ICMS: A Cloud-Based System for Production Management

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Abstract. Modern production industry calls for a new generation of production systems. As a novel information technology, Cloud provides new service models and business opportunities to manufacturing industry. In this research, a Cloud-based manufacturing system is developed to support distributed production management. Recent Cloud manufacturing approaches are reviewed. The Cloud-based production management and localisation mechanisms are proposed and evaluated during case study. It is shown that the Cloud-based manufacturing system is capable of supporting distributed and customised production services and managements.

Keywords: Cloud Manufacturing, Cloud, Production Management, Cloud Production, ICMS

1 Introduction

In recent years, Cloud has become a popular technology which gains huge market success globally. Cloud concept indicates a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [1]. It provides elastic and flexible supports for service-oriented production models. Based on NIST’s definition, Xu [2] extended the Cloud concept to manufacturing, which is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable manufacturing resources (e.g. manufacturing software tools, manufacturing equipment, and manufacturing capabilities) that can be rapidly provisioned and released with minimal management effort or service provider interaction. In practice, it is possible to utilise Cloud model to improve the performance of current production systems. In this paper, Cloud-based manufacturing research is reviewed, and a Cloud-based system is developed to support flexible, customised and sustainable production managements at high level.

adfa, p. 1, 2011.

2 Literature Review

Recently, Cloud-related production research has been conducted world-widely to explore Cloud-based manufacturing models and solutions. In general, these research works can be categorised into two types, i.e. Cloud computing in manufacturing industry, and Cloud manufacturing systems. In this section, these two types of research are reviewed and discussed respectively.

2.1 Cloud Computing in Production Industry

The Cloud technology offers on-demand service access and resource pooling on the computing market. Thus it is a natural thinking to utilise Cloud applications in manufacturing directly. In this type of research, computer-aided or web-based manufacturing applications are deployed in the computing Cloud, which can be considered as a *manufacturing version of Cloud computing*. These applications are implemented at two levels of system, which matches two service levels of Computing Cloud, i.e. Service and Platform levels.

At the *Software* level, production software-as-a-service is particularly suitable for Small and Medium-sized Enterprises (SMEs) since it offers on-demand services with lower entry barriers and initial investments. Manufacturing software applications, e.g. Design [3, 4, 5], Visualisation [6], Simulation [7], and Enterprise Resource Planning (ERP) [8, 9], were deployed on the Cloud to realise remote access and flexile billing.

At the *platform* level Cloud computing technologies were adopted to support the whole supply chain [10, 11]. Qualitative results supported the assertion that information processing requirements and information processing capability affected intention to adopt Cloud computing. Multiple models were developed to examine both information processing requirements and capacity, which eventually influenced the firm's desire to adopt Cloud-based supply chain innovations [12, 13, 14, 15].

2.2 Cloud Manufacturing Systems

In this kind of Cloud approach, the production system is established based on service-oriented architecture of Cloud system. It reflects the *infrastructure* level of Cloud approaches. Li et al. [16, 17, 18] first suggested a high-level manufacturing system based on Cloud. The manufacturing Cloud aimed to share and utilise manufacturing abilities over a configurable and virtual manufacturing network [19, 20]. Lu et al. [21] proposed a hybrid Cloud structure that allowed companies to deploy different cloud modes for their periodic business goals. During the implementation of Cloud manufacturing systems, it needs to be noted that the performance of the system also needs to be monitored and measured in a standardized and quantifiable manner [22].

Wang and Xu [23, 24, 25] proposed a Cloud-based Manufacturing system to support production service integration and interoperability. The manufacturing Cloud was also extended to the remanufacturing sector for electronic wastes managements [26, 27]. However, despite Cloud-based manufacturing achievements above-mentioned, there is still a lack of research in a Cloud system which is able to support production managements as a whole solution. Thus in this paper, the Interoperable Cloud Manufacturing System (ICMS) is presented along with the management structure and modules.

3 ICMS for Production Management

The ICMS system architecture is illustrated in Fig. 1. Physical production resources are integrated in the system in terms of production services. The *Cloud layer* works as the service coordinator and supervisor of the whole production system. Cloud users and administrators access to Cloud over the network, with the help of standardised Application Programming Interface (API). Inside the Cloud layer, the Smart Manager mechanism is the core execution module which interacts with Cloud users, and executes the service packages accordingly. The Cloud database maintains information regarding Cloud user, Cloud service packages, service histories, and most importantly resource profiles that are utilised to schedule and execute Cloud services. These specifications guarantee the capability, availability and feasibility of production facilities at the Physical Resource level.

