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A study on the collaborative management method of product design cycle knowledge

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Abstract Because of the ever-increasing market competition and rapidly changing of customers' requirements, the innovation quality and design efficiency of knowledge-intensive product has become the key factors in business success. The traditional knowledge management method which is based on design reuse and the single categories of design knowledge cannot satisfy these demands any more. Therefore, in order to effectively support the innovative design process of enterprises, a design knowledge collaborative management method based on multi-knowledge migration is proposed. According to the characteristics and functions during the product design process, the design knowledge is divided into three categories, design principle knowledge, design domain knowledge and design object knowledge. By extracting the operation attributes, relation attributes and physical attributes of the design knowledge, a unified knowledge representation model is established for different design participants. The ontology concept and knowledge matrix are used to establish the association between various categories of design knowledge. Multifarious knowledge search methods include keyword, function, principle and natural semantics are proposed for different design participants in different design stages. They can not only realize the knowledge reuse in the same domain but also support the cross-domain knowledge migration among different domain. Finally, based on the system analysis modelling, a design knowledge collaborative platform is established for the design process of mechanical products. A case study is also presented to illustrate the implementation of the platform.

Keywords Product design · Knowledge management · Knowledge migration · Knowledge cooperation

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1 Introductions

In the knowledge-based economy environment present, the design process of new products requires the support of multi-disciplinary knowledge and technologies more and more. It has become the process of the knowledge migration, fusion and reconstruction among multi-disciplinary domains [17]. The knowledge during product design process has three features, knowledge fusion, collaborative design and creative design [11]. With the rapidly increasing of the accumulated knowledge in modern enterprises, it has become a bottleneck on how to organize and manage the design knowledge effectively. It needs to convey the appropriate knowledge to the design participants at the right time so as to motivate them to accomplish the knowledge migration and the creative design process [33]. At present, the knowledge management process of the enterprise is highlighted in the following two aspects. (1) Because most of product design process is a pipelining-like serial process and the design participants in the previous design phase just mechanically pass their design results to the design participants in the next design phase. There is little knowledge communication and migration among different design participants. Which will restrict the generation of innovative design schemes because the high level of innovation is the result of multi-disciplinary knowledge migration. In addition, this situation will increase the difficulty to find the upstream design flaws in the downstream stage timely. Which will increase the design cycle and cost of product. (2) Enterprises have accumulated plenty of design experience and knowledge resource in the past design process. However, most of them exist in scattered and multi-source forms, or even in the form of tacit knowledge in human brain. Which will create an island of information between different design participants. Enterprises often failed to efficiently use their design knowledge resource just because lacking effective knowledge representation, organization and management methods. Therefore, it is necessary to effectively manage the design knowledge supporting enterprise design activities. A collaborative management method of design knowledge is proposed in this paper to integrate design knowledge in different design stages. In addition, a knowledge application platform is created to provide the theoretical and methodological supports for enterprises' knowledge engineering.

2 Related research about knowledge management during design cycle

The purpose of enterprises' knowledge management is to synthesize different sources, levels, structures and contents knowledge together and integrate to support the product design cycle. The enterprises' knowledge includes the designer's own invisible knowledge and the designer's external explicit knowledge [26]. In view of knowledge migration and knowledge collaboration is the foundation of knowledge management, the next will introduce the current research status of knowledge management from the two aspects.

2.1 The research of knowledge reuse and migration

The aim of knowledge management in a enterprise is to integrate and share the knowledge resource in the whole enterprise. Knowledge reuse and knowledge migration are two forms of knowledge sharing. The knowledge reuse is to regard the integrated knowledge as a prototype to revise and refine it, so as to meet a new design requirement. Because the knowledge reuse can improve the design efficiency and reduce the design cost, it has become the research hot

spot in knowledge management. Baxter [4] proposed a knowledge reuse frame and a processing model based knowledge reuse method. The knowledge reuse frame includes not only the capturing technique of existing successful experience and design principle, but also the knowledge reuse based application technologies and methods. Based on the practical design of mechanical products, Wang [35] proposed a design strategy of knowledge reuse for mechanical design. It developed the knowledge reuse framework for mechanical product design based on the summarized enabling techniques. Case-based Reasoning (CBR) has been extensively used as its capability to reuse previous solvable problems in recommending new solution. Relich [22] proposed a CBR approach towards using neural networks to estimate the cost of new product development in one-of-a-kind production enterprises. Mustapha [27] proposed a user profiling based on mixed sources in identifying leader and measuring and comparing strategy on expertise skill set in locating new knowledge leader.

