold for experts to accumulate knowledge independently. It requires continuous guidance, circulation and continuous interaction to obtain it. This paper analyzes the process of industrial manufacturing quality optimization, adopts the research method of spiral optimization to improve production quality, and creates an open "Yunzhou" industrial Internet operating system based on heterogeneous Data connection and control, provide modeling, simulation, optimization, and control services for lean production, continue to accumulate experience and data in the industrial field, form a lean production service model, and output algorithm application APPs such as process improvement and equipment efficiency improvement to achieve online Improve productivity and manufacturing quality.

Keywords: *Industrial Internet, operating system, intelligent manufacturing, lean production, industrial mirroring, microservices, process optimization, equipment efficiency improvement*

1. Introduction

As a new industrial ecology, key infrastructure and new application mode, the Industrial Internet builds a network connecting all elements of the industry and the entire industry chain through a new generation of information and communication technology. Real-time collection, free transmission, accurate analysis and intelligent feedback support scientific decision-making of business, efficient allocation of manufacturing resources, and promote the transformation, upgrading and integrated development of the manufacturing industry [7].

The concept of Operating System (OS) is more common in the consumer Internet. In this field, it is defined as a computer program that manages hardware and software resources of smart devices such as computers. The operating system handles basic tasks such as managing and configuring memory, prioritizing the supply and demand of system resources, controlling input and output devices, operating the network, and managing the file system. The operating system also provides an operating interface for the user to interact with the system [1].

"Yunzhou" Industrial Internet Operating System ("Yunzhou OS" for short): It is a new type of industrial manufacturing technology optimization and service ecology generated by integrating the upstream and downstream technologies of "Cloud Network Edge". Refine management of the production process to achieve production process optimization and healthy operation of industrial equipment, provide networked, scenario-based and intelligent management services for the manufacturing industry, and provide high-availability and operational intelligence for practitioners in industrial production and manufacturing scenarios System enabling platform.

In the manufacturing process, the manufacturing equipment and production lines are distributed in different factories, and the industrial products are circulated all over the country. The information technology involved in the manufacturing process is all-round, not limited to the Internet of Things, distributed cloud computing, large-scale Information technology (Information Technology, referred to as: IT) such as data technology, but also includes operation technology (Operation Technology, referred to as: OT) of process optimization and production quality improvement of the manufacturing process. As enterprises pay more and

more attention to efficiency, quality and cost in production and manufacturing, enterprises are forced to upgrade and transform, and IT and OT are gradually transformed from two separate paths into one. Equipment production and manufacturing capabilities are managed by resource pooling, which can be flexibly changed according to business needs and application needs. Users can develop and model business analysis and management models by themselves in combination with OT on the system, and intelligently analyze with industrial data to form parameter optimization instructions. Sent to industrial equipment for process optimization. Through the industrial Internet operating system device, it can complete various tasks such as industrial equipment online, data acquisition, data processing, modeling analysis, operation visualization, parameter optimization, and industrial control.

2. Technical Architecture and Implementation Path

Yunzhou OS is deployed in a distributed cloud architecture. There are multiple management nodes, and the regional nodes and edge nodes distributed in different locations are controlled and managed in a centralized and unified manner in the cloud. The user does not need to go to the location where the physical node is located to manage it. Yunzhou OS performs distributed management on multi-region and multi-edge nodes. Computing and management nodes can be distributed in different factories, workshops, parks and cities; large-scale access to industrial equipment and data collection through distributed nodes and control, analyze industrial data and data from other business systems in the cloud to obtain analysis and optimization parameters, and form optimization instructions; Yunzhou OS connects gateways and industrial control devices distributed in different regions through the cloud to achieve optimization Parameter execution and control of the process.

Yunzhou OS is divided into four layers from bottom to top according to the "cloud-network-edge-terminal" collaborative architecture. Industrial data flows through the network at high speed between layers, forming a free flow of industrial trusted data.