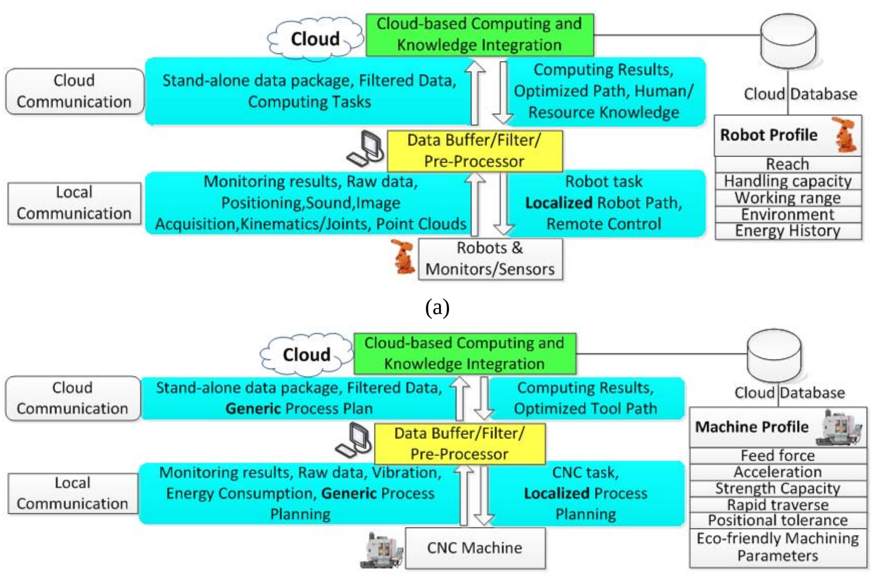
At the *Physical Resource Layer*, production tasks assigned by Cloud are taken by control units of production devices, e.g. Robot-as-a-Service (RaaS) unit and Machine-as-a-Service (MaaS) unit. Robot operation systems (ROS) and CNC controllers interpret the production documents from Cloud into process working steps and then controlling signals that directly drive physical devices eventually. In this top-down approach, human operators are also able to interact with the Cloud layer via devices like smart phones, PCs and PDAs. Real performance on shop-floor is monitored by range cameras, sensors, smart meters and device controllers. Monitoring results are fed back to Cloud for service supervision and future improvements. Thus, it forms a closed-loop production system.

Between the Cloud layer and Physical Resource Layer, *Local Servers* are optional due to two main reasons. First, during the monitoring process, shop-floor sensors generate huge amount of data dynamically, e.g. power, current, vibration, and force readings. It is inefficient to stream all raw data to Cloud directly, since most contents are not essential but generate heavy network traffics. Thus a local PC or server is necessary in this case to play as the data filter and pre-processor. Raw data is locally filtered and processed by the server, and then uploaded to the Cloud. It thus balances bandwidth loads and Cloud data management.

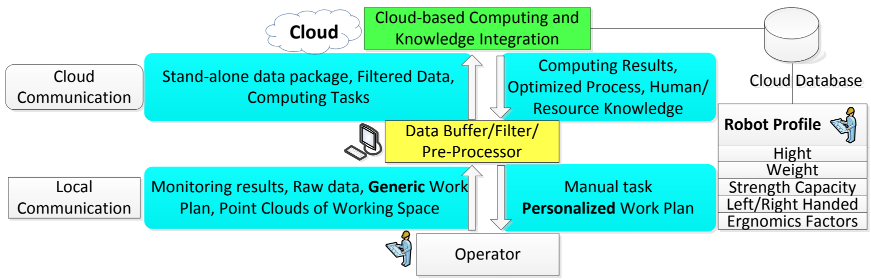
Second, in some cases the local server needs to work as an interface between Cloud layer and Physical Resource Layer. In practice, many commercial controlling units (ROS and CNC controller) are designed as a semi-closed system. To some degree it guarantees the robustness and safety of the unit. However these systems are difficult to interact with the Cloud directly. Thus in these cases, a local PC or server is needed to interact with operation systems at low level via user interface on one hand (over local network in most cases), and communicate with the Cloud via the Internet on the other hand.

Fig. 1. ICMS System Architecture

The communication methods between production facilities and Cloud are shown in Fig. 2. Localised production plan is possible thanks to Cloud databases and local monitoring devices. For instance, detailed industrial robot specifications are kept in the Cloud, including reach envelope, handling capacity, working range and energy history (Fig. 2a). When path planning and optimisation is needed, the Cloud is able to pull the data regarding positioning, kinematics/joint status from shop floor and profile specifications in Cloud database. Then the Cloud is able to take heavy computing task and output optimised path to the robotic cell.



(b)



(c)

Fig. 2. Localised Production Plan based on Cloud

As a specific type of resource, human resource can be integrated with ICMS also, considering physical and ergonomic factors of individual operators specifically (Fig. 2c). Exclusive human factors differ among individual operators, e.g. height, weight, strength, handedness (left or right), and other ergonomic factors. Before an operator starts to work, his or her staff barcode can be quickly scanned and the personalised ergonomic specification can be identified in Cloud database. Based on these profiles, a personalised work plan is generated. It is especially helpful during the implementation of human-robot collaborations, since robot movement strategies can be adjusted based on human factors aforementioned.

