Design of the Intelligent Manufacturing Demonstration System based on IoT in the Context of Industry 4.0

Yiyang Liu¹, a, Zenghui Li², b, Zhining Wang¹, c, Hongfei Bai¹, d, Yun Xing¹, e, Peng Zeng¹, f

¹The eighth Research Room Shen Yang Institute of Automation Chinese Academy of sciences Shenyang, China
²Academy of Information Science and Engineering Northeastern University Shenyang, China

a sialuiuyiyang@sia.cn, b lizenghui@sia.cn, c wangzhining@cau@126.com, d baihongfei@sia.cn, e xingyun@sia.cn, f zp@sia.cn

Abstract. With the concept of German Industry 4.0, the Chinese manufacturing industry is in a critical period of restructuring and upgrading. With the gradual change of Chinese manufacturing industry from the mass and mass to the niche, personalized stage, the traditional rigid production system couldn't make enough. This paper designed an Industry 4.0 intelligent manufacturing demonstration system based on Internet of Things. The system is based on the background of the model car assembly, which simulates the whole process of the delivery of the consumer from the single to the manufacturer. The vertical seamless integration of network production system is realized by getting through the information communication interface on the device layers between ERP and MES. The system adopts modular manufacturing mode, via WIA-FA and Software defined Control System technology, adjusting the production process dynamically, to achieve the function of scale production of customized products and the predictive maintenance of equipment etc. This system may reduce equipment downtime and improve equipment utilization, which solves the lower flexibility of the traditional rigid production system responding to the changing demands of design the production. It fully embodies the concept of Industry 4.0 in the smart factory.

1. Introduction

The Chinese manufacturing industry is in a critical period of restructuring and upgrading at present. With the concept of German Industry 4.0 in 2011, the standardized circuit diagram is published in 2013 and Industry 4.0 has formal became one national strategy [1-2]. The concept of Chinese Manufacturing 2025 has been also put forward in 2014, which is formal published in May 8, 2015. As the main direction of Chinese manufacturing, intelligent manufacturing will provide powerful technology supporting for changing from Made in China to Design in China and significantly enhance international competitiveness in manufacture industry [3].

In the recent years, because of the pattern of global industrial competition is undergoing tremendous changes. China is facing huge challenges as a manufacturing power. With the trend of population aging is continuously strengthening in China and the cost of Made in China is rapid increasing, so China is no
longer a cheap production base, meanwhile, Chinese manufacturing industry is at the stage of rapid development [4]. This prompts Chinese restructuring and upgrading in the manufacturing sector. For China, the ultimate goal of the restructuring and upgrading also points to intelligent manufacturing. Only in the way can deploy, integrate and utilize resources in wisely. In a more economical and convenient way of production to provide personalized products and services, thus gaining advantage in the fierce competition of the manufacturing industry in the future [5].

Chinese manufacturing changes gradually from the mass and mass to the niche, personalized stage at present, especially discrete manufacturing industry [6-7]. Consumers pay more and more attention to the personality features and tastes products. So the large scale customization and economical production of high customized products will be the main trend of discrete manufacturing in the future [8-9]. But the large scale and mass production models cannot meet this urgent need [10]. The traditional mass and rigid production system is specialized design for one or more products, whose mechanical structure, control system and network system are all rigid design without flexible and modular attributes. Once the product design and production requirements change, it will need a considerable method to adjust production system cycle and workload. So it can’t meet the rapid and large scale production of customized made up of many personalized configurations [11-12].

In order to solve the above problems, this paper put forward the design scheme of an industry 4.0 intelligent manufacturing demonstration system based on Internet of Things. This system can meet the personalized demands of customers in the maximal degree and produce highly personalized products on a large scale. It also realizes the management of product life cycle and the data standardization, so it shortens the cycle from design to production.

2. System architecture

2.1. System Overview
This paper designs an industry 4.0 intelligent manufacturing demonstration system based on Internet of Things. The system is based on the background of the model car assembly and simulates the whole process of the delivery of the consumer from the single to the manufacture. All steps are tight integrated in the whole system. Through the electronic business platform, consumers can match products and produce orders according to their favorite model and color. Subsequently, the order will be tight integrated to the system of manufacture’s background ERP, which will purchase materials and make preparations for manufacturing. Meanwhile, it makes production plans and all the relevant information of produce orders will instantly send to Manufacturing Execution System (MES). Through the manufacturing execution system connected with the workshop control system, it leads instrumented reconstructible intelligent production system and manufactures the model car that meet the consumer requirement, for fig.1.

This paper bases on the system of industrial internet of things and software defined management and control Technology. It not only covers from software to hardware but also manufactures personalized orders from consumers and orders are delivered to production delivery process. The vertical seamless integration of network production system is realized by getting through the information communication interface on the control system between Electronic Commerce, ERP, MES and other management software, which make personalized customized products manufactured quickly.
Meanwhile, through the reconfigurable wireless control network system defined by the self-designed software, it makes structural module of control system and dynamic reorganization as required. Besides, it constructs an ontology library for industry control based on the technology of research and development of digital factory modeling that is a virtual manufacturing system that corresponds to the actual physical system one by one in the information space. It makes production systems recombined quickly and adapts dynamically the changes of production requirements according to the way of software definition, which bases on virtual system and the technology of service management engine. It also solves the problem of poor flexibility in the design and production of requiring changes what is faced by traditional rigid production systems [13]. This system reflects fully the advantages of high individual customization, self-reconfiguration of production line, predictive maintenance of production equipment and other intelligent factories.