1. Acquisition and control layer, establish connection and access with industrial equipment, open up the data path between physical resources and Yunzhou OS, realize the north-south data channel of industrial operation services, and meet the equipment of various manufacturers such as airports, motors, welding guns, etc. And the requirements of the access scenario, to achieve interconnection and control channels.

2. Industrial equipment image layer to build a data-driven industrial image. Data is extracted through edge gateways, peripheral terminal devices, sensors and other underlying terminals, and linked to virtual scenes to build a virtual-real digital twin.

3. The kernel layer of Yunzhou OS builds a micro-service platform based on cloud native technology to realize the allocation and configuration management of resources such as memory, CPU, thread and other core businesses such as data, business model, process orchestration, and business operation visualization analysis, based on micro-services The component library of the architecture forms a development, optimization and maintenance tool for the industrial core business model. Users can use the platform to model industrial knowledge and business rules combined with experience, and collect data through the acquisition and control layer. Learning and refining the core business models and open components that form Yunzhou OS, all these models and components are stored in the platform microservice API pool, and finally call the interface through the microservice, combine with the upper application layer, interact and iterate into a general lean Application software and service tools for production.

4. Application service layer, based on zero-code and application-level, open APP development platform oriented to business scenarios. Users can combine and generate industrial APP software under various industrial scenarios by calling micro-services to form business analysis and optimization for lean production. and manipulation tools. Yunzhou OS has accumulated many years of industry accumulation, and can already provide a series of industrial APPs in desktop-level industrial scenarios, including Yunzhou design simulation system for intelligent manufacturing, lean manufacturing management system, and equipment health management for predictive maintenance. The system serves to improve the efficiency of the entire production process.
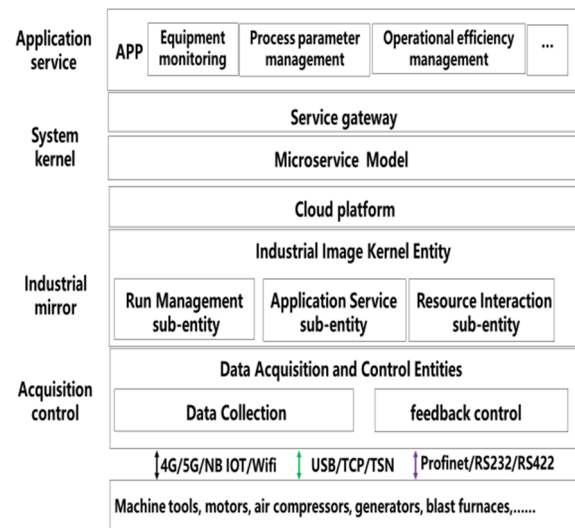
Figure 1 : Architecture of Industrial Internet Operating System

2.1. Acquisition control

Through the acquisition control layer, unified management protocol conversion, equipment online can be realized, and the acquisition object, acquisition cycle/frequency, acquisition data type, unified scheduling of data acquisition operation instructions, priority and execution order; control to realize automatic operation adaptation of equipment, Send optimized production parameters and production scheduling instructions to equipment, production lines, workstations, etc., to provide basic data and channel capabilities for fault location, process optimization, and human-machine collaboration; products and equipment involved include: edge intelligent gateway , industrial bus, soft PLC, feedback controller integrating software and hardware, VR/AR wearable devices, sensor devices based on identification analysis, etc.

Data acquisition, storage and control distribution for industrial equipment. According to the data flow direction, it is divided into two main directions: northbound data collection, upload, and southbound control delivery and feedback control; according to different physical objects, different hardware and software are used to realize data collection and feedback control, and through the edge gateway Connect to the industrial protocol of the underlying equipment controller, realize equipment online, and establish an instruction channel, such as the FOCAS dynamic link instruction library of FANUC CNC system. The edge gateway comes with USB\RJ45\RS232\RS422\RS485 and other communication interfaces to realize data expansion acquisition and feedback control of general peripheral devices, such as code scanners, VR/AR, printers, PDAs, etc. Soft PLC realizes feedback control based on industrial control bus network. Industrial control bus includes but is not limited to RS485\RS232\PROFINET\I/O LINK, etc. At the same time, it can also realize distributed networking based on industrial bus very efficiently and at low cost. , to realize data access and feedback control of non-industrial controller equipment or equipment without data interface.

