KNOWLEDGE ACQUISITION FOR CLOUD MANUFACTURING

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ABSTRACT
This paper proposes a methodology for knowledge acquisition in cloud manufacturing (CMfg) system which refers to a new knowledge based manufacturing paradigm. In view of the practical needs, the proposed methodology is designed to be cross-domain. Non-automatic and semi-automatic knowledge acquisition methods were used with the assistant of the automatic one. Details over knowledge acquisition for CMfg were presented, as well as the proposed methodology. System architecture for the knowledge acquisition tool was also put forwards with analysis and illustration.

Keywords: knowledge acquisition, cloud manufacturing, system architecture

1. INTRODUCTION

Cloud Manufacturing (CMfg) refers to a new service-oriented intelligent manufacturing paradigm based on knowledge with high efficiency and low consumption. It is a confluence of multiple disciplines, such as networked manufacturing, web services, cloud computing, cloud security, high performance computing, Internet of Things and so on, which is pushing the manufacturing to be agile, virtualized, intelligent, service oriented, integrated and green (Bo Hu Li, Lin Zhang, and Xudong Chai 2010; Bo Hu Li, Lin Zhang, and Shilong Wang 2010; Fei Tao, Lin Zhang, and VC Venkatesh 2011; Lin Zhang, Yongliang Luo and Fei Tao 2012). During the lifecycle of CMfg system, knowledge is recognized as the key to carry out the intelligent cloud services. It can be classified into five parts including domain knowledge, task knowledge, case knowledge and service description knowledge as required. Concretely, it may appear in the form of service labels, service rules, service ontology, case descriptions, intelligent algorithms, and so on (Anrui Hu and Lin Zhang 2012). From the manufacturing resources' perception to its virtualization package and access, from the cloud services' description to its combination, from the cloud services' scheduling to its optimizing, from the system's fault-tolerant management and task migration to its business process management (Fei Tao, Lin Zhang, and Hua Guo 2011), all the vital parts of CMfg seem to rely on knowledge firmly. When perceiving the manufacturing resources, the system builds up mappings between various resources and their corresponding virtual resource pools while packages the resources as services. When constructing the manufacturing cloud, the system labels each cloud service with its sort, promulgator, application implement and usage before stores these messages into knowledge bases. When matching and combining the cloud services, the system works smoothly owing to the efficient pre-analysis of the users' demands and service descriptions. When dispatching the cloud services, the system makes solutions with the help of the service rules and description labels and optimizes them on the basis of some specific tactics to avoid service scheduling conflicts. During the fault-tolerant management, the system first evaluates the loads of both its physical and virtual modules and stores the results into knowledge bases. Then all the indexes are accessed and abnormal modules are migrated virtually to maintain the load balance while the system is on run. During the business process management, the system first puts some basic flow descriptions of the cloud services into knowledge bases as rules. Then it decomposes the submitted tasks into smaller ones according to the rules and optimizes the combination of the services with some corresponding algorithms. Solutions are returned to the users at last. Obviously, CMfg is a modern manufacturing paradigm depending on the application of knowledge, which is rest upon the accurate knowledge acquisition.

For half a century, knowledge acquisition has restricted the development of knowledge based systems. Many experts and scholars have done a lot of researches on this domain. For example, Cairo and his group proposed (Osvaldo Cairo 1998; Osvaldo Cairó and Silvia Guardati 2012) a graphical logic language for knowledge expression and designed a methodology for multiple-domain knowledge acquisition, which is achieved basically by setting up communications between domain experts and knowledge engineers. Tang and his team (Yuan Yan Tang, Chang De Yan, and Ching Y. Suen 1994) divided documents into geometric layer and logic layer, and mapped the information mined from the geometric layer into the logic layer to accomplish automatic knowledge acquisition. Chen (Ping Chen and Chris Bowes 2012) proposed a word sense disambiguation method based on automatic knowledge acquisition in which he used the DepScore function and GlossScore function together with the most-frequent-sense method to determine the feasible word sense in a given English context. Yu and his partners (Daren Yu, Qinghua Hu, and Wen Bao 2004) developed a way to acquire knowledge from quantitative data by merging the rough set and fuzzy clustering algorithms, which has been successfully used in the diagnosis of the vibration fault of turbine, etc. However, due to the differences in knowledge definition, these researches are always limited in some specific domains and their strategies are not available for knowledge acquisition in CMfg system.

