Design and application of intelligent equipment management platform

Dongqi Li¹, Peng Liu¹, Guotai Huang²,³, Yuan Ma¹, Zheyu Xie¹, Yunfeng Li¹ and Xin Huang¹

¹School of Mechanical and Aerospace Engineering, Jilin University, Changchun, Jilin 130025, China
²Department of Mechanical Engineering, University of Bristol, Queens Building, University Walk, Bristol BS8 1TR, United Kingdom
³E-mail: vc20622@bristol.ac.uk

Abstract. Discrete manufacturing enterprises are developing towards the direction of intelligence. This paper designs an intelligent equipment management platform aiming at the equipment management and production efficiency problems of discrete enterprises. Intelligent method and advanced IE technology are used to provide a safe and efficient intelligent equipment management platform for discrete manufacturing enterprises through signal processing technology, multi-sensor sorting technology, big data analysis, artificial intelligence technology and visual design (based on the principle of information processing economy). According to the improvement, monitoring, early warning and analysis can understand the status better of workshop equipment in real time, provide decision-making basis for the enterprise and workshop managers, and ultimately improve the overall efficiency and management level of the enterprise, improve the operation efficiency and emergency command ability of the enterprise, and strengthen the core competitiveness of the enterprise.

1. Introduction

With the rapid development of modern industry, the concept of intelligent manufacturing has been mentioned in the manufacturing development strategies of various countries [1]. In the process of exploring transformation for manufacturing enterprises, digitalization, networking and intelligence are key development directions [2, 3]. Intelligent manufacturing contains three basic attributes: automatic perception and analysis of information flow and logistics, autonomous control of manufacturing process information flow and logistics, and autonomous optimization of manufacturing process [4]. To realize intelligent manufacturing, enterprises need to transform by IoT. Therefore, how to realize the intercommunication between equipment and information platform is the main problem of the transformation at home and abroad [5, 6].

There are many scholars are studying and developing the platform for equipment management at present. FANG focused on discrete production workshop, and put forward MES management information system by the use of RFID technology and ZigBee technology, and using Justep X5 implements the MES system for application [7]. Sun and Hu proposed a workshop material conveying system that could update the information of production and material transportation in real time, which solved the problems of backward field data collection means inefficient and chaotic material distribution in workshop [8]; Xu realizes the remote management of industrial equipment power
supply, which can monitor the equipment power supply in real time and control the start and stop of the equipment remotely [9].

The analysis found that most of the platform limited to the equipment management and state monitoring level, do not have the ability of active fault perception, that is not accord with the requirement of intelligent manufacturing, so combine AI method to develop a predictive maintenance function of the equipment management platform has high application value.

Its main advantages are as follows:
(1) Reduce unnecessary losses and improve economic benefits;
(2) Realize integrated equipment management and solved management problems;
(3) Improve efficiency and production capacity, then enhance enterprise competitiveness.

How to support enterprise development strategy and how to meet the needs of enterprise core business by intelligent equipment management platform has become a common issue facing by enterprises. This paper aims to solve the common problems of difficult equipment management and low production efficiency in enterprise transformation. By designing an intelligent equipment management platform to solve the problems of equipment integrated management and efficiency in discrete manufacturing enterprises, the preventive maintenance function has achieved basically. Provide decision advice for the implementation of equipment maintenance strategy, maximize the reduction of downtime and prolong the lifetime of equipment, improve the production efficiency of the plant.

Figure 1. Intelligent equipment management platform development architecture.
2. Design and application of intelligent equipment management platform
Firstly, the intelligent equipment management platform installs a smart terminal for the equipment to enter the network and collect equipment data in real time, and then transmit the collected data to the database for analysis. Secondly, accurate monitoring of equipment status is realized, and intelligent health assessment model of equipment is established by using big data and machine learning to achieve equipment health management. Thirdly, establish the process management model by adopting the whole life cycle management technology [10]. In addition, connect the automation software system and each production machine. And realize the three functions of energy consumption statistics, energy consumption planning and real-time energy consumption monitoring [11]. Finally, design the interface basing on the principle of information processing economy. In order to guide intelligent management of equipment, construct the intelligent equipment management platform development architecture as shown in Figure 1.

3. Platform functions
The intelligent equipment management platform mainly includes equipment monitoring module, fault report module, process management module and energy consumption management module.

3.1. Equipment monitoring module
Equipment monitoring module includes equipment status monitoring and equipment KPIs view.

**Equipment status monitoring**, can show the planned use time of equipment, yield rate, actual utilization rate and net production time, and it can provide equipment status information in the workshop. Additionally, it includes the function of equipment fault diagnosis which could diagnoses CNC fault, turning tool damage, incorrect tool reset, tool collision during turret rotation, etc.