2.2. Industrial mirror

Data-driven industrial mirroring is based on real data to perform high-precision simulation of physical objects in the industrial production process, and map various attributes of physical equipment to the virtual twin space. In the virtual environment, simulations such as robot debugging, testing, and optimizing operation status are realized, and simulation verification, prediction evaluation, and iterative optimization are realized, so that the optimal solution can be applied to the machines in the physical world, thereby saving a lot of maintenance and debugging costs. The essence of industrial equipment mirroring is based on its real-time status presentation and historical data recording, and oriented to specific application requirements, it analyzes the physical space activities for decision support or closed-loop control, and realizes two-way iterative optimization of the equipment entity and the mirror system.

In the industrial mirroring system of Yunzhou OS, accurate mapping, interactive fusion and intelligent feedback control of physical entities and virtual entities are realized according to the real data of production activities and the feedback control instructions of intelligent applications, serving R&D design, manufacturing, intelligent operation, etc. Maintenance, operation optimization, intelligent decision-making and other whole process.
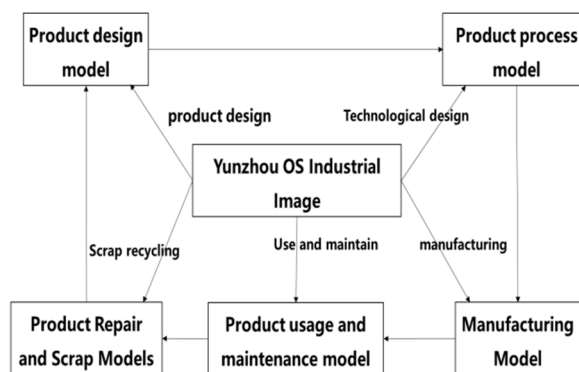

Figure 2 : Schematic diagram of industrial mirror reaction production activities

Yunzhou OS Industrial Mirror provides digital access, integration and conversion capabilities for the entire process of industrial production lines, manufacturing processes, etc. Its goal is to run through the life cycle and value chain of lean production, achieve comprehensive traceability, two-way sharing/interaction of information, Value chain collaboration. Therefore, industrial mirroring is the mapping and synchronization of objects, models and data.

The Yunzhou OS industrial image system as a whole includes all the components of the physical entity and the sensor system;

1. The modules deployed at the edge include perception module, edge communication module and control module

2. In the process of system operation, an accurate, real-time, efficient and configurable twin system of flexible production services is built through industrial protocol conversion and edge computing capabilities.

3. The virtual-real fusion system constructed by virtual simulation technology realizes the accurate mapping of the production process in the digital world and the real-time synchronization of information through the conversion of data to information.
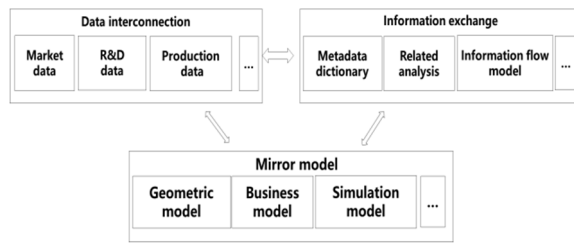
Figure 3 : Data transformation into business-meaningful information flow

As shown in Figure 3, the image layer of Yunzhou OS realizes the conversion of data to information and the free flow of information flow, that is, the original isolated data is associated and transformed into information flow with business significance. Information flow construction requires four key elements: metadata dictionary, correlation analysis, information flow model and information storage. Correlation analysis is a set of correlation self-learning algorithms, which can autonomously and efficiently extract relevant signals from the signal pool and combine them, and obtain relevant scene information through calculation. According to its function, it mainly includes time correlation analysis, time series correlation analysis, causal correlation analysis, etc.