The rest of the paper is organized as follows. Section 2 studies knowledge acquisition for CMfg and proposes a potentially feasible solution for it. Section 3 presents an architecture view for the proposed solution. Finally, conclusions are drawn in Section 4.

2. THE PROPOSED METHODOLOGY

As a new intelligent manufacturing paradigm, the realization of CMfg is bound up with knowledge acquisition. How to acquire knowledge effectively is the premise of knowledge based application. Generally, knowledge acquisition is achieved in the following three ways: non-automatic acquisition, semi-automatic acquisition, and automatic acquisition (Na Li 2009).

(1) The non-automatic knowledge acquisition is usually up to domain experts' own oral instructions.

(2) The semi-automatic acquisition adopts the man-machine interactive mode to help extracting knowledge from domain experts.

(3) On contrast to the former two ways, automatic knowledge acquisition shows strong capabilities to sum up and extract new knowledge from the system's self-learning process automatically.

Considering the practical situation of CMfg, the non-automatic and semi-automatic knowledge acquisitions are primarily introduced into the manufacturing process with the assistant of the automatic knowledge acquisition (Anrui Hu and Lin Zhang 2012). Firstly, the system acquires domain knowledge, reasoning knowledge, and task knowledge through non-automatic acquisition and stores them into knowledge bases. Then it refreshes the existing knowledge as well as gains new service description knowledge by means of semi-automatic acquisition. At last, case knowledge are achieved from knowledge both obtained non-automatically and semi-automatically in its self-learning process automatically. Knowledge storage is also setup. The basic flow of the described knowledge acquisition for CMfg is depicted in Fig. 1, which acts as a dynamic cycle.

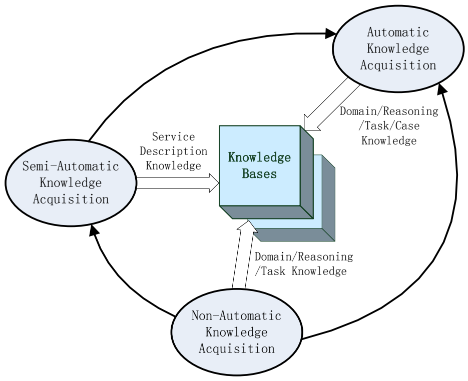

Figure 1: Process of Knowledge Acquisition in Cloud Manufacturing.

2.1. Non-Automatic Knowledge Acquisition

A non-automatic knowledge acquisition model for CMfg is presented in Fig. 2. It is the most crucial step in knowledge acquisition for CMfg, which is mostly oriented to domain knowledge, reasoning knowledge, and task knowledge. The traditional non-automatic knowledge acquisition tends to be adapted only to problem solving in some specific domains and have less trouble in knowledge fusion. However, CMfg is an integrated service paradigm, from which users are always looking forwards to complete manufacturing schemes. In fact, a whole manufacturing process often consists of small multiple processes, which requires varieties of professional knowledge. For instance, from design to implementation, from component manufacturing to assembly line working, from machine debugging to safe testing, from coating to after-sales services, a car manufacturing process can be rather complex. It seems that using only single domain knowledge may be likely to lose some important manufacturing details and lower the quality of the service combination, which will lead to resource wastes.

