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Real-time information driven intelligent navigation method of assembly station in unpaced lines

Yingfeng Zhang *, Jianxue Xu, Shudong Sun, Teng Yang

Key Laboratory of Contemporary Design and Integrated Manufacturing Technology, Ministry of Education, Northwestern Polytechnical University, Xi'an 710072, China

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ABSTRACT

This paper considers the assembly station as a breakthrough to improve the real-time information driven control and optimization of assembly process in unpaced asynchronous line. By adopting automatic identification technologies, the overall architecture of the real-time intelligent navigation of assembly station (INoAS) is put forward. Under this architecture, three core services, namely the real-time assembly operating guidance service (OGS), collaborative production service (CPS) among assembly stations and real-time queuing service (RQS) of the jobs at each station, are designed to provide optimal and dynamical navigation for assembly activities for each station. Then, the disturbances and exceptions could be timely captured by installing the INoAS at each station, and the operating guidance, collaborative production information sharing and real-time queuing could be easily achieved. The presented architecture and services of INoAS will facilitate the real-time information driven process monitor and control between the line and stations.

1. Introduction

With the increasing competition in the global marketplace, manufacturing enterprises have to strive to become responsive to business changes which have further impacts upon production goals and performance during the production stage. Assembly lines are flow-line production systems which are of great importance in the industrial production of high quantity standardized commodities and more recently even gained importance in low volume production of customized products (Boysen, Fliedner, & Scholl, 2008). According to the classification of assembly systems (Altiparmak, Dengiz, & Bulgak, 2007), it can be classified as two types, namely paced (synchronous) and unpaced (asynchronous) systems. In synchronous assembly systems, the transfer of all assemblies occurs simultaneously at fixed time intervals and the whole system is placed by speed of transfer mechanism. In asynchronous assembly systems, the assemblies can move independently and can be queued in front of a workstation.

In unpaced lines, workpieces are transferred whenever the required operations are completed, rather than being bound to a given time span. After transference the station continues to work on a new workpiece, unless the preceding station is unable to deliver (Boysen et al., 2008). In unpaced lines, the production rate is no longer given by a fixed cycle time, but is rather dependent on the realised task times. Contrasts to paced lines, unpaced lines do not have a fixed cycle time. Then, the real-time execution status of stations in unpaced lines will provide important information for the line managing. Therefore, in this research, we focus on the unpaced asynchronous assembly line.

Recently, the rapid progress of IT (Information Technology) and Auto-ID techniques provides assembly line system with strong supports to implement real-time information based optimal management. Although the promotion and application of the management systems such as MES (Manufacturing Execution System) (Möllmann, 2012), ADS (Assembly Digitalization the System) (Zeng, Chang, & Mo, 2007), LP (Lean Production) (Schaerli, 2004), JIT (Just In Time) (Emde & Boysen, 2012) etc. have brought many creative strategies and models for production management, it is still difficult to solve the stochastic problems during the production stage. The main reason is that the upper level management cannot get the changing information of the execution in production process immediately, and the real-time information driven navigation services is lacked. When exceptions occurs, it will spread gradually because of the lack of timely, accurate and consistent manufacturing information and the information sharing capabilities between the upstream and downstream stations, further exac-

* Corresponding author at: B509, Hangkong Building, Northwestern Polytechnical University, No. 127, Youyi West Road, Xi'an, Shaanxi, China. Tel.: +86 13991135396.

E-mail address: zhangyf@nwpu.edu.cn (Y. Zhang).

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erbating the disturbance of the assembly line. Therefore, it is essential for manufacturers to upgrade the management methods with advanced IT and IoT (Internet of Things) technologies to improve the quality and efficiency of the assembly.

Real-time manufacturing information collecting and dynamic optimization for shop-floor received wide attention by both academia and industry with the rapid development of automatic identification technology (Huang, Wright, & Newman 2009; Keskilammi, Sydänheimo, & Kivikoski, 2003; Zhang, Huang, Ho, & Sun, 2011). The MIT Auto-ID Laboratory (http://web.mit.edu/lmp/research/manufacturing.html) is dedicated to creating the Internet of Things (IoT) using RFID and Wireless Sensor Networks. Huang, Zhang, and Jiang (2007) implement RFID technologies to capture the real-time information of workers, machines and materials of fixed-position assembly line. Zhang et al. develop a RFID-based smart Kanban (Zhang, Jiang, & Huang, 2008), a WIP (Work In Progress) management framework (Zhang, Qu, Ho, & Huang, 2011a), and an agent-based smart gateway (Zhang, Qu, Ho, & Huang, 2011b) for implementing the real-time shop-floor management.

