

Research on Key Technologies of Intelligent Perception and Control in Discrete Manufacturing Industry based on IEC61499 Standard

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Abstract

This paper aims at the characteristics of discrete manufacturing, such as changeable process, complex process, multiple varieties and small batch, the mechanism of real-time perception and dynamic optimization of various production factors such as materials, equipment and personnel in the production process is established, the interaction and integration between the physical world and information space in the discrete manufacturing environment is established, and the distributed industrial intelligent perception and control solution is developed based on the industrial Internet IEC61499 standard.

Keywords

Intelligent Control; Discrete Manufacturing Industry; IEC61499.

1. Introduction

As the deployment of the industrial cloud platform and the application of artificial intelligence in the production line, increasingly more enterprises urgently need more and richer data, hoping to improve business efficiency and innovate business models through data analysis and closed-loop optimization. The factory external network has been basically interconnected, realizing the flexible connection between headquarters, multi-base, multi-cloud and the upstream and downstream of the supply chain. Currently, the key contradiction lies in the factory intranet, and the traditional industrial control automation system is relatively backward in this aspect. Traditionally, enterprises adopt the newly-built mode, conduct AOI quality inspection through AI machine vision, deploy data acquisition devices for big data analysis of production line data, optimize the process flow by employing industrial intelligent algorithms, and incorporate a series of means such as AGV automatic logistics, Pad electronic work orders, wireless intelligent helmets, underground video safety supervision, etc., which improve the digital networking rate of the factory and eliminate information isolated islands.

In view of the characteristics of discrete manufacturing process, such as changeable process, complex process, multi-variety and small batch, the mechanism of real-time perception and dynamic optimization of all kinds of production factors such as materials, equipment and personnel in production process is established, the interaction and integration between physical world and information space in discrete manufacturing environment is established, and a distributed industrial intelligent perception and control solution is developed based on IEC61499 standard of industrial Internet. The research and application of key technologies enable the industrial Internet system to have a wider range of portability, performance and interoperability, and cloud-side collaborative applications support the realization of discrete manufacturing workshop operation management and decision-making mode digitization.

2. Research Scheme

As for the overall research idea of the project, the first is to carry out the research on the underlying application of the distributed operating system based on OpenHarmony Industrial Project (OHI), to master the intelligent perception and real-time industrial control technology that meets the IEC61499 standard, and then to design the intelligent collection strategy of multi-source and heterogeneous data based on the OPC UA data acquisition standard. In the face of diverse and complex discrete manufacturing sampling data, the data fusion method is studied. At the same time, the transmission technology needed for real-time perception of discrete manufacturing industry field data will be optimized and dynamically adapted. Subsequently, the model will be used to predict and optimize the production process faults according to the collected production data, and realize the data analysis and visualization application based on the micro-service architecture. Finally, the research work of this project will be completed through the combination of experimental analysis and theoretical derivation.

2.1. Underlying Application of OpenHarmony Industrial Internet in the Field of Discrete Intelligence

In the field of discrete intelligent manufacturing, this work studies the hardware real-time and micro-kernel capabilities of the distributed operating system based on OpenHarmony Industrial Project (OHI), the functions can be tailored and fully configured, and a unified technical platform, including customizable system functions, detailed configuration for functions, and compatibility with mainstream software and hardware technology platforms at home and abroad.

Through the research and development of unified, standard and easy-to-use product functions and technology platforms, a series of industrial control real-time system products with the integration of software and hardware are developed, which are localized and customized, which are compatible with the International Electrotechnical Commission Industrial Control programming language standard IEC61499, which enables it to have stable, reliable, completely autonomous and controllable technical capabilities, reduce dependence on foreign technology, improve system security, and achieve the first level of industrial control system safety standards.

