The 50th CIRP Conference on Manufacturing Systems

Manufacturing system on the cloud: a case study on cloud-based process planning

Xi Vincent Wang*, Mohammad Givehchi, Lihui Wang

Department of Production Engineering, KTH Royal Institute of Technology, Sweden

* Corresponding author. Tel.: +46-736-441-433; fax: +46-8-210-851. *E-mail address:* wangxi@kth.se

Abstract

The modern industry requires the next generation of manufacturing system to be intelligent, flexible, and interoperable. The manufacturing system also needs to offer better performance with lower cost. The huge success of cloud computing brings the opportunity to the manufacturing systems with high scalability, productivity and agility. It also provides practical solutions to the small and medium-sized enterprises with elastic investment solutions. In a cloud manufacturing system, the manufacturing resource and capability are provided in the service-oriented architecture as cloud services. In this research, the practical models of the cloud-based system are investigated, and distributed process planning services are developed accordingly. The proposed infrastructure is evaluated via a case study in which the industrial demonstrators are practised in the cloud as one specific type of process planning service.

1. Introduction

The trend of the modern production system is clear in recent years, which is a collaborative environment supported by Computer-Aided software (CAx) and networks. Conventional paper-based technical documents have been gradually replaced by the data files from computer-aided software applications, e.g. Computer-Aided Design (CAD), Computer-Aided Process Planning (CAPP), Computer Aided Manufacturing (CAM), and Computer Numerical Controller (CNC). These data files are exchanged over the network to support the complex interactions between stakeholders like multiple departments, providers and contractors. In this type of environment, the manufacturers are required to provide shorter responding time and higher agility to the fast changing market and dynamic task assignments.

CAPP is a critical function bridging CAD, CAM and Manufacturing Execution Systems (MES). At the middle position of the so-called CAD-CAM-CNC chain, an advanced CAPP system can provide adaptability, responsiveness, robustness and sustainability of the manufacturing system. Even though the CAPP system has been widely researched and developed in both academia and industry, the conventional CAPP system is incapable of meeting the manufacturing trend mentioned above. The heterogeneous data environment generated by multiple stakeholders and dynamic contexts in modern manufacturing market put the conventional CAPP system in the bottleneck position in the middle of the CAD-CAM-CNC chain. Thus it is necessary to improve the performance of current CAPP systems towards the dynamic context between product design, tooling and manufacturing companies. CAPP applications need to adopt continuous technological improvement and innovation of companies. Among multiple automation and information technologies, Function Block (FB) and cloud show promising potential to enhance the functionality and capability of CAPP solutions. The rest of this paper is structured as follows. Section 2 discusses the related research work on FB and cloud technology. Section 3 proposes the cloud-bade process planning system. Section 4 and 5 introduce the distributed mechanism based on FB and its execution. The proposed

system is validated in section 6 via an industrial case study. Finally, Section 8 concludes the paper with discussions.

2. Literature Review

2.1. Cloud-based system

In recent years, the Information and Communication Technology (ICT) changed the landscape of the manufacturing industry. Conventional paper-based technical documents are replaced by data files processed computer-aided design and manufacturing software applications. Traditionally, the production work is centralised in the same location or shopfloor close to the optimised resource or logistic centre. Nowadays, the production departments, providers and contractors can be distributed globally based on their expertise and specific requirements. The product data and document, e.g. process plans, can be easily exchanged and transported over the network, which enables collaborative and dynamic interactions between manufacturing stakeholders. However, current CAPP systems are challenged by the heterogeneous environment, which consists of multiple CAD, CAPP, CAM and CNC applications that are developed on different platforms using different programming languages and communications protocols. Eventually, it is very difficult for these applications to interface with each other due to various interfaces and data formats. Among multiple interoperable solutions, cloud technology is a promising option to combat the challenge mentioned above.

The definition of cloud was initiated by NIST. In their definition cloud is a computing model provides a shared pool of configurable computing resources for ubiquitous, convenient, on-demand network access [1]. These computing services can be provided and released with minimal management effort or service provider interaction. Then the researchers in manufacturing discipline extend the computing service to the manufacturing context. The concept of Cloud Manufacturing (CM) is proposed to adopt cloud computing technology in the manufacturing context and to improve the current manufacturing systems [2-7]. In general, there are two types of cloud manufacturing approach, which is directly offering manufacturing software on the cloud as a service, and providing manufacturing capabilities as an entirely new type of cloud service [8].

The deployment of CM requires implementation of each manufacturing application in the manufacturing cloud. In an ASME (American Society of Mechanical Engineers) web seminar, it was specifically pointed out that cloud providers can support manufacturing applications with cheaper and more scalable access [9]. Some industry has already recognised the importance of the cloud approach. NVIDIA, one of the largest Graphics Processing Units (GPU) providers, has developed a cloud-based GPU that is capable of delivering virtualised workstation performance and capabilities to desktops [10]. It is predicted that cloud-based CAD systems will be available in a very near future [11, 12]. In fact, Autodesk can already provide cloud-based applications to support collaborative design [13]. Via the

environment called Autodesk 360, users can access some simulations such as mechanical simulation for linear and nonlinear static stress and dynamics, computational fluid dynamics analysis for fluid flow and thermal simulations, rendering, design optimisation, energy analysis, and structural analysis.

From the cooperation perspective, Tai and Xu [14] discussed the complexity of collaboration in a CM environment. Cooperation is classified into four types, i.e. random, operational, tactical and strategic. In a matured CM environment, the system is required to process all types of collaborative interactions at multiple levels, including typical manufacturing applications such as simulation and optimisation.

Chai et al. [15] established a High-Performance Cloud Simulation Platform for efficient execution and problem solving for complex simulation tasks. A simulation task is developed as a cloud computing service. Computing performance can be improved by the collaboration of computing nodes in cloud computing approaches.

To facilitate a cloud-based on-line optimisation system, Chandrasekaran et al. [16] developed a system named cloud computing-based optimisation (CCBOD). In CCBOD, the main server keeps the repository of data and carries out optimisation. Its data input and retrieval mechanisms were developed to cooperate with an online optimisation process. However, the method of promoting an optimisation process in the cloud is not as clear in the report, and this system is not capable of identifying user/data in various domains.

2.2. Process Planning

Process planning in machining generally refers to those preparatory tasks from design to manufacturing of a mechanical product, such as process sequencing, machine and cutter selection, tool path planning, operation optimisation, NC code generation, as well as setup/fixture planning, etc. Since the introduction of computers to the field of process planning in the 1960s, subsequent research has been numerous. By the end of 1980s, more than 156 computer-aided process planning (CAPP) systems have been reported in the literature survey by Alting and Zhang [17]. CAPP domain is surveyed and reported by Marri et al. [18] in 1998. Xu et al. [19] conducted a more recent survey on the related research, including object-oriented approach, neural network-based approach, Petri net-based approach, genetic algorithm-based approach, multi-agent bidding-based approach, constraint-based approach, feature-driven approach, and information and knowledge management. The reported approaches in [19] and their combinations have been applied to several specific problem domains, such as setup planning, process sequencing, tool selection, cutting parameter selection, and tool path planning, to name a few. More recently, research efforts on process planning have shifted to distributed process planning [20], planning and scheduling integration [21], reconfigurable process planning [22], and intelligent process planning based on capacity profile of machine tools [23]. The common objective of the recent research is to generate robust, precise yet flexible process plans, effectively.