Production-Intralogistics Synchronization in Physical Internet-enabled Manufacturing Systems

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Introduction

The widespread adoption of Physical Internet (PI) technologies has promoted data and information sharing, real-time communication, and networking in the industry, transforming the operations are managed and performed in many fields such as manufacturing. For example, the production operations and intralogistics operations in a shop floor are inherently coupled and entangled by physical flow (raw materials, components, sub-assemblies, or work-in-progresses). In traditional management mode, the production and intralogistics processes are managed separately by different departments without considering global benefits because the information cannot be timely collected and shared among the department to make informed decisions. Nowadays, advanced Industry 4.0 technologies such as Industrial Internet of Things (IIoT), digital twin, and cloud computing are gradually adopted by manufacturers to upgrade their factories. The sheer amount of data are real-timely collected, transmitted, and analyzed so that the information barriers among different department of a single factory are removed. Therefore, it is possible to manage the production and intralogistics processes in a synchronized manner by leveraging the strengths of real-time data, to improve the overall production efficiency and resource utilization.

The Flexible Assembly Line

The investigated workshop is called flexible assembly line (FAL). FAL combines the features of flexible/hybrid flow shop (FFS) and traditional assembly lines. The FAL integrates the feature of parallel operations in FFS into the assembly line. As the figure depicts, there are a series of workstations that contain a work area for operations and a buffer area for placing the required tool and parts corresponding to the specific operation. Mobile assembly tables and part trolleys are adopted to replace the conveyor belt and line side stocking in traditional assembly lines. Each product is carried by an assembly table to go through all workstations in a unidirectional flow. All operations of a single product are performed at the table. Parallel operations are allowed at the workstation, which means one job can overtake another if necessary. Required parts are consolidated in the part trolleys, and logistics operators take the loaded trolleys to the designated workstation as scheduled. Now the manufacturer is faced with two new problems:

• What IIoT devices to deploy and what data to capture? How to utilize the real-time data for decision-making under various spatiotemporal uncertainties (e.g., equipment failure, stochastic operational time, new job arrivals) and minimize their adverse effects?

• How to manage and perform the production-intralogistics operations in a matched, coordinated, and synchronous manner to ensure a smooth workflow and high throughput with improved customer satisfaction?

Production-Intralogistics Synchronization in FAL

The structure of FAL is flexible to achieve dynamic line balancing; thus, the focus of the production management in FAL has to switch from balancing the line to managing the production-intralogistics operations in a matched, coordinated, and synchronous manner to ensure a smooth workflow and high throughput. The paper defines it as the PIL synchronization problem. As shown in the figure, the decisions are to make a production plan/schedule for assembling request products and corresponding intralogistics plan/schedule for each workstation to fulfill the demand and optimize selected measures regarding customer satisfaction, throughput, and the PI synchronization degree.

5-Phase Implementation of PI-enabled Synchronizd PiL System

This study investigates the production-intralogistics (PiL) synchronization problem in a new assembly system. A 5-phase framework is proposed to implement the synchronized PiL in the manufacturing system. It has made pioneer work in investigating the production-intralogistics synchronization problem in PI-enabled manufacturing environments and contributes to the methodological research in utilizing real-time data to facilitate operations management in the context of Industry 4.0.

Conclusion

This study investigates the production-intralogistics (PiL) synchronization problem in a new assembly system. A 5-phase framework is proposed to implement the synchronized PiL in the manufacturing system. It has made pioneer work in investigating the production-intralogistics synchronization problem in PI-enabled manufacturing environments and contributes to the methodological research in utilizing real-time data to facilitate operations management in the context of Industry 4.0.