To gain reuse knowledge effective, Zhang [36] proposed a two-level knowledge searching method based on the function and the object. Huang [14] proposed an automatic knowledge searching method based on the initiative study ability and fuzzy logical structure of neural network. Lin [19] proposed a design knowledge searching method which integrated the information science, knowledge engine and computer technology for mechanical engineering domain. Tao [29] presented a dual-regularized KISS (DR-KISS) knowledge learning method. By regularizing the two covariance matrices, DR-KISS improves on KISS by reducing overestimation of large eigenvalues of the two estimated covariance matrices. In expressing aspect of reused knowledge, Shen [24] created a design knowledge representation model with multi-categories and multi-level which focused on the different forms of design knowledge. Peng [21] proposed a knowledge representation model which can combine geometric model, knowledge-based analysis codes, problem-solving strategies and processes. A smart collaborative system is also designed and developed to streamline the design process as well as to facilitate knowledge capture, retrieval and reuse as users with different roles are working on various tasks within this process. Gu [12] proposed a knowledge representation model based on the design function, behavior and structure. This model has two layers which are the rule layer and the physical layer. The rule layer expressed the design criteria with function knowledge unit while the physical layer verified the function unit case-based method. In the management aspect of reused knowledge, Fensel [10] proposed a knowledge management framework based on the design catalogue. Suh [23] proposed a layered index management method to improve the search efficiency and developed a related knowledge reused system. Baxter [5] built a knowledge reusing system based on product function decomposition which applied the form of QFD (Quality Function Deployment).

Although the knowledge reusing has been used in enterprise knowledge widely, but it was improved on the basis of the existing prototype and the obtained solutions were often short of innovation. Because the high level of innovations were not improved based on existing plans mostly, but were the migration of knowledge from different domains. So, how to achieve the knowledge migration effectively has being a research focus.

The design knowledge in enterprise The design of enterprise has the characteristics of wide range, multidisciplinary and diverse forms. They were existed often in various design resources which were high dimensional, massive, heterogeneous, incomplete and semi-structured. Collating the migration source of knowledge is the foundation and premise to realize the knowledge migration [30]. The process of knowledge migration is a graded activity and different abstract representation form of knowledge determined the different migration range. The higher abstract levels of knowledge representation mean the wider of the related range

during the knowledge integration process [38]. In the aspect of migrated knowledge representation and management, Hakim [2] proposed a graphic method to realize the visualization representation and knowledge migration. Due to the ontology technology has the characteristics of stable after building, so it was applied to the related research about representation, association, and attributes extraction of migrated knowledge. Chen [16] proposed a representation model and an ontology-based knowledge management method of product life cycle. It integrated the heterogeneous knowledge of product life cycle among different enterprises and promoted the sharing and migration of product knowledge [7]. Barao [3] presented a knowledge management and engineering perspective (ontology based) for the application of predictive analysis and insights at the organizational (corporate) workplace. On this basis, a smart collaborative system is also designed and developed to streamline the design process as well as to facilitate knowledge capture, retrieval and reuse as users with different roles are working on various tasks within this process. Cao [9] proposed a knowledge representation based on ontology framework and computer science. Moreover, he also created a intelligent application system of knowledge acquisition.

At present, the main ideas of knowledge management research were focused on the rapid reuse of knowledge. Mainly includes how to excavate, manage and use existing design knowledge of the enterprise in order to improve the design efficiency. However, it is difficult to achieve the high level of product innovation only relying on domain knowledge reusing. It also more needed the migration and combination of knowledge among different domains [32]. Therefore, it is necessary to research the knowledge management method from knowledge migration and combination.

2.2 The research of knowledge representation and collaboration

If the enterprise wants to use various kinds of design knowledge effectively, it needs to classify various kinds of design knowledge and establish the information structure of each kinds of design knowledge firstly. It will facilitate the storage and communication of design knowledge. Hicks [13] divided the design knowledge into four categories according to the abstract level which were case knowledge, concrete knowledge, universal knowledge and general principle knowledge. In order to realize the consistent presentation of design knowledge, a Product Information model (PIM) was created among different design participants. PIM could provide the product information and process description of whole life cycle of product design and management [25]. PIM should include the product information of geometric structure, manufacturing process, assembly process, product cost, performance index and making material and the implementing rules information product design, manufacturing and maintenance [6]. In order to examine the effects of product life cycle management systems on new product development, Tai [28] developed a conceptual model linking firms' ability to diffuse and routines PLM systems in new product development processes with process management, coordination, and absorptive capabilities. Zhang [37] developed a approach to integrate the business processes of an organization and more effectively manage and utilize the data generated during lifecycle studies. Violante [31] presented a methodical approach that incorporates user-centered design principles into the customization process of the tool. The method can help designers to structure and manage requirements not only in the product design phase but in all phases of New Product Development. The established product information model must first identify a unified standard.. The consistent information description was needed to apply either in the different stages of product life cycle or the different design domains in the

same product design stages [8, 15]. In order to establish the product information with good consistency, it also needed to establish a representation standard of product information model which has a good unity and expansibility [1, 20]. The Extensible Markup Language (XML) as an industry standard that expressed the semi-structured data, it had many advantages of platform independence, self-describing and extensibility. However, due to the deficiency supporting for semantics of XML, so researchers applied the ontology technology to solve the problem [20]. Lin [18].carried out some researches focus on the key technology of element model of knowledge management, application system and process information obtaining during product design Stephen [34] proposed a knowledge integration management platform of STARS which was a complex system for collaborative design. The system realized the unified management and storage of data sources through the integration of process information, product data, organize information with Internet.