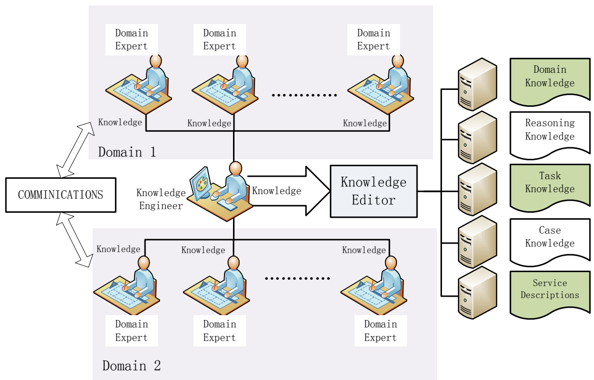

Figure 2: Non-Automatic Knowledge Acquisition in Cloud Manufacturing.

Due to the relatively closeness among knowledge from different domains, non-automatic acquisition is expected to solve the cross domain problems in CMfg. Therefore, the cloud service providers are asked to gather experts from multiple domains together to face-to-face communications and discussions. Then the knowledge engineers fuse the derived knowledge according to the discussions, and ask for the experts to evaluate the quality and feasibility of the fusion results. After that, they file the feasible knowledge in some structured forms and deposit them into knowledge bases. Seeing from the rapid evolvement of manufacturing resources, the cloud service providers should regularly repeat the above process to renew and maintain the knowledge bases and reassess the existing manufacturing knowledge as well.

2.2. Semi-Automatic Knowledge Acquisition

In the process of non-automatic knowledge acquisition, the structures and contents of the knowledge to be obtained are unknown before as well as the specific demands. Nevertheless, semi-automatic knowledge acquisition achieves the structured knowledge with clear demands from domain experts via man-machine interaction. In CMfg, semi-automatic knowledge acquisition is mainly used for getting service description knowledge. Sometimes it also helps updating the existing knowledge with certain templates. A brief architecture model is described in Fig. 3.

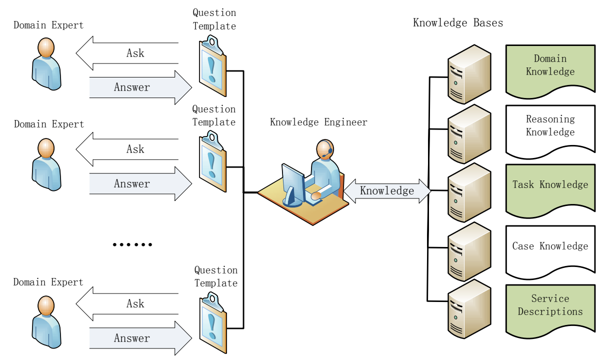

Figure 3: Semi-Automatic Knowledge Acquisition in Cloud Manufacturing.

Knowledge engineers get in touch with domain experts on line to achieve knowledge from them directly by taking prompts, showing guides and using question and answer method, and then finish the knowledge storage. To combine with the semi-automatic method in knowledge acquisition, CMfg can balance the high costs bringing by the non-automatic mode and improve the economic benefits of the whole.

2.3. Automatic Knowledge Acquisition

Automatic knowledge acquisition has been widely considered as the top level acquisition mode in knowledge acquisition as well as the most difficult bottleneck to break through. Compared with non-automatic knowledge acquisition, its difficulties are not only referring to the unclear demands for knowledge but also the ambiguity existing in the acquisition process. In CMfg, automatic knowledge acquisition is also supposed to be cross-domain. It deals with domain knowledge, reasoning knowledge, task knowledge and case knowledge primarily. A model is built up in Fig. 4.

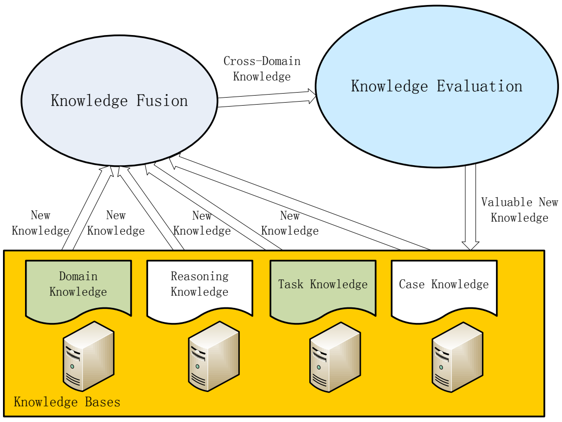

Figure 4: Automatic Knowledge Acquisition in Cloud Manufacturing.

