Cloud Service-Based Collaborative Design Resource Management

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Abstract Collaborative design is one of the research topics in the field of advanced manufacturing industry whose banner is intelligent manufacturing. Participants in the collaborative design always have some difficulties in fulfilling complex product design due to the lack of design resources. It is a crucial issue that how to help participants in the collaborative design to produce design with those correlative distributed design resources to achieve collaborative design. This paper is devoted to a cloud service-based design resource management in collaborative design. In order to improve the efficiency of resource management for collaborative design of existing industrial enterprises, some existing collaborative design resource management models are analyzed in this paper and typical characteristics and architecture of collaborative design resource management based on cloud service are expounded combined with cloud service. A knowledge expression model of object-oriented collaborative design resource management is established and a kind of collaborative design resource management system framework based on cloud

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service is also proposed. A computer aided collaborative design system is then developed. Finally, a typical case of collaborative design resource management based on cloud service is presented which proves the validity of the proposed methodology.

Keywords Virtual prototyping · Intelligent manufacturing · Collaborative design resource management · Knowledge expression model

1 Introduction

Industry is the national development and strong pillar industries and equipment manufacturing industry is the lifeblood of the national industrial development, which is the core of the manufacturing sector; the overall level of equipment manufacturing industry determines a country's industrial development and the status and competition strength in the world industry [1]. In the 21st century, USA and Germany, as two of the world's manufacturing and manufacturing industry leaders, have the development of manufacturing positioning to a new height especially in recent years [2]. From the current trend, the manufacturing industry is gradually entering the "Internet+" era. More and more industrial enterprises are also focused on the realization of automation and information, whose ultimate goal is to achieve intelligent manufacturing.

As an important part of intelligent manufacturing system, the collaborative design system has been widely recognized as beneficial to enterprise management, and one of its core implementation technologies is collaborative design resource management [3]. It is generally acknowledged that it involves all kinds of design resources owned by the distributed participants during the collaborative design. The product design is always so complex that the design efficiency should be improved by design resource management in collaborative design [4]. Thus, it becomes a key issue to realize effective design resource management in collaborative design. Therefore, how to achieve the effective management of design resources has become a hot topic. The current research on design resource management in product collaborative design could be basically classified into two types: one focuses on the research on design object and the other is collaborative design method.

The first kind focuses on the design object. For instance, Chen et al. put forward the concept of collaborative design resource management system, which resources were organized and managed in accordance with the design of parts library, standard parts library, material library, document library, design example library, design rule base and other major design resource library [5]. Gu et al. [6] put forward a remote collaborative design of resource management system under the grid platform, which provided service packaging to different collaborative design resources by grid services resource framework. And the rise of cloud services also provides new ideas for collaborative design resource management.

Another kind of research focuses on collaborative design method. For instance, the collaborative conceptual design based on distributed knowledge resource was discussed in detail in our research [7]. Mahdjoub et al. [8] discussed a collaborative product innovation framework via product life cycle management.

However, design resource management is one of the bottlenecks for product collaborative design with distributed participants. It is a crucial issue that how to ally those correlative, enormous, isomeric, and even distributed design resources with distributed participants in collaborative design [9]. For instance, 2000T offshore wind power installation platform is very complex product, which would integrate distributed participants to design. This paper is devoted to the cloud service-based collaborative design resource management.

In the remainder of this paper, Sect. 2 proposes the model of participants in the product collaborative design. In Sect. 3, it points out the typical characteristics of cloud service-based collaborative design resource management. In Sect. 4, it puts forward the knowledge expression model of resource management and describes its architecture and system framework. Finally, the effectiveness of the method is proved by experiments in Sect. 5 with a computer aided collaborative design system. And Sect. 6 concludes this paper.

2 Model of Participants in the Collaborative Design

2.1 Participants in the Collaborative Design

Participants in the collaborative design (PCD) is composed of demand publisher (DP), system administrator (SA), service provider (SP), which could be represented as:

$$\mathrm{PCD} = F(\mathrm{DP}, \mathrm{SA}, \mathrm{SP})$$

where demand publisher mainly refers to people who need a service or resource including those who lack research and development technology and want to outsource to save costs, system administrator is people who is to manage the demand publishers and service providers and the project to ensure that the project is completed smoothly and effectively besides doing some technical supports for the safe operation of the system, and service provider is people who wish to obtain funds by providing their own technology and raw materials and some other elements and most of these people are often the elite of all walks of life. As the core of participants in the collaborative design, there are complex relationships among these distributed demand publisher (DP), system administrator (SA), and service provider (SP).