Despite of significant progress achieved in the above researches in monitoring and optimization of the assembly process, the following challenges still exist for unpaced asynchronous line management:

(1) Due to the lack of real-time manufacturing information at the assembly station side, it is difficult to provide the operators with correct and real-time operation guidance. For example, some operation errors caused by improper operation or wrong installation of materials cannot be found and eliminated in time.
(2) The assembly process involves a number of stations and operators. Currently, when the exception occurs at any assembly station, it is difficult to timely transmit the exception to the relevant stations, which could result in further exacerbating influence among the stations.
(3) Currently, the task queue of each station is static. The order of the queue cannot be adjusted by the assembly station if the manufacturing environment has changed. Therefore, at the station level, how to re-queue the order of the tasks of each station to response the changed production environment in time should be considered.

To address the above questions, this paper considers the assembly station as a breakthrough to improve the real-time information driven control and optimization of assembly process in unpaced asynchronous line. By adopting automatic identification technologies, the overall architecture of the real-time intelligent navigation of assembly station (INoAS) is put forward. Under this architecture, three main services, namely the real-time assembly operating guidance service, collaborative production service among assembly stations and real-time queuing service of task, are designed to provide optimal navigation for assembly activities of each assembly station. Then, for the assembly line level, the disturbances and exceptions could be timely captured and reduced based on the INoAS of each station. The presented architecture and services of INoAS will facilitate the real-time information driven process monitor and control between the line and stations.

The rest of the paper is organized as follows. Section 2 reviews the related literature. The overall architecture of the real-time intelligent navigation of assembly station (INoAS) is described in Section 3. The three main services, namely the real-time assembly operating guidance service, collaborative production service among assembly stations and real-time queuing service of task, are discussed in Section 4. In Section 5, a case study is used to illustrate the implementation of the proposed INoAS. The conclusion and future works are presented in Section 6.

2. Literature review

Two streams of literature are relevant to this research. They are RFID-based applications in assembly line and assistant services for assembly line.

2.1. RFID-based applications in assembly line

In recent years, the applications of RFID technology have been widely investigated by researchers. A growing number of organisations have reported a detailed discussion on RFID-enabled tracking, monitoring and guiding in assembly line(Huang, Li, Yuan, Gao, & Rao, 2012; Huang, Zhang, Chen, & Newman, 2008; Liu et al., 2012; Makris, Michalos, & Chryssolouris, 2012; Wang, Luo, & Wong, 2010; Zhang, Ong, & Nee, 2011).

According to Liu et al. (2012), traditional paper-based or phone-based manual management will block the tracking and collection of real-time production data and make it impossible to realise a real-time production management due to time-consuming, error-prone and frequently damaged. The authors presented a production management system (PMS) integrated with an RFID enabled real-time data capturing system to facilitate the dynamically changing manufacturing activities. The application conducted by the authors proved that the effectiveness and quality are obviously improved. Similarly, Wang et al. (2010) developed an RFID-assisted object tracking system for a flexible assembly line. Two tracking methods were discussed to process the object tracking. As the data was tracked and collected, users can carry out a lot of implements in assembly line. Most of the implements mainly focus on the assembly monitoring and guiding. Huang et al. (2012) presented a RFID enabled real-time monitoring system (RRMS) to improve visualisation and controllability of the painted body storage (PBS). The authors emphasised that PBS has become efficient bottleneck of production in automobile factory since PBSs in many enterprises are still manual or semi-manual monitored and controlled. Through the RRMS, the PBS was developed into an efficient, open and controllable system. RFID-based monitoring technology helps to achieve a transparent assembly line, whereas guiding services will bring real-time assembly navigation for the operators to avoid mistake and promote assembly efficiency. Zhang et al. (2011) reported a study on implementing the RFID technology in the application of assembly guidance in an augmented reality environment. The RFID technology and sensor technology were implemented to detect the operator's activity to facilitate just-in-time information rendering and intuitive information navigation. Different from providing guidance for manual operation, Makris et al. (2012) presented a RFID based integration driven framework for enabling the parts to perform robotic assembly operations in a random mix manufacturing. The RFID infrastructure was applied to sense the newly arriving parts to be assembled and via the integration driven framework, the robots are able to recognize the parts and perform cooperative operations. More recently, Zhang et al. (2014) and Zhang, Huang, Sun, and Yang (2014) propose a framework of IoMT (The Internet of Manufacturing Things) for capturing and integrating the real-time manufacturing information based on Auto-ID technologies.

2.2. Assistant services for assembly line

For the purpose of increasing the effectiveness of assembly line, many advanced solutions were published by researchers recently. Due to the diversified and specialized of consumers demand for products, the assembly process have become increasingly complicated and widely ranged. Some novel researches such as real-time assembly guidance system (Gupta, Fox, Curless, & Cohen, 2012;