2.2. The Hardware Composition and Operating Principle of the System

In order to support the highly personalized customization of the system and the function of self-reconfiguration of line, the production line uses a modular manufacturing system, that is, flexible manufacturing system is divided into relatively independent modules and each module bears relatively stable function [14]. The modular production model makes the development of each module, the whole system design and fault diagnosis and maintenance easier. According to the immediate order information, it makes production more efficient by determining the bottleneck of the entire production line and scheduling each module flexibly. Through the modular production model, it combines the library of industrial controlling semantic ontology. When product changes or the production engineering is
When manufacturing system is not compatible with the requirements for changes of product, manufacturing system is redesigned at any time. According to a particular market or production need, it carries out the restructuring of the manufacturing process in a timely manner. The whole manufacturing system is composed of standard equipment and modular production units, which helps to eliminate island of automation and increase the reuse of machines. The flexibility in the manufacturing range helps to restructure production in a timely manner and adapts to the various targets of enterprise production. One of the decentralized results of modular manufacturing systems is the decentralization of system control functions, that is, each control module has its own control function.

This intelligent manufacturing demonstration system is an open set of equipment, which can select the type and number of component unit of equipment. The system consists of 7 work modules, as illustrated Figure 2.

The basic functions of each of its component work units are described below:
- Initialization of RFID: The management and assemble of chassis stereoscopic warehouse. According to personalized orders are generated by users in the electronic business platform, it generates a sequence containing all information of the order. The order information is recorded in storage module via the RFID reader. When the order is issued, the pallet enters this station to monitor the chassis material via WIA-FA industrial wireless networking technology. Placing the chassis on the pallet where the personalized is needed by robot, then enters the next station.
- The management and assembly of stereoscopic warehouse on the top of car: Material monitoring is carried out on the top of car cover by technology of WIA-FA. The robot assembles the top of cover of the personalized order requirements onto a pallet with a chassis.
- Laser scanning of front windshield dimension: After the order of the car is completed assembly, it comes to this station. It scans the front windshield for size by laser scanning and sands the windshield in turn at the next sanding station according to a different type of car.
- Roof spoiler sanding: The sanding station is composed of a three dimension simulation sander which is mounted on two AGV cars respectively. Sanding station are time-consuming when the order is surging or the original station is out of station and the car moves to ease the need of intelligent production.
- Appearance inspection: Before the product goes out of line, it inspects car type, color and size comparing with the personalized order and checks whether it meets the order requirement.
- Manual rework: Through the inspection of the last station, the unqualified production will enter the manual rework area and re-enter the test station after the manual maintenance or scrapped directly.
- Product blanking and warehousing: The product enters the station through appearance inspection and consistent with customer order.

The above 7 work units form a demonstration line as shown in Figure 3. The system changes the traditional rigid transformation, the design and construction cycle of the manufacturing system. It improves the flexibility of the manufacturing system, realizes the rapid system integration and improves the market competition power of the enterprise.
3. The System Of Systematic Technology

3.1. WIA-FA

The system is supported by high reliability and high real-time wireless communication technology WIA-FA for industrial applications. Among them, WIA-FA is the only international standard for IEC wireless technology for factory high-speed automatic control applications [16]. Through industrial wireless communication products, such as independent-developed industrial wireless router, industrial wireless switches, all internet wireless gateway based on the management and control of industrial SDN, it structures a product system of industrial internet of things. It also can perceive the information of vibration and temperature of production equipment, collect the information of production process at any time and realize wireless and modularization of network communication in high real-time and high reliability control system. It lays the foundation for interconnection of equipment, production information perception and flexible reconfiguration of control system [17].
3.2. Software Defined Management Control System
Based on semantic modeling technology, the system maps the equipment of actual production, sensors, materials and other physical entities to the information space. Thus, it constructs a virtual and digital production system corresponding to the actual system. And based on the dynamic service composition engine technology, the manufacturing process and production tasks are encapsulated. Namely, the interoperable interface between different protocol, different software and different system has been opened and the problem of cross system information integration has been solved [18]. Meanwhile, according to the product design and the changes in production demand, dynamic automatic reorganization of production engineering and tasks enables the production system to be quickly restructured in a software defined way, which completely changes the traditional rigid production mode. It greatly improves the adaptability and flexibility of the production system to different product designs and production requirements.

3.3. MES, ERP
The system includes ERP and MES software. After the customer selects the configuration of the personalized product, the order will be manufactured synchronously in the ERP system and the production material preparation and plan will be carried out. The corresponding production order will be delivered to the workshop management system (MES) at the same time and the production order will be delivered to the equipment. The corresponding production configuration parameter are identified through RFID information, thus it can perform the production of the corresponding configuration of the order, so as to achieve the vertical integration from the side of customer sales to the enterprise management and then to the production management layer and finally to the equipment layer.