Small knowledge bases published in the manufacturing cloud modify and refresh their existing manufacturing knowledge dynamically by certain strategies and algorithms, and then fuse the new knowledge produced during the previous process with each other. At the meantime, the system evaluates the quality of the fusion based on some assessment mechanism given by domain experts before, and pushes the valuable new cross-domain knowledge into designated knowledge bases via some dynamic correlation and fuzzy clustering methods. However, as a result of the heterogeneity and magnanimity of knowledge in various domains as well as the poor assessment rules for knowledge qualification, to fully fulfill the automatic knowledge acquisition for CMfg without employing the other two modes seems to be next to impossible. Starting from the reality, automatic knowledge acquisition is more appropriate to play an auxiliary role instead of working as the core supporting way to help improve the service efficiency of the whole.

3. THE SYSTEM ARCHITECTURE

In the paradigm of CMfg, the knowledge acquisition tool is supposed to be composed of the following four layers: the knowledge storage layer, the logic interface layer, the application interface layer and the human interaction layer. An overall architecture is viewed in Fig. 5.

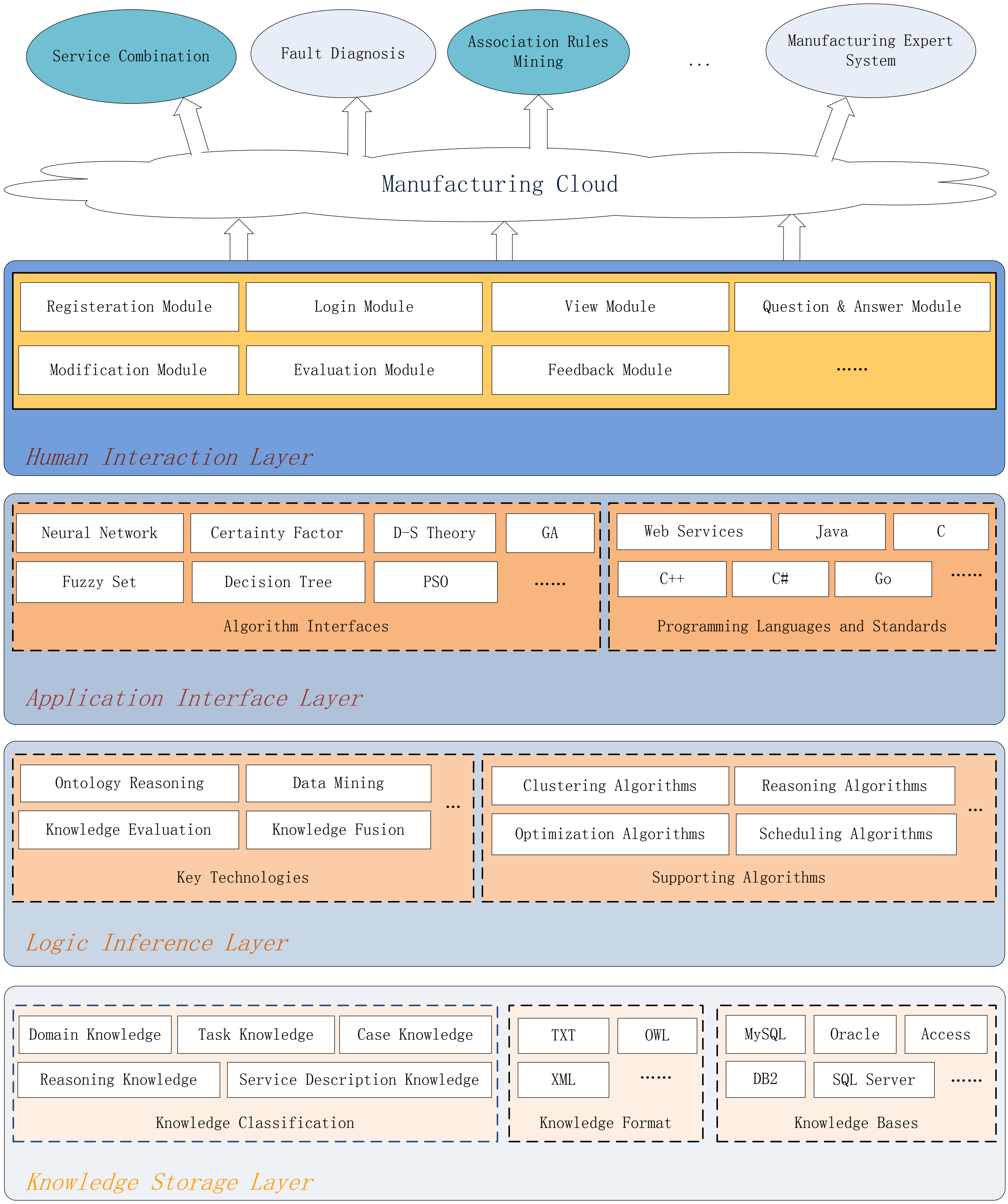

Figure 5: Architecture View of Knowledge Acquisition in Cloud Manufacturing.

3.1. Knowledge Storage Layer

The knowledge storage layer has a double-layer structure, including the index layer and the knowledge layer. The knowledge layer is composed of small knowledge bases published in the manufacturing cloud. The index layer is used to store description labels of each knowledge base and update them dynamically through some inner strategies. In the storage of knowledge, the new knowledge catches its membership notification by matching with labels in the index layer, and then knowledge bases in the knowledge layer distinguishes and receives different kinds of knowledge in the way of verifying these notification. The system updates the label layers at the same time.

3.2. Logic Reasoning Layer