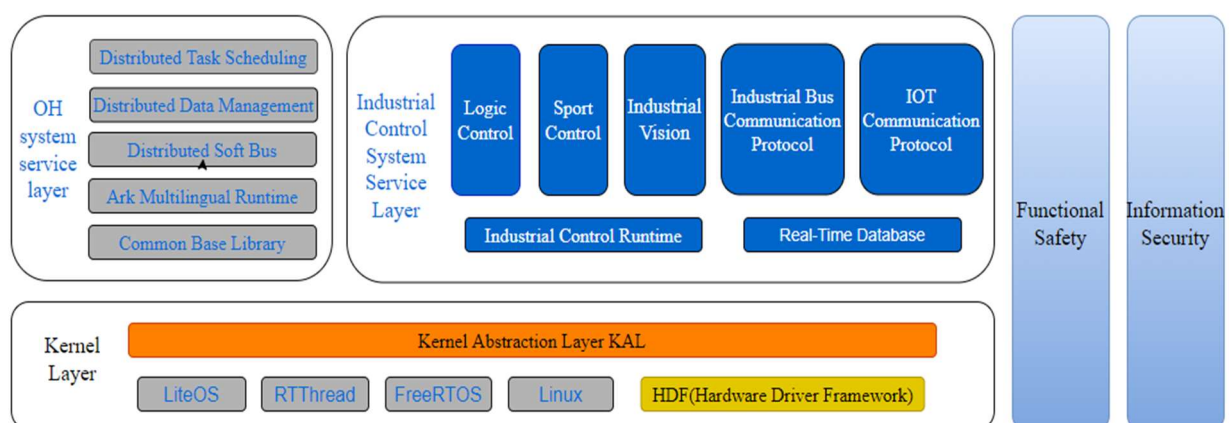


Figure 1. OHI Technical Architecture

2.2. Intelligent Perception and Acquisition of Multi-Source Heterogeneous Data in Discrete Manufacturing

In view of the diversity of discrete manufacturing equipment and the lack of unified standards for interfaces and protocols, the OPC UA data acquisition standard based on IP protocol is used to build a unified communication framework, combined with AutomationML technology to

achieve heterogeneous data integration and enhance the availability of the data model. Sales orders, purchase orders, inbound and outgoing orders, product data, employee information, design files, process files and other information are docked and obtained with related systems through the microservice interface. The production data are collected through bar code, QR code, RFID tag and equipment interface. A variety of random data fusion algorithms are combined with neural network, analysis and processing and automatic reasoning enable data fusion. The hybrid network of industrial bus, Ethernet and 5G technology is used to divert and unload the data according to the data types and applications collected in the field. In the discrete manufacturing process, the data sources obtained include unstructured data such as image and sound, structured data such as temperature, pressure, flow and composition, and a large number of semi-structured data generated by product life cycle management system, application life cycle management system, service life cycle management system, etc.

2.3. Multi-source Heterogeneous Data Fusion of Discrete Manufacturing Data

In this project, the K-means data clustering algorithm of large-scale data processing is used for data fusion to realize the integration and fusion of multi-source and heterogeneous data, so as to solve the problems of diverse data sources and forms, complex conversion and processing, multi-sampling rate and multi-modal characteristics in discrete manufacturing. The data of discrete manufacturing reflect the multi-sampling rate and multi-modal characteristics of the data in the form of collection. Multi-rate process is an industrial process in which variables have multiple sampling rates at the same time, such as the sampling interval of electrical and mechanical signals is usually in seconds or even milliseconds, and the sampling interval of process variables such as temperature, flow and pressure is usually in minutes. The data sampling intervals related to production performance indicators are generally at the small or even celestial level. As a result, the traditional modeling and analysis methods of sampling interval will have great problems when they encounter multi-source data.

