

Cloud Manufacturing Service Selection Model Based on Adaptive Variable Evaluation Metrics

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Abstract. Efficient solution for Cloud Manufacturing (CMfg) service optimal-selection plays an increasing critical part in CMfg systems as an ever-growing number of CMfg services are aggregating in a CMfg platform. In most current methods, a set of relatively fixed quality of service (QoS) indicators are adopted to deal with the optimal-selection for different types of CMfg services. However, this often leads to low accuracy and flexibility, especially when cloud users' requirements involve different CMfg services with respective individualized characteristics. This paper presents evaluation metrics pool based CMfg service selection model (CSS-P), a framework of CMfg service selection that introduces an evaluation metrics pool as well as a new service selection mechanism based on adaptive variable evaluation metrics. Adaptive individualized metrics contribute to improving the accuracy and flexibility of CMfg service matching and selection, and better meet the customized needs of cloud users.

Keywords: Cloud Manufacturing · Service-oriented manufacturing · Service selection · Adaptive variable evaluation metrics

1 Introduction

Against the background of the in-depth development of global industrial chain, manufacturing industry is transforming from traditional production-oriented mode to high value-added service-oriented mode [1]. Driven by the rapid development of information technology and advanced manufacturing mode, a new manufacturing paradigm as well as a new integrated technology, Cloud Manufacturing [2–7], is taking its shape gradually. CMfg is a service-oriented net-worked manufacturing model. By providing various manufacturing resources and capabilities as standard manufacturing services, CMfg makes it possible to achieve high utilization and on-demand use of manufacturing resources and capabilities conveniently and efficiently during the whole lifecycle of a product [2]. In addition, reliable and high-quality manufacturing services in CMfg platform will definitely benefit different customers with individualized requirements. Under the centralized management of a CMfg platform, various heterogeneous manufacturing resources and capabilities could be virtualized and encapsulated as CMfg services with

standard interfaces, thus different cloud users could request and invoke the customized CMfg services for product design, simulation, and fabrication on demand.

Numerous manufacturing services are aggregating in CMfg platform and becoming accessible to customers with various manufacturing requirements, there raises the concern over CMfg service optimal-selection. As one of the key issues as well as an essential supporting technique for CMfg platform, the CMfg service optimal-selection problem has attracted broad attention. A number of optimal-selection research works on manufacturing resource and manufacturing service have been carried out in the scenarios of advanced manufacturing systems. Existing researches on manufacturing resource and manufacturing service optimal-selection process focus on the decision model and the corresponding solving algorithm. Compared with optimal-selection model, it seems that researchers pay much more attention to high efficient intelligent solving algorithms.

Actually, the challenge to CMfg service optimal-selection lies in that how to design efficient model to meet consumers' customized demands for CMfg services, which is critical to the performance of a CMfg platform as well as to user satisfaction [8]. Current research fruits regarding such models mainly include QoS based model [9, 10], energy-aware resource service scheduling model [11], as well as QoS and energy consumption based service optimal selection model [12]. In practical terms, Tao et al. [13] studied the manufacturing grid resource service scheduling problem by introducing a new concept, trust-QoS. Measurement and evaluation approaches for trust-QoS are given in the context of manufacturing grid system. In order to achieve optimal allocation of the computing resources in the scenario of CMfg environment, Laili et al. [14] proposed a comprehensive optimization model with computation, communication and reliability constraints considered. In [9], Huang et al. presented a service composition selection model based on QoS for CMfg system. Then a chaos control mechanism based optimization algorithm is given to address the proposed optimal-selection model. In addition, Cheng et al. [11] investigated the energy-aware CMfg service scheduling mechanism based on a utility evaluation process. Taking energy consumption, cost, as well as risk for the providers, the consumers, and the operator into consideration, a comprehensive utility model is established for the manufacturing resource service scheduling process.

While these approaches address specific issues successfully in corresponding application scenarios, much more work need to be done when we face the personalized evaluation indices for CMfg service as well as reuse of CMfg service evaluation historical knowledge. The majority of existing CMfg service optimal-selection models usually employ a set of uniform metrics of QoS indicators, e.g., service time, cost and quality grade, for the evaluation process of all different types of CMfg services. However, relatively fixed metrics often leads to an overlook of the difference among different types of CMfg services that belong to different stages (product design phase, simulation phase, production phase, testing phase, etc.) of a product life cycle. For instance, parts processing services require more emphasis on product qualification rate, while simulation services need to focus on simulation accuracy and credibility. In fact, a CMfg platform should discover and select the services based on individualized evaluation indicators. In other words, it is more practical to design CMfg service optimal-selection model by employing variable QoS metrics. Besides, a CMfg platform can be regarded

as an ever-growing knowledge base from another perspective. The CMfg platform could accumulate a large amount of historical service transaction data. The abundant knowledge contained in historical service cases has great potential for a CMfg platform to pick up the most suitable QoS indicators for different CMfg services [15], enabling intelligent discovery of adaptive evaluation metrics for specific service. In fact, adaptive individualized metrics contribute to the improvement of accuracy and flexibility of CMfg service matching and selection, which better meet the customized needs of CMfg service consumers. So far, there still lacks a theoretical framework that could support CMfg service optimal-selection based on adaptive variable evaluation metrics.