As shown in Table 1, it uses the time correlation analysis model. After the automatic pairing of the feeding command signal and the feeding in-position signal is successful, the time of the feeding action is obtained by combining the information flow model, as shown in Table 1. Obtained: the feeding action time of the equipment at 19:00:39:500 is 0.45 seconds. Use the information tag to uniquely identify the physical resources of the information. The information tag contains: collection time_place_name, then the information tag of the above calculation result is: 2021-3-21 19:00:39:500_Shandong_Jinan_heavy truck Main engine factory_engine factory_cylinder head production line_OP20_automatic feeding manipulator_feeding action time.

Table 1 Construction of the information flow model of the feeding manipulator

Acquisition time	2021-3-21 19：00：33：500			
Place	Shandong_Jinan_Heavy Truck OEM_Engine Factory_Cylinder Head Production Line_OP20 IP address 10.10.121.33			
Name	Automatic feeding manipulator			
timestamp	Interval (500ms)	Loading instructions	feeding in place	Feeding action time
19：00：33：500	1	0	0	
19：00：34：000	2	0	0	
19：00：34：500	3	0	0	
19：00：35：000	4	1	0	
19：00：35：500	5	1	0	
19：00：36：000	6	1	0	
19：00：36：500	7	1	0	
19：00：37：000	8	1	0	
19：00：37：500	9	1	0	
19：00：38：000	10	1	0	
19：00：38：500	11	1	0	
19：00：39：000	12	1	0	
19：00：39：500	13	0	1	0.45 seconds
19：00：40：000	14	0	1	
19：00：40：500	15	0	1	
19：00：41：000	16	0	1	
19：00：41：500	17	0	1	
19：00：42：000	18	0	1	
19：00：42：500	19	0	1	

19：00：43：000	20	0	1	
19：00：43：500	21	0	1	

Through information tags, information can be easily retrieved and sorted by the system to meet different application requirements in industrial scenarios.

The mirror system based on real data builds business scenarios that conform to industrial laws and data-driven. The data of the scene comes from the underlying equipment. After the data is analyzed in real-time information flow, the information data is obtained, and the business model formed based on the rules and knowledge of the business scene is used as the input source of the simulation model container to drive and output the virtual and real interaction with the physical object. Industrial image, the mechanism model is based on different industrial Know-How, industry experience, and process models. The algorithm components formed are responsible for computing the input and feeding back the compensation results to the physical object, ultimately realizing the closed-loop improvement and optimization of the entire physical layer.
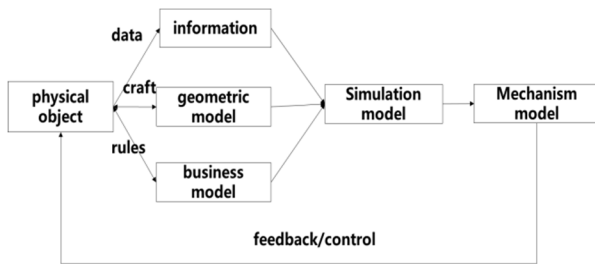

Figure 4 : Mirror simulation verification process

According to IDC official data, in 2018, 40% of the data was stored, processed and analyzed at the edge [4]. The combination of edge and end technologies builds an industrial mirror entity in an industrial scene, and realizes the representation and control of physical objects.

2.3. The system kernel

The cloud-native container cloud platform is the carrier of the core of the industrial Internet operating system. It carries a large number of digital models and information flows based on the microservice architecture. The container technology is responsible for the deployment, isolation and resource allocation of business model codes, and creates business models. The "container" of code; cloud native technology realizes faster iteration of business functions, and the system can withstand traffic shocks of various magnitudes; microservices can split complex applications into small service units, so as to achieve local units Independent upgrade and replacement, so as to achieve rapid iteration, while managing internal data resources and hardware resources and their external interfaces. Yunzhou OS connects people, processes, data and physical objects, gathers industrial knowledge and experience, and