Data fusion technology can organically fuse and analyze the multi-source data of the workshop, effectively obtain the production status of the workshop, and lay an important foundation for the decision-making of the workshop. K-means clustering algorithm has the advantages of simple and fast, and has good scalability and high efficiency when dealing with large data sets. When the difference between clusters is obvious, the effect is more prominent. At present, K-means algorithm is mainly used in data mining, image processing and other fields. In a discrete manufacturing intelligence workshop, suppose an object sample set, in which p_i is represented as an element or object in the sample set P , any cluster represents the combination of a group of similar elements, and k is the total number of clusters, and the specific k value can be determined according to the data characteristics generated by different objects in the workshop. For example, in the fault diagnosis of equipment, its main characteristics are normal, large spindle speed, large tool wear, large spindle speed and large tool wear. The cluster center of each cluster is m_i ($i = 1, 2, \dots, k$) represents the mean of all objects in each cluster. According to the above definition, the clustering process of massive workshop data based on K-means clustering algorithm can be completed as follows:

- (1) select k objects from the object sample set P as the initial center of each cluster.
- (2) calculate the d_p of each remaining object p in each set P to the center of each cluster. In general, m_i can choose the Euclidean distance to calculate, and assign each object p to the cluster closest to itself (Min. of d_p, m_i).
- (3) After each cluster is assigned a new element, update the center m_i ($i = 1, 2, \dots, k$) of the cluster with the new element.

This step can be obtained by the following formula:

$$m_i = \frac{1}{|C_i|} \sum_{p \in C_i} p$$

The algorithm is judged by clustering criterion function. If the difference of the clustering criterion function of the two adjacent iterations is less than the given threshold, the algorithm is terminated and the clustering is completed, otherwise the above steps are repeated until the convergence conditions are met. The clustering criterion function here is often dealt with by the error average sum function, that is:

$$E = \sum_{i=1}^k \sum_{p \in C_i} d_{p, m_i}^2$$

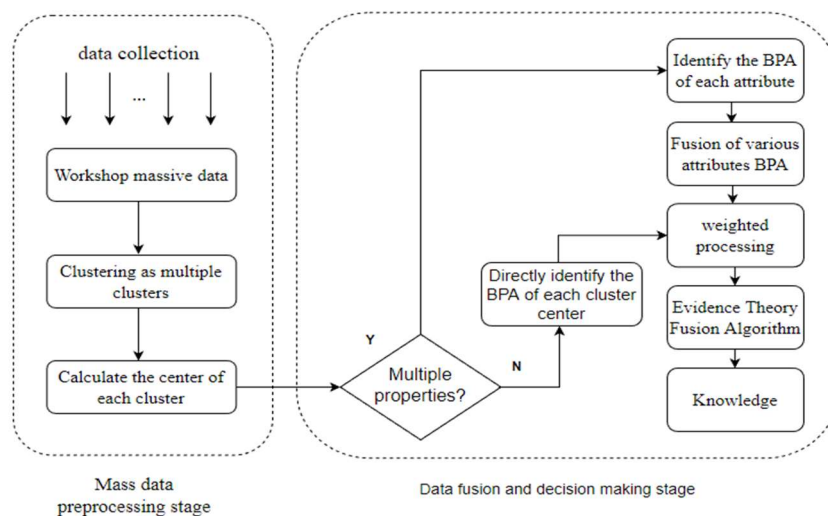


Figure 2. Flowchart of massive data fusion algorithm in discrete manufacturing workshop

In this project, K-means data clustering algorithm of large-scale data processing is adopted and combined with evidence theory, a massive data fusion method based on data clustering is proposed, which dynamically displays and tracks production data in real time, reduces the management complexity of flexible production, and realizes the visualization of production digital workshop.