The model of participants in the collaborative design is proposed as shown in Fig. 1.

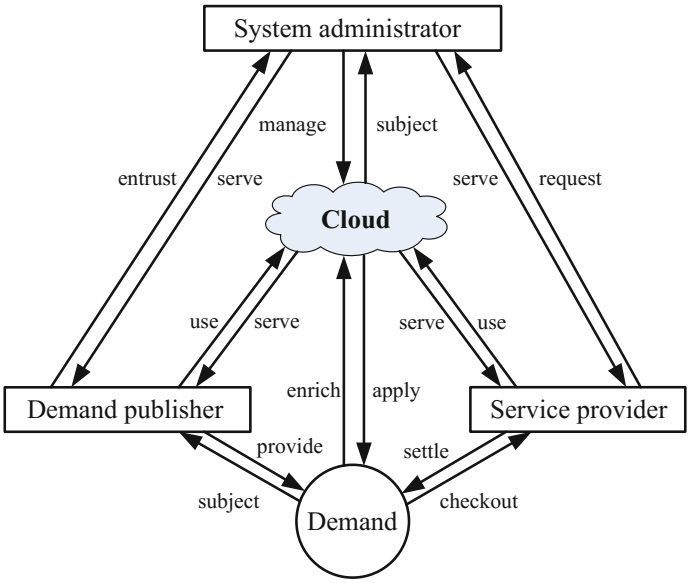

Fig. 1 Participants in the collaborative design

Demand publisher entrusts the system administrator who manages the whole resources on the cloud to product development by using cloud. After reviewed by the system administrator, a service provider could then find the demand description on cloud via the Internet. However, they may not hold all the knowledge resources to complete current demand task and need to apply to system administrator for knowledge resource on cloud. After authorized by system administrator, service provider could then use the corresponding knowledge resource to current product development. In the design process, new generated knowledge would be concluded and enriched into knowledge resource on cloud. At the same time, demand could be used to check out the ability of the service provider, i.e., it could be seen that the service provider have enough abilities to complete product development, if demand task is completely finished.

2.2 Cloud Service Based on Design Knowledge Resource

In Fig. 2, Cloud services architecture based on knowledge resource has three roles: knowledge resource provider, knowledge resource requestor, and knowledge resource cloud service registry. In this architecture, a knowledge resource provider publishes a knowledge resource description to a knowledge resource cloud service registry, and a knowledge resource service requestor could then find the knowledge resource description in a knowledge resource cloud service registry via the Internet.

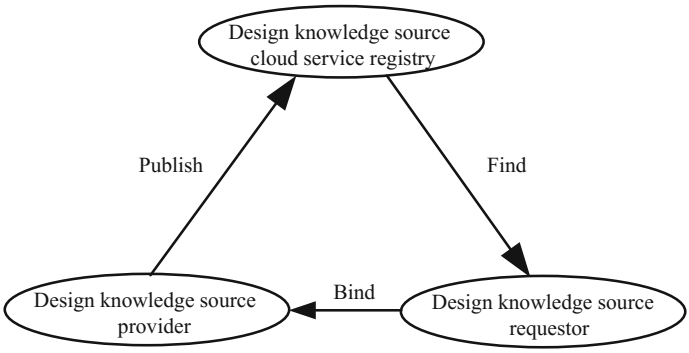

Fig. 2 Working principle of cloud service based on design knowledge resource

The knowledge resource description contains sufficient information for the knowledge resource requestor to bind the knowledge resource provider.

3 Typical Features of Cloud Service-Based Collaborative Design Resource Management

Compared with the existing collaborative resource management technology, the typical features of cloud service-based collaborative design resource management could be summarized as the coordination, virtualization and service of resources on the basis of digitizing (common feature).

(1) **Resource synergy**

Collaboration is an inevitable feature of resource in collaborative design resource management. Cloud services enable collaborative design resources to form a flexible, interconnected, interoperable module through information technology which is standardized, virtual and distribution of high-performance computing [10]. The cloud-based collaborative design resources could dynamically realize the interconnection, interoperability, coordination in whole system, whole life cycle and all-round Internet to meet user needs by collaborative technology.

(2) **Resource virtualization**

The combination of cloud services and collaborative design is the embodiment of advanced manufacturing concepts. Cloud servers which are composed of a large number of server arrays to achieve the adjustment flexibility of service configuration and business scale is used to meet the needs of various changes. The cloud server which uses virtualization technology to simplify their representation and access could store all kinds of resources, such as knowledge base, model library, and unified optimization management [11]. Users in the cloud service are faced

with a virtual environment, which could reduce coupling degree between the user and the specific implementation of the resources.