The logic layer encapsulates the inference engine for knowledge acquisition in CMfg, which consists of the intelligent reasoning algorithms library, the intelligent optimization algorithms library (F Tao, D Zhao, YF Hu, and ZD Zhou 2008; Fei Tao and Lin Zhang 2012; Fei Tao, Yuanjun Laili, and YL Liu 2013; F Tao, YJ Laili, L Xu, and L Zhang 2013; YJ Laili, F Tao, and L Zhang 2013) and the ontology reasoning machine and so on. In the process of automatic knowledge acquisition, the system updates and fuses the existing manufacturing knowledge by calling some high performance algorithms and logic strategies.

3.3. Application Interface Layer

The application interface layer provides general interfaces for calling algorithms and logic strategies in the logic reasoning layer under Web service. Web service is a kind of modular component which is language and platform independent. It can be used to realize the combination of various algorithms feasibly by standardizing the input and output interfaces accompanying with their description messages. The standardization of the application interfaces may contribute to developing the performance of the knowledge acquisition in Cloud Manufacturing. Moreover, the application interface layer enhances the extensibility of the knowledge acquisition tool.

3.4. Human Interaction Layer

The human interaction layer offers I/O interfaces for both domain experts and knowledge engineers. It is mainly made up of the modification module, the question and answer module, the evaluation module and the feedback module and so on.

4. CONCLUSIONS

Cloud Manufacturing is a modern service-oriented intelligent manufacturing paradigm, which is based on knowledge. In the lifecycle of cloud manufacturing, the key to improve the quality of cloud services is the accurate knowledge acquisition. However, due to the highly heterogeneity in knowledge representation, knowledge acquisition has been extensively recognized as the kernel and bottleneck of knowledge based systems. In no doubt, it is going to be one of the most important technologies in the future development of Cloud Manufacturing.

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