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Value co-creative manufacturing system for mass customization: Concept of smart factory and operation method using autonomous negotiation mechanism

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Abstract

This paper proposes smart manufacturing systems for tailor-made rubber runninng shoes production. With the development of information and communication technology, manufacturing machines and products embedded with intelligent sensing devices can connect to each other, and acquire the current conditions and changes of each machine and product. Drastic changes in production fields based on the IoT (Internet of Things) technology have been occurred, and then several countries and companies have been tackling the development of smart manufacturing system such as Industrie 4.0 and Industrial Internet Consortium (IIC). This paper focuses a concept of value co-creation for improving users' delights, and describes the constructed smart factory model system based on Cyber-Physical Systems (CPS). The current conditions and changes of the simulated production machines and products can be acquired using RF-ID systems. Our smart factory is implemented using a multi-agent system and managed in accordance with the mechanism of the autonomous negotiation such as a combinatorial auction mechanism.

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Keywords: IoT, Mass-customization, Cyber-Physical Systems

1. Introduction

Recently, many manufacturing machines and sensing devices excluding communication equipments can connect Internet network because of the rapid development of information and wireless communication technologies. The environment of the IoT (Internet of Things) based on these technologies has been established[1], and then concepts of smart manufacturing system based on the IoT technology are performed by Industrie 4.0 (Germany) [2], IIC (Internet Industrial Consortium, USA)[3], IVI (Internet Valuechain Initiative, Japan)[4] and so on.

In our research, a domestic research project, "Research on Innovative Design/Manufacturing Methodology of Tailor-made Rubber Products and Socio-Economic Value Co-Creation with Reactive 3D printer" is conducted in Strategic Innovation Program (SIP) with the support of Cabinet Office, Government of Japan[5]. In this project, the users' values for the products such as design and usage condition are considered and then the smart manufacturing system with users' values is proposed[6].

Especially this paper focuses on production sheduling and proposes an optimizaiton method for production scheduling. Mass customized manufacturing system[7] can respond variety of customers' demands, and achieve high production efficiency with low-cost production. To realize the mass-customization, customer involvement is important[8].

Therefore this paper focuses on a combinatorial auction[9, 10] which is imitating a negotiation process as a framework to claim customers' demands simulatively, and proposes an optimizaiton method for production scheduling by negotiation between manufacturers and customers.

Soles of the shoes are tailored or custom-made in this research. This study is the first step to actualize the value co-creative manufacturing system for tailor-made shoes by a reactive 3D printer[11].

In this paper, a concept of our smart factory system is introduced, and an operation method using autonomous negotiation mechanism is described with numerical experiments. Our smart factory defines that the manufacturing schedules can be changed autonomously and automatically using current conditions acquired with ICT technologies.

2. Smart Factory Demo System

In the constracted smart factory, the target product is sports shoe, called "Work".

Proposed smart factory has a scheduler, two simulated processing machine (machine number $m = 1, 2$), one 3D printer

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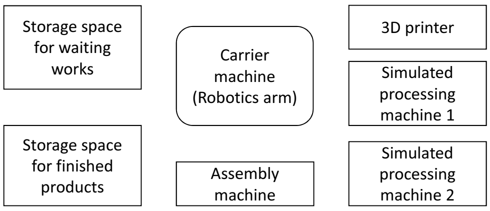

Fig. 1. Schema of proposed smart factory

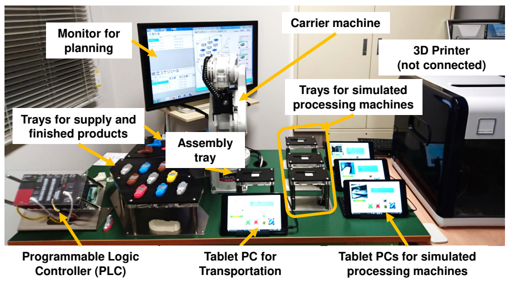

Fig. 2. Picture of the smart factory

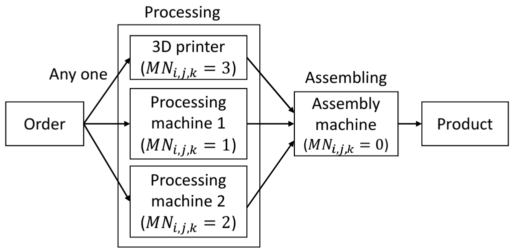

Fig. 3. Production flow

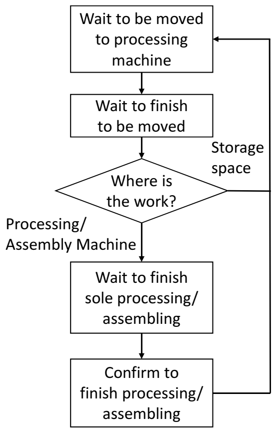

Fig. 4. Transition of work

(machine nubmer $m = 3$), one assembly machine (machine number $m = 0$) and one carrier machine. Fig. 1 shows schema of proposed smart factory. Fig. 2 is the picture of our smart factory.

Components of the smart factory and these behavior are as follows:

2.1. *Scheduler*

The smart factory has a scheduler. The scheduler recieves information about customers who ordered a product in the term, and establishes production schedule. In this smart factory, lack of information does not occur. The detail of method for scheduling algorithm is discribed in chapter 3.

Fig. 3 shows the production flow from raw materials to finished products. A product consists of two parts. Processing machine makes soles in the first process. Assembly machine assembles soles and upper parts. The factory has sufficiet parts stocks. Established schedules can be confirmed by using the monitor for planning of Fig. 2.

2.2. *Work*

In this smart factory, "Work" as a product simulates the shoe. The Work has two parts: upper and sole parts in common with real shoes. Each Work has RFID tag, and keeps the information such as Work number, schedule, and so on. Possible states and the transition is shown in Fig. 4.

2.3. *Facilities*

The smart factory has one carrier machine. The machine can carry one work at a time. Carring time is shorter than processing and assembling time, then carring time can be ignored in this study.

The smart factory has two processing machines. There are no difference in each machine performance. The machine can process parts of one work at a time.

The smart factory has one 3D printer as shown in Fig. 2. The 3D printer can process parts of one work at a time. The 3D printer can process soles which is ordered by the customer who wants processing machine to process soles. On the other hand, there are soles which only 3D printer can process.

The processing time by the 3D printer is longer than that by a processing machine, when they process the same soles.

Even if the 3D printer and a processing machine process same soles, processing time by the 3D printer is longer than processing time by a processing machine.

The smart factory has one assembly machine. The assembly machine can assemble shoes of one work at a time.

Proposed smart factory is demo system. Each machine can process or assemble automatically without fail.

3. Scheduling

In order to meet the customer requirements with high efficiency and effectiveness, customer involvement should be essential[8].

Our research group focuses on customer involvement in scheduling[12]. This paper proposes a production scheduling method by using combinatorial auction[10] modelling negotiations between manufacturer and customers. The combinatorial auction has two advantages. At first, the combinatorial auction