(3) **Resource service**

Cloud service collects large-scale design resources and capabilities, the virtualization of which is based on service technology to encapsulate and combine, to form various services of design process, such as design services, simulation services, process services and integration services.

4 Architecture and System Framework of Cloud Service-Based Collaborative Design Resource Management

4.1 Architecture of Cloud Service-Based Collaborative Design Resource Management

The architecture of cloud service-based collaborative design resource management is shown in Fig. 3. A collaborative design of a cold heading machine is taken as a practical example to introduce the practical application of cloud service-based collaborative design resource management.

(1) Portal layer

The layer is mainly to provide users with user interface and human-computer interaction interface. It is convenient for users to login the system by the user interface in the portal layer and identity identification. In addition the user could also use the human-computer interaction device to achieve the operation of the virtual model [12].

(2) Network layer

The actual access of the network is realized by utilizing the physical transmission medium, link and various hardware interfaces in the network layer [13], which provides support for the collaborative design of system communication.

(3) Protocol layer

The protocol layer mainly refers to the communication protocol and the database interface. The TCP/IP protocol is used here to provide reliable transmission service, and the system cloud database is docked to realize the stable transmission of system and cloud server data.

(4) Cloud service layer

The cloud service layer which is mainly relying on the characteristics of the cloud provides system with cloud search service security services, data services and

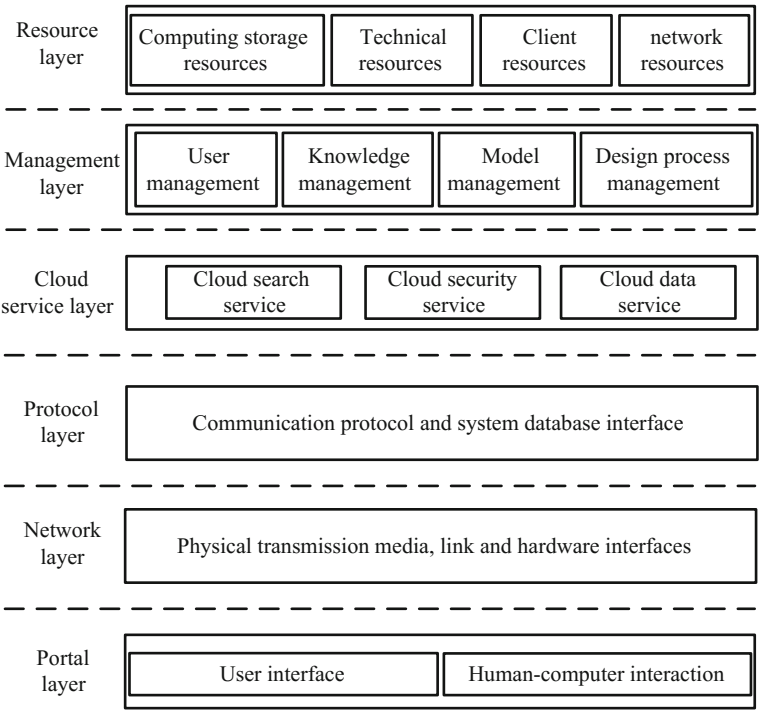

Fig. 3 Architecture of cloud service-based collaborative design resource management

other related services and the uses related functions to achieve massive data retrieval and interaction. The use of Ali cloud services includes the elastic calculation, the database services, large data, cloud communications and cloud shield. The elastic calculation is easy to use and could be large-scale parallel batch calculation. Database services are able to cache online and provide high-speed response to hot data.

(5) Management layer

The management layer mainly includes four parts: user management, knowledge management, model management and design process management. User management includes user registration, user authentication and user related information management. Knowledge management is mainly to manage the technical knowledge provided by the designers, which uses the data to solve the problem and enriches the database to facilitate the continuous expansion of data services. The model management is the management of model library and tool library, which could support the model access and add. Design process management which is completed in the process of the project, achieves the management of the project and

the design staff where the administrator views the system project current state, and it is convenient to check whether the ongoing project at present, how to carry out and complete acceptance or not [9].

(6) Resource layer

Users use the collaborative design system platform to achieve the organic integration of various distributed resources and mobilize various types of resource services, covering storage resources, technical resources, customer resources and network resources, to solve the problem of the collaborative design resource management depending on the portal layer.