deposits it on Yunzhou OS in the form of a digital model. That is, the industrial technical principles, industry knowledge, basic processes, and model tools are regularized, softwareized, and modularized to form a digital industrial model. The digital model has strong adaptability to different business scenarios. Common models are classified as follows: process logic model (such as the logical relationship contained in business processes such as ERP, SCM supply chain management, etc.), component model (such as the three-dimensional model of parts), process model (such as various types of products involved in the production process) Process, formula, parameter model), fault model (such as equipment fault correlation, fault diagnosis model, etc.), simulation model (such as wind tunnel, temperature field model, etc.). Digital industrial models are essentially solidifications of various empirical knowledge and methods, packaged as reusable components. The external output specifically includes general business model components, tool business model components, management business model components, control business model components, and industrial scene-oriented business model components. These knowledge bases, which encapsulate a large number of industrial technology principles, industry knowledge and basic models, serve as the core connecting enterprise IT and OT, and solidify industry understanding and first-line production experience in the form of code and information technology, and become the entire factory or industry. The management and control brain on the manufacturing side.
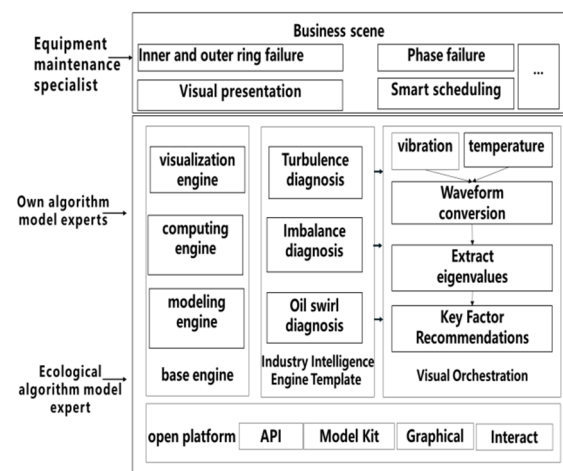

Figure 5 : System kernel architecture and schematic diagram

The kernel platform supports visual and drag-and-drop rapid construction of real-time control processes, through the control components and feature processing components provided by the platform, and the use of API function development mode to develop customized

computing logic, and integrate them into the entire real-time control process. |Based on its own computing power engine, it conducts data analysis, integrates historical data and prior knowledge, simplifies the mechanism model, and improves the reliability and availability of the model.

The core platform supports all capability domains and capability items of data management, provides users with one-stop data resource management services, and facilitates users to complete multiple data management applications such as data architecture, data standards, data quality, data applications, and data lifecycle management. At the same time, it provides an industry-oriented algorithm integrated management platform. Through the integrated management of algorithm deployment, access, debugging, and invocation, the decoupling of algorithms and applications and algorithm reuse are realized. Applications can quickly package solutions based on the unified interface of standardized products to improve algorithm engineering efficiency. The platform provides WYSIWYG visual business orchestration tools. Developers can use drag and drop to assemble business processes, business data dictionaries, business rules, and industry algorithm components arbitrarily, so as to realize the demands of artificial intelligence in specific business scenarios.

The kernel platform reinvents the way industrial software is innovated, deployed and integrated. In the traditional IT development model, enterprises develop independent software systems according to business processes, and functions and data are scattered in different software, making it difficult to coordinate and integrate. In the kernel platform development model supported by microservices, traditional industrial requirements are decoupled, and divided into more specific and refined functional components to build a microservice gateway. Developers call and combine microservice components according to specific user needs, and solidify them into APPs. Based on the platform, APP realizes rapid interaction and integration, forming a new development method of on-demand customization and comprehensive integration [9]. Different microservices are combined into applications to realize the circulation and interaction of data acquisition, data calculation, and data use, that is, to form a service oriented to lean production.

In actual work, the platform provides a working engine. Users can freely drag and drop existing microservices according to business rules, or combine and generate new microservice APPs, which are packaged into firmware and built into the platform.

The Yunzhou OS system already has a variety of microservice applications, some of which are listed in Table 2.