4 Implementations and Case Study

To validate and evaluate the proposed production system based on Cloud, ICMS is implemented based on previous research works [28, 29, 30]. In the Cloud that hosts virtual environments and service modules. 32 cores and 132 gigabyte memories are deployed to provide the computing power for the proposed system. In this research, java applet is utilised to develop the user interface since it offers light weight environment of ICMS and mobility among different systems/environments. MySQL databases are established to maintain production specifications mentioned above.

To secure the safety of the Cloud system and privacy of users, Secure Sockets Layer Virtual Private Network (SSL VPN) is utilised to provide protected remote access to the Cloud. ICMS's Cloud production service flow is shown in Fig. 3. A user firstly accesses to the Cloud environment through VPN over the Internet. Command dashboards are developed for Cloud administrators and users respectively as indicated in Fig. 1. A Cloud administrator is able to manage broadcasted services, customer orders and user profiles remotely.

After the product 3D design is uploaded to the Cloud, the user's requirements of machining service are interpreted by the smart manager mechanism. Multiple candidate solutions are identified in Cloud database. Among multiple machining providers, the user is able to filter the candidate pool based on different preference criteria e.g. price, duration and quality priority.

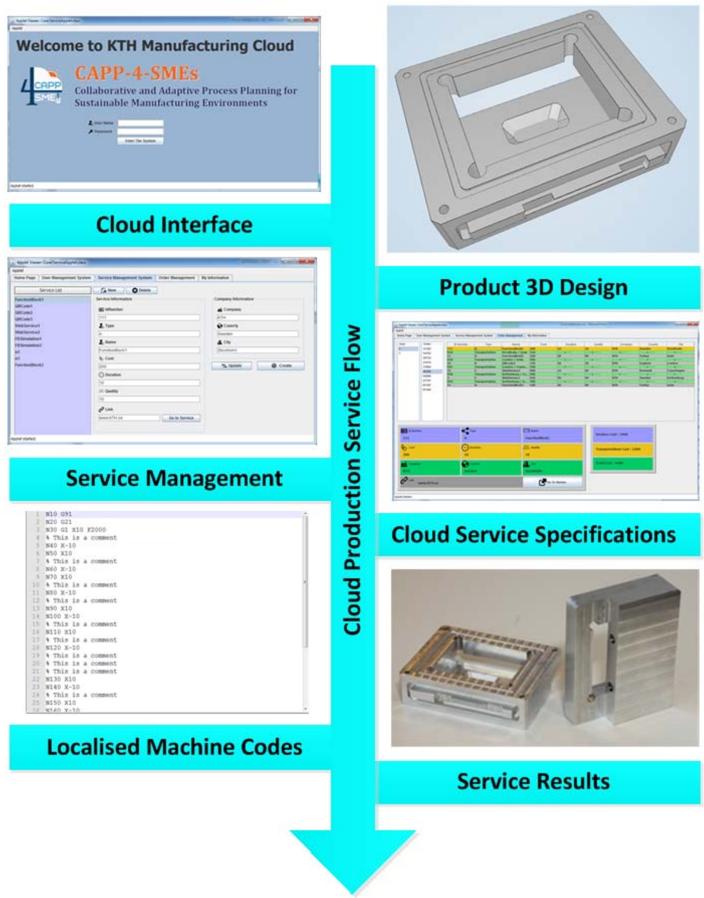


Fig. 3. Cloud Production Service Flow

Being part of the Cloud service, process planning is generated based on generic feature information from the product 3D design. After the machining service provider is determined, generic production document is converted to localised NC codes which are specifically amended for the chosen machine and cutters based on technical specifications maintained in physical resource database (Fig. 2). It forms a from-design-to-production environment on the Cloud.

5 Conclusions

Morden production industry calls for a new generation of production systems. Nowadays fast-changing ICT technologies have dramatically altered the way people think and do business. However, most of current production systems still function as twenty years ago. As a disruptive technology, Cloud offers an environment with remote access, resource pooling and customisation. In this research, a Cloud-based system is developed especially for production management. Integration mechanisms of physical resources are proposed, and customised production planning methods are developed and validated by the case study.

It has to be admitted that security concerns exist among current and potential Cloud users due to possible data leakage and destructive cyber-attack. In this research, SSL VPN is thus utilised to maintain security and safety of Cloud system and data. In the future, Cloud-based production systems can learn from successful web-based businesses, e.g. online banking, stock market and e-logistics. To guarantee the privacy of Cloud services, more information technologies can be adopted in the future, including encryption, private keys, firewalls and so forth.

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