Towards Smart Factory for Industry 4.0: A Self-organized Multi-agent System with Big Data Based Feedback and Coordination

Shiyong Wang[1], Jiafu Wan[1,*], Daqiang Zhang[2], Di Li[1], Chunhua Zhang[1]

[1]School of Mechanical and Automotive Engineering, South China University of Technology, Guangzhou, China
[2]School of Software Engineering, Tongji University, Shanghai, China

Abstract: The proliferation of cyber-physical systems introduces the fourth stage of industrialization, commonly known as Industry 4.0. The vertical integration of factory to implement flexible and reconfigurable manufacturing systems, i.e., smart factory, is one of the key features of Industry 4.0. In this paper, we present a smart factory framework that incorporates industrial network, cloud, and supervisory control terminals with smart shop-floor objects such as machines, conveyers, and products. Then, we give a classification of the smart objects into various types of agents and define a coordinator on cloud. The autonomous decision and distributed cooperation between agents lead the process achieving high flexibility. Moreover, this kind of self-organized system leverages on the feedback and coordination by the central coordinator in order to achieve high efficiency. Thus, the smart factory is characterized by the self-organized multi-agent system assisted with big data based feedback and coordination. Based on this model, we propose an intelligent negotiation mechanism for agents to cooperate with each other. Furthermore, the study illustrates that complementary strategies can be designed to prevent the deadlocks by improving the agents' decision and the coordinator's behavior. The simulation results assess the effectiveness of the proposed negotiation mechanism and deadlock prevention strategies.

Keywords: Industry 4.0, smart factory, cyber-physical system, multi-agent system, deadlock prevention

1. Introduction

The application of automation and information systems such as enterprise resource planning (ERP) and manufacturing execution system (MES), significantly improves factory productivity. However, the current industrial production faces many critical challenges. The end users continuously require highly customized products in small batches. In addition, the current production paradigm is not sustainable [1]. On one hand, the impact of industrial production on environment in terms of global climate warming and environmental pollution is severe. On the other hand, the consumption of non-renewable resources such as petroleum and coal increases and the industry suffers an ever-shrinking workforce supply because of population aging. Therefore, industrial processes need to achieve high flexibility and efficiency as well as low energy consumption and costs. Many advanced manufacturing schemes have already been proposed aiming to overcome the drawbacks of the current production lines, e.g., the flexible manufacturing system (FMS) and the agile manufacturing system (AMS). Among these schemes, the multi-agent system (MAS) is the most representative one [2], where the manufacturing resources are defined as intelligent agents that negotiate with each other to