**The equipment KPI view**, shows the comprehensive efficiency of each equipment, the first pass rate of maintenance quality and equipment failure rate in the form of chart, and can calculate the equipment OEE in real time to realize the dynamic OEE.

![Figure 2. Equipment failure report process chart.](image-url)
3.2. Fault report module
Fault report modules are maintenance management.

**Maintenance management**, including automatic equipment feedback maintenance request and manual fault finding request maintenance. The fault information includes the location information of the fault equipment, the maintenance priority level of the fault equipment, the specific parts of the fault equipment and the diagnosis suggestions to help the workers to make decisions. Maintenance workers can receive maintenance tasks on the platform interface. Report to the management platform after completion of the repair, and end the fault repair process. Figure 2 shows the process of equipment failure report.

3.3. Process management module
The process management module includes technical document management and process data management.

**Technical documentation management**, realize the management of equipment loss and compliance during operation, including material and energy consumption, equipment compliance, technical summary, and technical feasibility inspection. It also could check the product technicality through the engineering drawing design inspection.

**Process data management**, including new product prototype trial production process plan, product improvement process plan, small batch trial production process plan, batch production process plan, etc [12].

3.4. Energy consumption management module
The energy consumption management module consists of three parts: energy consumption plan, energy consumption trend and real-time energy consumption monitoring.

**Energy consumption plan**, including the collection of water, electricity, oil, gas and other energy consumption data, the development of the month's plan, the year’s plan. Compare the used energy with the estimated energy, implement quota control and formulate energy saving measures to improve energy saving efficiency.

**Energy consumption trend**, statistical energy consumption of each month, forecast the future trend of energy consumption. Including the overall energy consumption trend of the workshop and the energy consumption trend of each production line, according to the energy consumption trend timely adjust the production mode.

**Real-time energy consumption monitoring**, real-time monitoring of the workshop energy consumption of each period and display the trend of energy consumption. Other application subsystems can be extended according to user needs, including energy consumption audit, information publicity, energy consumption settlement, auxiliary system, data report, information query, user service and other functions.

4. Core technologies

4.1. Equipment intelligent health assessment model
The intelligent health assessment model can realize predictive maintenance of equipment, including component performance assessment and residual service life prediction, and provide decision advice for making equipment maintenance strategy. According to the diagnosis results of the intelligent health assessment model, the equipment maintenance personnel can schedule relevant resources in advance when the equipment is in sub-health state. When there are faults with the equipment, it can be maintained and repaired immediately to minimize the downtime and extend the lifetime of the equipment and improve the production efficiency of the plant [13]. Take the intelligent health assessment model architecture of Nc machine tools as an example, as shown in Figure 3.
4.2. Visual design based on the principle of information processing economy

The principle of information processing economy is a principle aiming at reducing the information processing load of workers, which can effectively improve the efficiency of information flow and ensure that workers can easily complete information processing operations.

It includes the following four aspects:

(1) To reduce the amount of information (The maximum amount of disposable information should be in accordance with the 7±2 principle). (2) Reducing the depth of information processing. (3) Audio-visual information presented at the same time. (4) Assessment of the level of relaxed work [14].

Basing on the principle of information processing economy, design the interface of the equipment management platform, because of the limit of the length of this paper to equipment management fault repair work as an example to introduce visual design work. The main purpose of the fault report interface is to let the maintenance team members get the equipment fault information at the first time and provide them with the path to the fault location.

Therefore, the fault report interface mainly includes two aspects:
①Fault information;
②Position indication information.

The interface layout should conform to the principle of 7±2, that is, 5-9 pieces of information. In addition, interface navigation is a problem involving knowledge of multiple disciplines, such as human-computer interaction, interface design, cognitive science, information technology, and information construction [15]. Based on cognitive psychology, Jun analyzed the design method of medical equipment interface experience, and divided the human-computer interface into three parts: structure, interaction and visual design. In the information architecture design, whether the key information can be clearly conveyed to the user is the most important thing in the design. At the same time, we should not blindly pursue simplicity and ignore the depth and breadth of the design itself [16].

The specific layout is shown in Figure 4:
The overall interface layout includes four modules: basic information module (time, position and fault point information), emergency level grading module, repair report feedback module and real-time navigation module, which conforms to the principle of reducing the amount of information. Color design indicates different levels of urgency through different colors, reducing the depth of information processing. In addition, according to the principle of simultaneous presentation of audio-visual information, the human-computer interactive navigation interface plays the navigation voice while presenting the navigation route plan during real-time navigation, so that the visual and auditory information can be presented to the maintenance personnel at the same time, so as to maximize the efficiency of information acquisition.

