Research on 3D Printing Resource cloud Platform Technology based on dynamic Service Composition

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Abstract. To improve the management and matching of 3D printing resources, a 3D printing cloud platform based on dynamic service composition technology is established, and the 3D printing composite service is optimized. First, cloud computing is combined with 3D printing to establish cloud manufacturing mode. According to the characteristics of each stage, the dynamic service composition technology under cloud manufacturing mode is divided into three stages. Then, dynamic service composition technology of 3D printing resource is established. Based on the logical relationship between services, breadth algorithm and depth algorithm are used to find the optimal service composition path in the search graph to meet the different needs of users. The experimental results show that the relationship between user requirements and services can be obtained by calculating the quality of service. In the case, the service quality required by users is less than 20, and service 1 and 3 can meet the needs of users. This exploration provides a reference for the study of 3D printing resources dynamic service composition.

1. Introduction

In recent years, the 3D printing technology has been gradually applied to the product R & D and production in various industries such as manufacturing industry, medical industry, and sports industry, thus improving the diversified production capacity of the enterprises. 3D printing cloud platforms have been established by combining the cloud computing and IoT with the 3D printing technology to provide the users with diversified online printing services [1]. Intelligence, customization, and platform have become the new development trends of the 3D printing and manufacturing industry. However, with the growth of 3D printing services and manufacturing resources, the user demand and complexity have impacted the development of the 3D printing services. Hence, the dynamic service composition technology can provide a technical support for the matching and composition of 3D printing services, and effectively manage and integrate the manufacturing resources [2].

Luo et al. (2020) put forward a 3D cloud printing platform based on dynamic and static data to effectively match the 3D printing task with printing resources, where the static data could be used to simulate the supply and demand matching process of the 3D cloud printing platform, and provide a supply and demand matching plan for the cloud manufacturing environment. A dynamic data acquisition system was established by combining the dynamic characteristics and static parameter indexes of the 3D printer to monitor and diagnose its operating state [3]. Jia and Liang (2019) proposed a cloud computing-based 3D printing platform for medical image processing, and realized the cloud data management, visualization model construction, 3D printing, and engineering service, etc. via the computer-aided technology, thus satisfying the demand of clinical operation [4]. Li et al.
put forward constructing the skeletal specimen imaging and 3D printing models using camera and cloud service, transformed the human skeleton model into a digital image via the camera, and submitted the generated mathematical model into the 3D printing platform to acquire the 3D printing model. In the end, the specimen fidelity was evaluated through the anatomical annotation and 3D scanning. The experimental results showed that the used digitalized photographic workflow, which was of very high accuracy, could rapidly obtain the skeletal 3D printing digital data and printing model [5].

In order to investigate the dynamic service composition technology of 3D printing resource cloud platform, the dynamic service composition technology was firstly used to combine the 3D printing with cloud computing, and then establish a 3D printing resource cloud platform. The dynamic service composition technology was established based on the graph search algorithm, and the optimal composition path was solved using the breadth first search algorithm and depth first algorithm, in an effort to satisfy the user’s 3D printing demand.

2. Scheme

2.1. Dynamic service composition technology of 3D printing cloud platform

As a networked manufacturing mode integrating the cloud computing, big data, etc., the cloud manufacturing mode can provide the centralized service for the diversified dispersive resources, realize the management and sharing of manufacturing resources, and provide the enterprises with unique manufacturing services. The traditional technology emphasizes the concentration of resources, and the scattered resources serve a user. Compared with this technology, the cloud manufacturing pays more attention to the centralized management of distributed resources, and configures the 3D manufacturing resources according to user requirements, so that distributed resources can serve multiple users. [6]. Therefore, the cloud manufacturing mode can satisfy different printing demands of the users by virtue of stronger demand-based allocation ability, and the dynamic service composition process of 3D printing resource cloud platform is shown in Figure 1.

![Dynamic Service Composition Process of 3D Printing Resource Cloud Platform](image)

The dynamic service composition under the cloud manufacturing mode is divided into four phases: demand analysis, supply and demand matching, service composition, and service execution. The
dynamic service composition process is shown in Figure 2. The following functional modules are contained under this technology framework:

1. In the demand decomposition module, the complex demands proposed by the users are decomposed, divided into subtasks with single functions, and then sealed by the user demands to form a task file that can be invoked by other modules [7].

2. As for the supply and demand matching module, the service candidate set satisfying the printing requirement for each printing service is established. First, the services are screened out using the semantic matching technology from the index levels like basic information and quality information, the printing service meeting the requirements is allocated to each printing subtask, and finally these services are established into a 3D printing service candidate set, in which the services present functional similarity [8].