That is to say, absent from the trend is the adaptive evaluation metrics for CMfg service. Thus, there is a need to develop a framework for CMfg service optimal-selection process with adaptive variable evaluation metrics considered. To address these issues, this paper presents CSS-P, a CMfg service selection framework that introduces an evaluation metrics pool as well as a new service selection mechanism based on adaptive variable evaluation metrics. By reusing the historical data of CMfg service transactions, the CMfg service evaluation metrics pool is able to provide adaptive assessment indices for different CMfg services. Moreover, the operational mechanism of CMfg service evaluation metrics pool is illustrated in detail.

The remainder of the paper is organized as follows. Section 2 is the framework of CMfg service selection based on evaluation metrics pool. Section 3 presents the detailed description of CMfg service evaluation metrics pool as well as its dynamic operational mechanism. Section 4 concludes the work with recommendations for future studies.

2 CSS-P: Framework of CMfg Service Selection Based on Evaluation Metrics Pool

The users submit their manufacturing service requests to the CMfg platform and then publish these requirements to the CMfg task publication center. Through CMfg task decomposition system, the service requests are decomposed into a series of corresponding atomic subtasks which can be finished by certain CMfg services. In general, the basic decomposition structures for CMfg task could be classified into four modes [12], i.e., sequence mode, circular mode, selective mode and parallel mode. More over, the CMfg task decomposition system converts the subtask requirement into standard description form (Fig. 1).

In the meantime, the manufacturing resource owners, either individuals or enterprises, publish their manufacturing resources to the CMfg platform via CMfg service publication center. The techniques of IoT and the relevant interfaces are utilized to perceive manufacturing resource [6]. Then, the virtual manufacturing resources are encapsulated into CMfg services. The corresponding standard CMfg service information is stored in the CMfg service information center.

In order to provide CMfg services for service users according to their individualized requirements, the CMfg platform intelligently selects services from the CMfg service information center for the subtasks generated in the CMfg task decomposition process. By invoking the similarity matching algorithms, the CMfg service matcher matches the

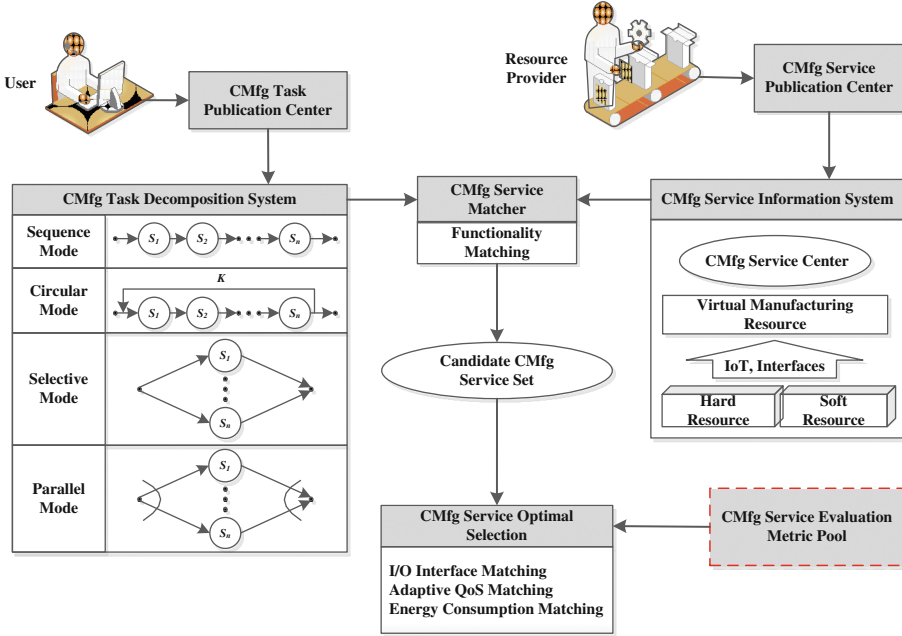


Fig. 1. Frame diagram of CSS-P

requested service information with each published CMfg service extracted from CMfg service information center. After the functionality matching step, each subtask obtains a candidate CMfg service set.

As there may exist a lot of services for a certain subtask according to the functional characteristics matching results, it raises the concern over CMfg service optimal selection. A CMfg service evaluation metric pool is introduced to achieve service optimal-selection according to their adaptive evaluation metric assigned by the pool. The detailed operational mechanism of the CMfg service evaluation metric pool will be presented in Sect. 3. The CMfg service optimal-selection module selects the optimal service through I/O interface matching, adaptive variable QoS matching and energy consumption matching. Note that the individualized assessment indices of each qualified CMfg service in the matching processes are provided by the evaluation metric pool.