3.4. Cloud Manufacturing Platform
The system deploys the e-commerce platform and the equipment predictive maintenance system on the cloud manufacturing service platform. Consumers can match model car configurations on the electronic business platform according to preferences, such as model, color etc. Then it creates orders for personalized products and triggers the scheduling and manufacturing of production systems. The equipment predictive maintenance system is based on the industrial wireless internet of things real-time acquisition of temperature, vibration and other equipment health status information, analyzing and determining the equipment’s health status, fault type, fault location, remaining life cycle and other information. Then it guides the maintenance staffs to carry out the initiative maintenance in a preventive manner, which greatly reduces the downtime caused by the malfunction and improves utilization ratio of equipment.

4. System function

4.1. The Function of Personalized Customization
Customers through the electronic business platform to freely select product configuration, generate personalized product orders. The order is synchronized production in the MRE system and is immediately distributed to the EMS system for scheduling. Then order scheduling information is delivered to the control system via the PCO interface. Through the RFID system, each production unit can communicate with products and materials and it assembles individual parts for the order or completes personalized processing tasks. And it monitors the production status and production schedule of the workshop equipment in real-time. Eventually, the intelligent factory quickly completes the single production task of the personalized model car.

4.2. Dynamic reorganization function
The structure of production system is dynamically adjusted and restructured according to order change. Specifically, it is embodied in part of the work unit of production system equipped with an AGV, which makes it modular and mobile. The dynamic services synthesis engine dynamically monitors the status
information of the production equipment through the industrial internet of things. According to the change of order, the bottleneck of production system is predicted. When the number of orders increases rapidly, firstly, the dynamic service synthesis engine analyzes and determines the bottleneck production units. Then the virtual manufacturing system is constructed through semantic technology to query and correlate related standby devices. After finding the spare production unit, it automatically restructures the production system structure. Based on software defined re-configurable control network and spare unit communication, it controls the movement of the spare units to the side of the bottleneck unit. And through the interfaces encapsulated by cross system and protocol, the control system automatically reconfigured and configured makes the spare units fit into the production system. That is plug and play, immediate sharing of production tasks and solving production bottleneck. After the rush of orders, for the sake of energy saving, the dynamic service composition engine automatically moves the spare units out of the production system and transfers them to the backup area.

4.3. Predictive Maintenance Function

The predictive maintenance function is embodied in the dynamic adjustment of the production system based on predictive maintenance. The predictive maintenance system deployed on the cloud manufacturing service platform senses and detects the temperature, vibration and other health information of the equipment in real-time through the industrial wireless internet of things. And it synchronously analyzes and determines the health condition of equipment, fault type, fault location, remaining life cycle and other information. When the device is judged to fail in the near future, the dynamic service composition engine will query the spare device through the virtual manufacturing system. Then the automatic control of the spare unit moves to the side of the fault equipment and automatically completes the configuration of the control system, making the spare units integrate into the production system quickly. Meanwhile, the equipment is automatically removed from the production system and informs and guides the operation and maintenance personnel, timely troubleshooting equipment. After the equipment has been completed and repaired, the dynamic service synthesis engine then restores the equipment into the production system and transfers the backup units to the standby area. Based on WIA-FA wireless communication technology, it monitors the information of device status in real time and makes real-time analysis and diagnosis of the date on the HANA cloud platform, predicts the fault and life cycle of the equipment, reduces equipment downtime due to failures and improves production efficiency.

5. Technical application

The system embodies the idea of an intelligent factory in industry 4.0, with many of the key technologies, such as perception technology of industrial wireless communication based on WIA-FA, industrial SDN technology. The management and control system defined by the software has been applied in the camera module assembly workshop in Sunny Optical Technology (Group) Company Limited. As shown in Figure 4, in this application, the perception and transmission of the AGV control instructions are realized by using WIA-FA technology and equipment. The industrial SDN technology is used to realize the rapid integration of field communication protocol and heterogeneous equipment and realize the wireless transmission between the work unit information and the main control. Using software defined management and control system, the distributed intelligence of production units is realized. Aiming at the customization characteristics of camera group and the requirement of frequent change production, it can adaptively adjust production processes, robots and production unit tasks, and the logistics scheduling of parts and finished products, which greatly improved production efficiency and intelligence of the whole system.

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Figure 4. Diagram of Intelligent Manufacturing Solution’s Application

6. Conclusion
Intelligent manufacturing system based on industrial of things can not only quickly complete the scale production of customized products, but also can be dynamically reconstructed and optimized according to the order requirements and real-time changes of equipment status, which makes the flexibility and intelligence of production system greatly improved. Meanwhile, through the predictive maintenance of the equipment, the downtime of the equipment can be greatly reduced and the utilization ratio can be improved. The supporting technical system and products of the system will provide technical standards and solutions for exploring intelligent manufacturing that meets the needs of China, which promotes the digital transformation of enterprises and plays a positive role in promoting.

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