3. The service composition module transforms the service composition process into a route optimization problem via the graph search algorithm, establishes a dynamic search graph based on the combinational relationship between services by integrating the breadth first algorithm and depth first algorithm, and further obtains the composite services meeting the specific requirements.

4. The service execution module conducts the resource binding and execution for the optimal composite service output by the service composition module, and feeds the result back to the user finally [9].

5. In the service monitoring module, the real-time data on the 3D printing cloud platform are monitored and transferred to the service execution module, but when the cloud service state is changed in the environment, the corresponding module should be substituted, and the substitution will be executed by the service execution module.

![Figure 2. Dynamic Service Composition Process](image_url)

2.2. Dynamic service composition technology

To adapt to the development needs of 3D printing services, the printing services are automatically combined by means of dynamic service composition to form the optimal composite service. The graph search algorithm reflects the problem structure in the form of graph, and transforms the problem into a simple optimal path seeking problem. The search method of graph search algorithm includes breadth first search and depth first search, where the former, which can traverse all executable fields fast, has been used to solve the forward extension problem, and the latter, which can rapidly obtain the feasible path in the search graph, is applicable to the process of seeking for the optimal path in the search graph. In way of depth first, the space tree search is started from the root node in the solution space, and in
any node of the solution space tree, whether the node satisfies the constraint is firstly judged, and if yes, the search will be conducted according to the principle of depth first; if not, the search will be continued by returning to the node at the upper layer. In the dynamic service composition problem, the constraint is that Qos is the optimal. In this research, the search graph was established using the dynamic service composition algorithm according to the principle of breadth first, and through the traversal search of each node in the graph, the optimal service composition was found in the traceback using the depth first algorithm [10].

Through the limitation of service quality during the processing of the 3D printing resource service composition problem, multiple services with single functions are assembled according to their characteristics and their logical relationships, and different functions are implemented through the assembled services, thus corresponding to different user demands. The dynamic service composition technology mainly involves diversified combining forms, so it shows different service structures and different Qos (quality of service) values, and the composition principles include:

(1) Composite services with sequential structure and parallel structure. The less the services, the higher the Qos value will be.
(2) Under the existence of selective structure, the branch with poor Qos value can be deleted while not influencing the correctness.
(3) The loop structures should be reduced as much as possible to avoid being caught in an insolvable cycle.
(4) The longer the sequence in the sequential execution, the lower the Qos value of the composite services will be.

Therefore, the composite paths were searched in this research using the sequential structure and parallel structure, the relationship between services in the service candidate set was expressed with a digraph, and the search graph was traversed using the related algorithm to seek for the composite path satisfying the user requirements. For instance, when a 3D figure printing model was established, the printing demand in the initial printing phase was divided into: model scanning, mathematical modelling, model printing, surface treatment, and colouring. The corresponding 3D printing services were matched according to the relation between supply and demand, followed by forward extension through the dynamic service composition algorithm to obtain the optimal composite path. Afterwards, an optimal path was output for the user. The 3D printing service composition process is shown in Figure 3.

![Figure 3. Printing Service Composition Path](image-url)
3. Results and Discussion

3.1. Example verification
In order to investigate the algorithm effectiveness, a printing model was constructed by comparing the Qos information of user demand and service, where the relationship between the Qos value of each service and that of user demand is manifested in Figure 4.

![Figure 4. Comparison of Qos Values of User Demand and Service](image)

3.2. Performance test of 3D printing resource cloud platform
The average completion time of 3D printing resource cloud computing platform is analysed (Figure 5).

![Figure 5. Completion Time of Different Tasks by 3D Printing Resource Cloud Platform](image)
show that the algorithm can realize the fast and effective allocation of 3D printing resources, and service composition, and improve the user satisfaction.

4. Conclusion

In order to explore the matching problem between the 3D printing resources and services, the centralized management of the dispersive printing resources was conducted to solve the resource allocation problem under the multi-user circumstance. The dynamic service composition technology was established based on the graph search algorithm, the logical relation between the 3D printing services was combined to construct the search graph, which was traversed through the depth first algorithm and breadth first algorithm to seek for the optimal service composition path. After then, this technology was applied to the 3D cloud printing platform, the dispersive printing resources were matched as required, different functional modules were built according to the different functions in each phase, thus realizing the effective allocation of 3D printing resources. According to the experimental results, the dynamic service composition algorithm is capable of effectively combining the 3D printing resources, selecting the most suitable composition path based on the user demand, effectively improving the 3D printing service composition process, and satisfying the user demand. However, some deficiencies still exist in this research. To be more specific, the printing services can be established only by combining the existing printing resources in the market. Therefore, the existing resources in the market will be integrated, and a corresponding database will be built to satisfy the user demand in the follow-up research.

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