Table 2 List of microservices

Name	A detailed description
Trend forecast	Provide time-based calculus, mean, variance, range and other statistical functions
Linear regression	Calculate Linear Regression Values for Time Series Data
envelope	Provides a dynamic envelope threshold function for a set of dynamic time series data
abnormal detection	Detect time series data exceeding the set value and provide detection results
Pairing function	Multi-channel time-series signals take time as a reference, and combine nearby functions to give physical meaning.
stack alignment	Free combination of multiplexed time series signals to distinguish difference functions with time axis overlay alignment
Dynamic self-learning	Multiple sets of continuous time series data, fit the band area chart of the output batch data
Gantt chart	Provides an example of a time series Gantt chart

2.4. Application Services

Industrial APP is a process, method, data, information, law, experience, knowledge and other industrial technology elements in the industrial field, through data modeling and analysis, structured sorting, systematic abstraction, in order to solve specific problems and meet specific needs. Refined, and based on a unified standard, these industrial technology elements are encapsulated and cured to form an industrial application that can be efficiently reused and widely disseminated [5]. Yunzhou OS links industrial scenarios through industrial knowledge, gathers people in the ecology, and iterates the ecology, and finally can rise to self-learning, self-decision, self-execution, and self-adaptation, realize value transmission through industrial APP, and empower manufacturing.

Yunzhou OS has hundreds of APPs in 9 categories, including Equipment monitoring, Troubleshooting, Process parameter management, Operational efficiency

management, Equipment Health Management, and Equipment Diagnosis Guide. Each industrial APP is very small and flexible, and different industrial APPs can pass the Certain logic and interaction are combined to solve more complex problems. Each industrial APP integrates and solidifies the industrial technical elements that solve specific problems. Therefore, industrial APPs can be repeatedly applied to different scenarios to solve the same problems.

Examples of application scenarios:

1. In the discrete manufacturing industry, automated assembly lines have replaced manual operations. Motors, cylinders, oil cylinders and other motion execution components are just like human hands and feet, and perform various operations instead of humans to complete each step of the product manufacturing and assembly process [2]. Once these motion execution components fail, it will bring about interruption of automatic assembly line production, which will directly affect the production efficiency and product quality, and bring about the loss and waste of manufacturing resources. The slow failure process of components is often accompanied by the gradual decay of the operating speed of the components, resulting in potential loss of efficiency and performance of the equipment, which cannot be detected by conventional management methods. By building a mechanism model on the platform, the movement time of each action component is compared with the standard value, and abnormal points are found and improved to avoid losses.

Through Yunzhou OS, machine tool data is extracted at high speed, and a concrete industrial image of hundreds or thousands of action sequences of machine tools is constructed. Microservices such as trend prediction and linear regression are used to realize the calculation and prediction of component life, which eliminates potential manufacturing efficiency. At the same time of loss, it can accurately perceive the status of the components and predict the life of the components. The system automatically feeds back the diagnostic content and suggested measures to the maintenance personnel in the form of standardized operating procedures. The specified actions can eliminate hidden dangers and avoid failures.

2. The iron and steel industry is facing many challenges such as the coal-based energy structure, the long-process structure dominated by blast furnaces and converters, and the uncertainty in the application of low-carbon or zero-carbon technologies. The method not only requires greater investment, but also has a greater impact on steel production capacity [8]. In this context, digitalization and intelligence have become important means for the steel industry to move towards "lean production".

Based on Yunzhou OS, according to the steelmaking production process, data models such as oxygen supply, slag making, scrap steel, end point prediction, oxygen lance location planning, cost optimization, etc. are constructed, and real-time calculation of steelmaking process parameters and dynamic control of the blowing process are realized through data analysis. Process, experts build a mechanism model based on experience, standardize and optimize the operation process according to lean expert experience, and form high-quality data. Use Yunzhou OS kernel platform for model training and optimization. Yunzhou OS industrial image supports model operation, real-time parameter calculation, and result display. Through the improvement of on-site lean management, the mechanism model combined with the data-driven model, the annual cost reduction of the two converters in the whole plant is nearly 100 million yuan, and the green transformation accounts for about 20% of the cost reduction space.