4.2 Resource Management Knowledge Expression

The resource management knowledge expression model was put forward in order to achieve the effective management of resources. Taking the demand publisher as an example, the resource management knowledge expression model [14] for the demand publisher is shown in the rectangle dashed box in Fig. 4, which includes the demand overview module and the demand material module. The demands material module includes detailed demands, project field, project time and budget. Among them, demand details, which could be very substantial response to the specific content of the demand, is the most direct demand description for the project. Project field is the classification of the project to facilitate the service provider according to the project area to select the familiar industry to solve the demand. As an important attribute of the project, project time, which is the start and

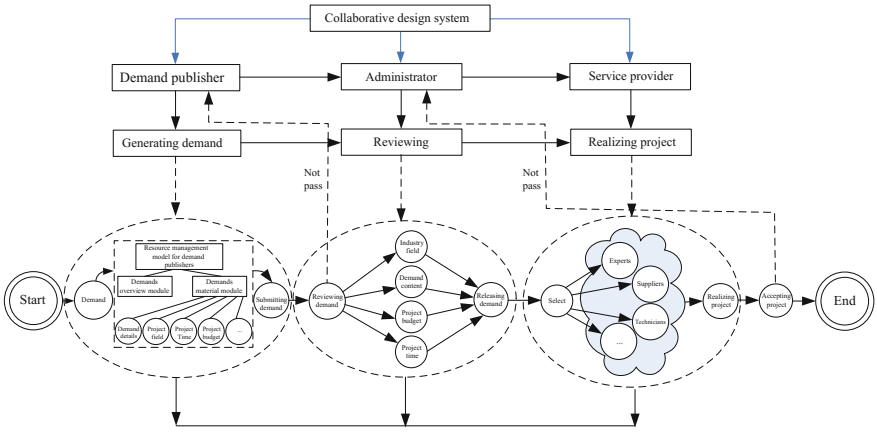

Fig. 4 Cloud service-based collaborative design resource management system framework

end time of the project completion, is defined for the project completion node and service provider to determine whether the problem could be solved. The project budget is the most significant attribute of the demand material and the most important characteristic of the service provider.

4.3 System Framework

In order to clarify the main idea of collaborative resource management, a three-level system framework is established, which is based on demand publishers, administrators and service providers, as shown in Fig. 4.

The first layer is the demand publisher, who is mainly to release actual needs, the establishment of project requests by filling out the demands description and uploading details.

The second level is the administrator, who reviewed the project establishment request which issued by the publisher and the upload file. The review includes the factors such as demand content, project budget and project time. Then a project is created, as well as a high-level discussion group for the service providers who have the ability to solve the problems, which is convenient for them to discuss and solve project problems and improve the efficiency of collaborative design. Since then the follow-up of the project is continued to be responsible until the completion of the project acceptance.

The third layer is the service provider, who is mainly composed of cutting-edge talent in the social sector, including technical staff, suppliers and external experts. After the administrator released the project, the service provider could choose the project by thoroughly understanding the actual situation of the project and positive interaction, which meets their own professional conditions, and use their own technology to complete it on the basis of their knowledge of technology, production capacity and time period and other comprehensive factors. Participants who are eligible to participate after administrator's selection could participate in the specific design of the project and work together to achieve the completion of the project acceptance through online interaction.

4.4 System Process Control Strategy

Cloud service-based collaborative design resource management is a dynamic federated organization whose biggest problem is how to achieve remote collaboration. In order to realize the process, a system process control strategy is proposed as shown in Fig. 5.