In the fault report repair work, another important point is the fault information record and view. In traditional equipment management work, this is done by paper forms. But in the equipment management platform, we can re-carry out the visual design, so that workers and information management personnel in the most intuitive way to obtain the necessary information, to achieve the purpose of easy operation.

Figure 5 below shows the interface for viewing fault information:
In terms of overall layout, it can be divided into three areas to reduce the amount of information processing and cognitive load. The whole interface adopts the combination of pictures and texts, which reduces the depth of information processing and maximizes the efficiency of information acquisition.

5. An example of application
Take an auto parts manufacturing enterprise as an example, managers can monitor equipment real-time state, equipment maintenance process schedule and other relevant information. As a front-line workshop management system, the intelligent device management platform has its own unique Web management end and a more comprehensive mobile phone APP.

According to the platform managers can complete workshop equipment monitoring, fault repair service, process management, energy consumption under the management, production plan management, material management, and other daily management work, realize the integrated factory management from scattered to centralized management mode.

The application of the platform eliminates the bottleneck process and greatly improves the rate of qualified products. The number of finished products per day increased from 1168 to 1348, and the qualified rate increased from 97% to 99%; the construction of the platform improves the overall intelligent level of the factory, reduces the operating cost of the enterprise and improves the operating efficiency.

6. Conclusions
To sum up, the main research results of this paper are as follows:
(1) Through literature research and practical investigation, analyze and summarize common problems in equipment management of discrete manufacturing enterprises at present, and develop an intelligent equipment management platform for discrete manufacturing enterprises.
(2) The development architecture of intelligent equipment management platform was constructed. Collect real-time information of equipment and realize data informatization, which is helpful to improve the transparency of production and discrete manufacturing process.
(3) The equipment intelligent health assessment model is established. Through machine learning, convolutional neural network and other means to predict the functional status of the diagnostic equipment. Provide advice for the equipment maintenance strategy.
(4) Design the interface based on the principle of information processing economy. On the basis of improving the process execution efficiency, it further reduces the information load of workers in the production site, making the production easier.

References
[1] Chen X Y and Ren G Q 2020 Key technologies and development trends of intelligent manufacturing and robot application IOP Conf Series: EES 461 12-49
[2] Zhou J 2015 Intelligent Manufacturing---Main Direction of “Made in China 2025” CHIN J MECH ENG-EN 26 2273-84
[3] Li P X and Zhang C L 2019 Intelligent Manufacturing and Intelligent CNC Machine Tool China Southern Agricultural Machinery 50 15-16
[4] Tang T, Teng L, Wu J and Chen M 2018 Comprehensively Realizing Digitalization is the Only Way to Intelligent Manufacturing -- An Interpretation of "The Road to Intelligent Manufacturing: Digital Factory". CHIN J MECH ENG-EN 29 366-77
[5] Tao F 2017 Digital twin workshop: a new paradigm for future workshop CIMS 23 1-9
[6] Tao F, Cheng J F, Qi Q L, Zhang M, Zhang H and Sui F Y 2016 Digital twin-driven product design, manufacturing and service with big data 12th Int Conf on Frontiers of Design and Manufacturing (Shenyang: Natl Nat Sci Fdn China)
[7] Fang Y D, Zeng S H, Chen H and Mao X B 2016 The technical implementation of internet of things on the executive system of workshop manufacturing Manufacturing Automation 38
15-7, 32

[8] Sun S W and Hu G Q 2014 A study of discrete workshop material conveying system based on RFID internet of things *MANUF ENG* **11** 25-30

[9] Xu Z H, Zhang Z, Fang Z H and Cheng X M 2017 Design of Remote Management System for Power Supply of Industrial Equipment Based on Wireless Network Technology *Digital Technology and Application* **7** 174-5, 7

[10] Pan G F and Ji X 2018 Process management system for forging hydraulic press *J MECH DESIGN* **A1** 349-51

[11] Wang C Y 2019 Power consumption management system based on SECS/GEM standard *Shanxi Normal University*

[12] Agostino IRSa, et al. 2020 Forecasting models in the manufacturing processes and operations management: Systematic literature review *Journal of Forecasting*

[13] Lei Y G, Jia F, Lin J, Xing S B and Ding Steven X 2016 An Intelligent Fault Diagnosis Method Using Unsupervised Feature Learning Towards Mechanical Big Data *IEEE T IND ELECTRON* **63** 3137-47

[14] Kong F S 2019 Development of metric method and framework model of integrated complexity evaluations of production process for ergonomics workstations *INT J PROD RES* **57** 2429-45

[15] Yuan L J 2017 Research on 3d navigation design of human-computer Interaction interface *Southeast University*

[16] Hu J 2018 Research on interface Experience Design of Medical Devices based on cognitive Psychology *Zhejiang University*