There are many more scenarios that will not be listed one by one. Yunzhou OS provides a unified operation platform for lean production, which brings together different equipment and production system data and industrial knowledge models on the same platform, allowing users and partners to On the platform, various applications are developed around the needs of safe production, energy saving, consumption reduction, quality reduction, cost reduction and efficiency improvement, and the traditional industrial software is transformed into a lightweight industrial APP running on the platform. In the exploration of lean production, It requires more participants to join in, collaborate and innovate, and experience this endless journey together [3].

3. In conclusion

Facing the needs of scenario-based, networked and intelligent manufacturing, Yunzhou OS redefines the concept of industrial Internet operating system, and supports the construction of concrete scenarios for various elements of the manufacturing chain and an open industrial application platform for zero-code development. Its essence is to establish a development environment for industrial big data storage, management, modeling, empowerment, and reuse through the ubiquitous connection of people, machines, and things, and to expose knowledge in the fields of industrial R&D, design, manufacturing, and operation management. It can be standardized, modeled, and standardized, and packaged into various application services for monitoring, diagnosis, prediction, and decision-making, so as to realize the global optimization of manufacturing resources in the entire manufacturing process, the entire value chain, and the entire life cycle. Summarize the five main steps of Yunzhou OS construction:

Step 1: Identify and manage industrial equipment and solve data channel and data source issues

Step 2: Realize Industrial Mirroring: Build data-

driven and vivid industrial digital assets.

Step 3: Build micro-cloud services: Use industrial knowledge and Know-How to form intelligent analysis. Carry out industrial Internet ecological construction, and integrate cutting-edge technologies such as industrial images, algorithms, mechanism models, and microservice components.

Step 4: Application as a service: gradually replace workers with "intelligent collaborative robots" to perform daily operations in actual industrial scenarios, such as pre-maintenance, inspection, process parameter adjustment, and handling emergencies.

Step 5: Analyze and compare the data after process improvement and equipment parameter optimization, carry out lean production improvement based on the concept of quality spiral, continue to iteratively optimize, and continuously improve the level of lean.

The Yunzhou OS system constructed based on the above five steps has the following characteristics:

1. It has the ability to simulate people's thinking independently, has strong coordination ability and learning ability, and can bionic evolution intelligent algorithm, and can accurately predict the links of design, simulation, manufacturing, operation and maintenance, and post-service. Using the forecast results, companies can adjust production supply to form precise production and save costs and energy consumption.

2. Fully excavate and utilize various data resources, set up equipment monitoring and operation and maintenance management systems, and establish a set of standard equipment maintenance and processing procedures, as well as a complete fault alarm and emergency response mechanism, so as to realize equipment predictive operation and maintenance, reducing the probability of equipment failure and other problems.

3. Through a data acquisition array composed of multiple sensors, data such as water temperature, pressure, and temperature during the production process are collected to reflect the health status of the production equipment, thereby supporting the accurate delivery of materials, reducing costs and reducing unplanned downtime. Improve production efficiency.

4. Cross-industry applications are universal and universal. The business model of Yunzhou OS in equipment monitoring and diagnosis, health management, equipment predictive maintenance, energy consumption optimization, etc., has strong versatility and can be reused across industries.

As the industry's leading industrial Internet infrastructure builder and manufacturing intelligent transformation service provider, Inspur takes Yunzhou OS as the center and integrates technologies such as artificial intelligence, big data, and digital twins. The data of the life cycle (R&D, material supply, production, assembly, packaging, storage/logistics, use), the data of physical entities such as sensors, machines, equipment, facilities, factories, and the data of people and processes, etc., are integrated and processed, Open up all links, form an industrial mirror body, combine artificial intelligence and optimization algorithms, continue to sink application scenarios, and gradually form a new self-decision and self-adaptive intelligent manufacturing service ecology with Yunzhou OS as the intelligent center, improve The lean capability of production and manufacturing creates incremental value.

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