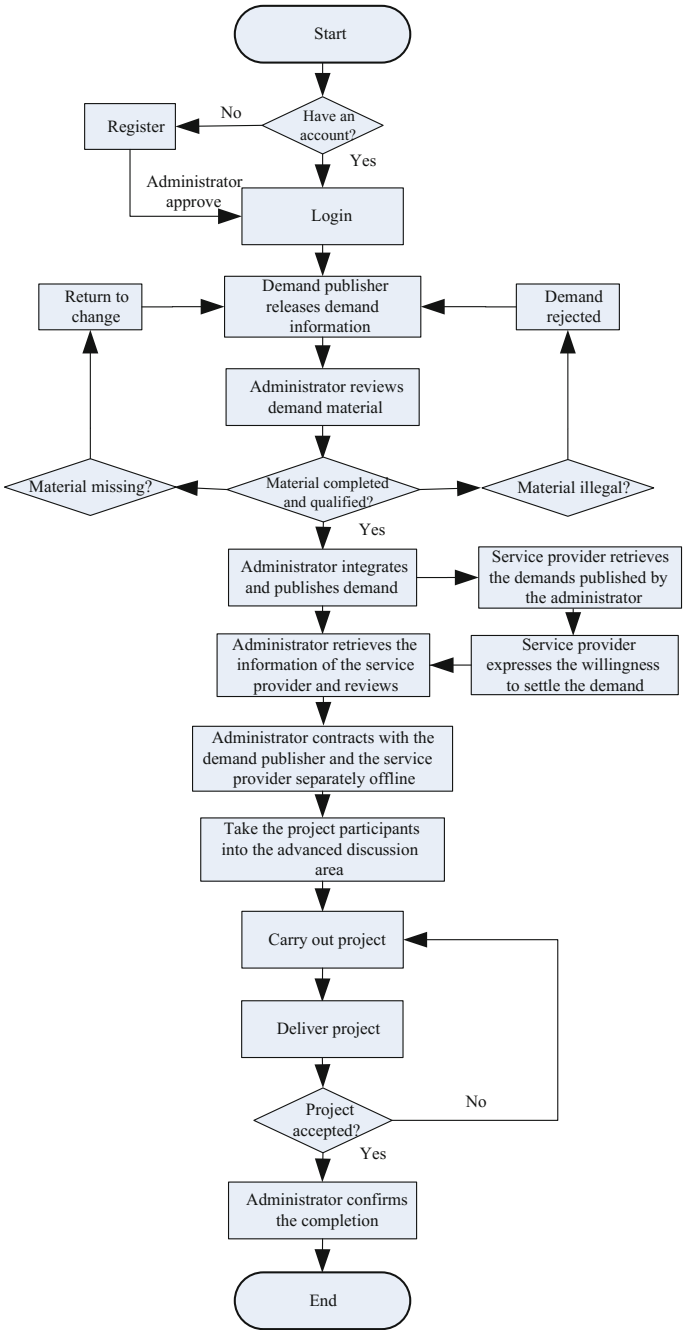

Fig. 5 System Process Control Strategy

The following steps of the system process control strategy are shown as follows:

1. Log in the system. Once start the system, you need to enter the username and password before actually using it. If you don't have an account, you need to register for one and fill in some personal information and then use it after receiving the approval from the administrator.
2. Demand publisher releases demand information. After administrator receives it in the system, material would be reviewed to judge whether it is completed and qualified or not. If material is missing, it would be sent to the publisher to change. If it is illegal, the demand would be rejected directly. Once the material is ok, go to the next.
3. Administrator integrates and publishes demand. Then service provider could retrieve the demands published by the administrator and could express the willingness to settle the demand according to their field and interest. Meanwhile, administrator needs to retrieve the information of the service provider and reviews after the publication to ensure the accomplishment of the demand. Once the qualified service providers are identified, go to the next.
4. Carry out project offline. First, administrator contracts with the demand publisher and the service provider separately offline. After signing the contract, project participants would be taken into the advanced discussion area for the safety of inner files transmission. Once the project is carried out, it would be delivered to the demand publisher. If it is accepted, the administrator confirms the completion. If not, service provider needs to go on to finish it according to their contract.
5. The collaborative design is completed. Refresh the system, participants would see information updated in their catalogue.

5 Application

In order to validate the model and idea of the resource management based on cloud services, a resource management system has been developed and applied in a certain equipment manufacturing enterprise, as shown in Fig. 6.

Taking the design and manufacture of a multi station cold heading machine as an example, after the service provider login the system, the list of newly released items could be viewed by clicking on the items to see the interest and clicking on the "I want to solve the problem" button to express the intention to solve the problem and asking for details in the comments section. A large amount of data would be transmitted to the administrator who uses the cloud search service to filter all kinds of resources and obtains the best results by comparison to achieve the management of resources by cloud services. The service provider could view the latest state of the undertake project by retrieving.

Fig. 6 Collaborative design software prototype system

6 Conclusions

Collaborative design resources are relatively complicated. Therefore, the management must be focus on the future, persistent and could continue to adapt to the development of enterprises. And it must take into account the development needs of the business users in the next period time. The architecture and modules of cloud service-based collaborative resource management is studied in this paper. The experimental results show that the model and software prototype system proves the effectiveness of the method. With the deepening development of cloud service for collaborative design resource management, information security issues are to be resolved.

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