2.4. Field Data Interconnection and Interworking in Discrete Manufacturing Industry

Combined with the current CPS system and the current situation of industrial Internet, advanced and reliable, dynamic and efficient data transmission technology is adopted to deal with the problems of complicated equipment and many fine numerical control equipment in some discrete manufacturing industries. In order to facilitate the centralized management and control of data, it is necessary to interconnect and communicate the data of on-site manufacturing resources. In the discrete manufacturing industry, part of the manufacturing environment is a harsh environment such as high temperature, which is not suitable for wired communication and the information upgrading of the original factory area, so it is necessary to adopt wireless network communication technology. Some workshops have a high degree of information, high requirements for on-site networking, and need dynamic adaptation. Part of the discrete manufacturing process or business, need to have remote diagnosis, predictive operation and maintenance means. The demand of system data transmission technology puts

forward higher requirements for the bandwidth, delay, security and other characteristics of the network. In the communication protocol, it is usually realized by industrial Ethernet, ZigBee technology, WiFi6 technology, 5G technology, etc. Comparing the different characteristics of the communication protocol, it is required to adapt dynamically in the networking process to achieve the best results such as bandwidth, delay, security, etc.

2.5. Fault Diagnosis and Safety Inspection in Discrete Manufacturing Process

A database including equipment status and product quality is constructed. on the basis of traditional Kalman filter, time series and linear regression model, expert knowledge and feature engineering are used to train the model with fault events as tags. Deep recurrent neural network technology is used to predict assembly quality problems, diagnose product quality problems and actively correct them.

The DRNN prediction model based on IPSO algorithm is used to study the fault prediction of key equipment and its safety monitoring technology to count the status information and production information of the equipment. The state of the time series data is judged based on the deep recurrent neural network, and the corresponding control instructions are obtained through the main control system. The active diagnosis method is introduced to monitor the operation of the equipment, health diagnosis and fault early warning.

2.6. Intelligent Prediction Model of Production Process

The production data in the production process are preprocessed, such as data aggregation processing, data validity screening, abnormal value processing, missing value processing and normalization processing. The exponential smoothing prediction model and the grey theory GM(1,1) prediction model are selected to forecast the production capacity.

Based on high throughput data, deep reinforcement learning is used to solve the dynamic scheduling problem of flexible manufacturing with shared resources, route optimization and random arrival of materials, and the network structure of time and location characteristics is combined to improve manufacturing efficiency and avoid deadlock. The graph convolution layer is used as a multi-module network state approximation tool to reduce the number of training parameters, ensure the robust convergence of the learning process, and realize the optimal scheduling scheme based on big data.

2.7. Research and Application of Micro Service in Cloud Edge of Discrete Manufacturing

In the current development stage of discrete manufacturing industry, it is difficult to realize the independent iterative upgrade of algorithms and software due to the lack of overall software architecture design and serious coupling between software and hardware, the replacement and upgrading of hardware equipment will cause a large number of inefficient software upgrades, and the level of automation software is extremely uneven. In view of the problems encountered in the combination of discrete manufacturing and edge computing, the introduction of edge computing micro-service architecture can provide an effective solution. Traditionally, most of the IT industry software are piled up of various independent systems, which have some problems, such as poor expansibility, low reliability, high maintenance cost, and can not be executed directly on the edge side, and micro-services effectively solve the above problems. It is worth noting that it is allowed to be put into separate services through micro-service-specific functions, allowing these services to be distributed and replicated between servers, and reducing the difficulty of software upgrades for each module of discrete manufacturing. Each component of the micro-service architecture can be upgraded and iterated independently to promote the flexible and rapid industrial transformation and upgrading of the discrete manufacturing industry. The combination of micro-service architecture with edge computing

and discrete manufacturing industry can improve the overall digital, intelligent and automatic level of discrete manufacturing industry, and optimize productivity.

Each application runs in its own process, communicates with lightweight mechanisms, takes up less resources, and can be flexibly deployed on the edge side. In addition, the degree of centralized management of these services is greatly reduced, and they can be written in different programming languages and incorporated into different data storage technologies, which is also in line with the characteristics of flexible and heterogeneous edge computing resources.

3. Conclusion

This paper introduces a research on the key technologies of intelligent perception and control in discrete manufacturing industry based on IEC61499 standard. This research enables the industrial Internet system to have better portability, performance and interoperability, and adopts cloud-side collaborative application to effectively realize the digitalization of operation management and decision-making mode in discrete manufacturing workshop.

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