3 Operational Mechanism of CMfg Service Evaluation Metrics Pool

For the sake of picking a suitable CMfg service which providing both high quality and low energy consumption service from the candidate CMfg service set for a certain CMfg service requirement, the quantitative evaluation metrics of CMfg service are indispensable. Existing works on resource service assessment, whether QoS based or energy consumption oriented, possess the fixed quantitative assessment indices which neglect

the difference among the varied resource services. By utilizing intelligent inference algorithms, the CMfg service evaluation metric pool customizes evaluation metrics for CMfg service according to the accumulated knowledge in the pool as well as the specific demands of the service user. At the same time, new CMfg service types and fresh evaluation metrics are added to the evaluation metric pool constantly through the implementation of machine learning algorithms. The brief working flows of the CMfg service evaluation metric pool are described as follows:

1. The detailed description information of the candidate CMfg service is presented to the CMfg service evaluation metric pool. Next, the system matches the service type of the input CMfg service with the historical service types in the evaluation metric pool. There are two possible options according to the matching result (Fig. 2).

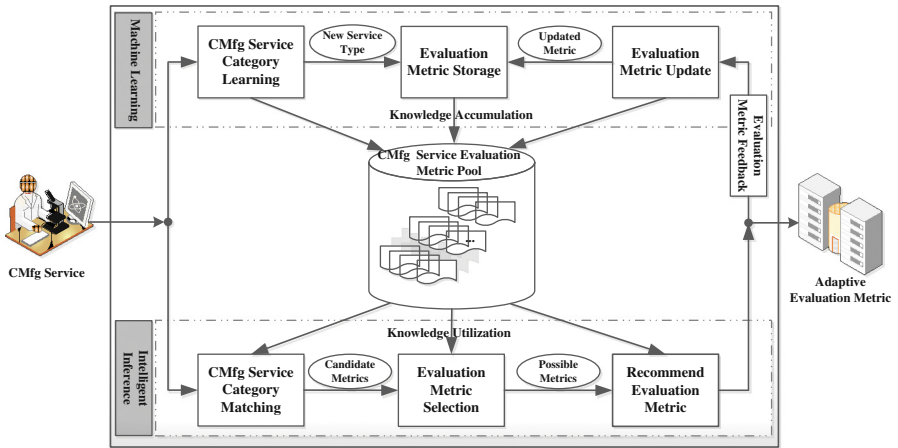


Fig. 2. Operational mechanism of CMfg service evaluation metrics pool

2. If the input CMfg service acquires a matched service type from the CMfg service evaluation metric pool, then the historical assessment indices of the specific type of CMfg service are listed as the candidate metrics of the input service. As one kind of service probably get several quite different indices, the evaluation metric selection process choose the most promising metrics in the light of a statistical analysis of the historical records of the service users, which generating the possible metric set. In addition, the customer of the input CMfg service perhaps pays extra attention to some special aspects of the service. With user's concerns taken into account, the adaptive evaluation metrics are finally identified. In short, the adaptive evaluation metrics for CMfg service take the individuality of the service, the specific requirements of the customer and the solving complexity into consideration comprehensively.

3. Else if the input CMfg service does not match any available information from the CMfg service evaluation metric pool, it indicates that the input service belongs to a totally new CMfg service category which has little information in the evaluation metric pool. In this case, the input CMfg service should be expanded in the CMfg service evaluation metric pool as a new type of service. Meanwhile, a number of general metrics, i.e., service execution time, service cost, are recommended to measure the input CMfg service. And then, the eventually selected metrics which consider the user's concerns are recorded in the evaluation metric pool via the evaluation metric feedback mechanism. Better still, the new CMfg service type and the adaptive metrics are related to each other and could be updated continually.

Along with the constant invoking of the CMfg service evaluation metric pool, new service categories and fresh service evaluation metrics are accumulated and updated continually. By means of machine learning and intelligent inference, the knowledge accumulation and knowledge utilization procedures of the evaluation metric pool play an irreplaceable important role in the process of CMfg service optimal selection.

4 Conclusion and Future Works

As an ever-growing number of CMfg services are gathering in a CMfg platform, efficient solutions for CMfg service optimal-selection play an increasing critical part in a CMfg system. In most current methods a set of relatively fixed QoS indicators are adopted to deal with the optimal-selection for different types of CMfg services. This tends to lead to low accuracy and flexibility especially when cloud users' requirements involve different CMfg services with respective individualized characteristics. To address this problem, this paper proposes a framework for CMfg service optimal-selection based on a service evaluation metrics pool. The adaptive assessment metrics for different types of CMfg services can be identified by using the knowledge and historical service evaluation data in the CMfg service evaluation metrics pool. Historical evaluation knowledge of CMfg service is accumulated constantly and then be used to select the optimal service to meet users' request. The prototype experiment platform of CMfg service evaluation metrics pool is under development.

In our future work, analyzing the relationships between different service evaluation metrics is quite necessary. From the perspective of algorithm design, it could be very interesting and important to develop advanced algorithms for knowledge accumulation and update in CMfg service evaluation metrics pool.

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