Although numerous studies have been conducted on knowledge management of enterprise product design, these studies still have the following problems. First, the design knowledge management is mainly based on the knowledge reuse in same domain. It has limited support for cross-domain knowledge migration. Secondly, the knowledge representation is mainly for single design participants. It needs to establish a unified product information model to meet the different design participants.

Based on the above two problems, a design knowledge collaborative management method for product full life cycle is presented in this paper. The design knowledge from different domains and departments is divided into principle, domain and object knowledge. The design knowledge is expressed using the operation attribute, relation attribute and physical attribute. A unified expression method is adopted to normalize the different design knowledge. The relation between knowledge resources is established through ontology concept and knowledge matrix. It can provide multifarious knowledge searching method for different design participants according to the design requirements. Suitable design information model is provided for different design participants to realize knowledge synergy among different design participants.

The proposed method has three contributions. The first is to divide the enterprise design knowledge into principle knowledge, domain knowledge and object knowledge and to extract the operation attribute, relationship attribute and physical attribute from design knowledge. A unified knowledge representation model is established based on knowledge attribute for different design participants. The second is to establish the attribute relationship among different categories of design knowledge with concept ontology and knowledge matrix. It can break the knowledge barriers in different design domains and design departments. The third is to provide multifarious knowledge searching methods for different design participants in different design stages. It can meet the different knowledge needs for different design participates during product life cycle.

3 The knowledge management model for product design life cycle

3.1 Product design process based on multi-knowledge collaboration

Currently, the knowledge management in majority enterprises were carried out by individual department and major separately, as shown in Fig. 1. In this one-direction knowledge management model, the design participants comply their design task according to the design procedure. Then, they pass the design results to the design participants in the following design

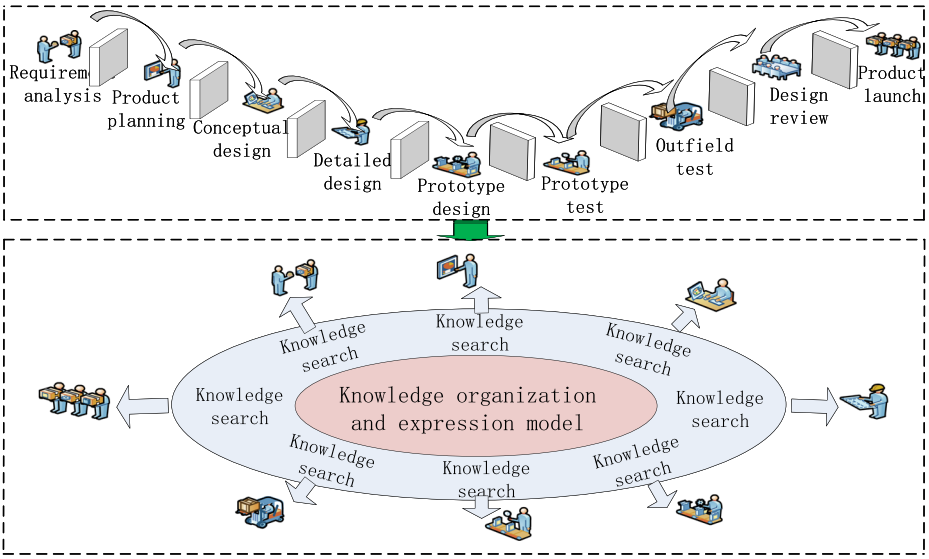

Fig. 1 The design process based on multi-knowledge cooperation

stage mechanically. There was little communication and knowledge sharing among different design participants. Although this knowledge management method is simple and easy to implement, it would hinder the flow of design knowledge and form information island among different design departments. Moreover, because a design domain expert cannot effectively share knowledge in other domain, limit knowledge migration and product innovation can been realized based on cross-domain knowledge. Therefore, this paper divided the design knowledge into three categories, design principle knowledge, design domain knowledge and design object knowledge according to the characteristics and functions in product design process. A unified knowledge expression model is established based on the knowledge attributes extraction from different knowledge. It will facilitate cross-domain knowledge migration for different design participants. In addition, multifarious knowledge search methods are provided for different design participants in different design stages. It can meet the different knowledge needs for different design participates during product life cycle. A new knowledge sharing and collaboration between design participants is realized.

3.2 Design knowledge collaborative management framework

Based on the product design process model of multi-knowledge cooperation proposed above, a management framework of design knowledge collaboration is established, as shown in Fig. 2. The framework consists of three parts. The first part is the knowledge application. During in the product design process, different design parameters propose the knowledge appeal according to the different design task and obtain matching design knowledge with knowledge search methods. Based on the knowledge motivation, the design participants will establish the corresponding design scheme and form it into a new knowledge source. The second part is the knowledge management. The concept ontology and knowledge matrix are used to establish the relationship between various kinds of design knowledge. It can not only realize the knowledge reuse in the same domain but also support the cross-domain knowledge migration

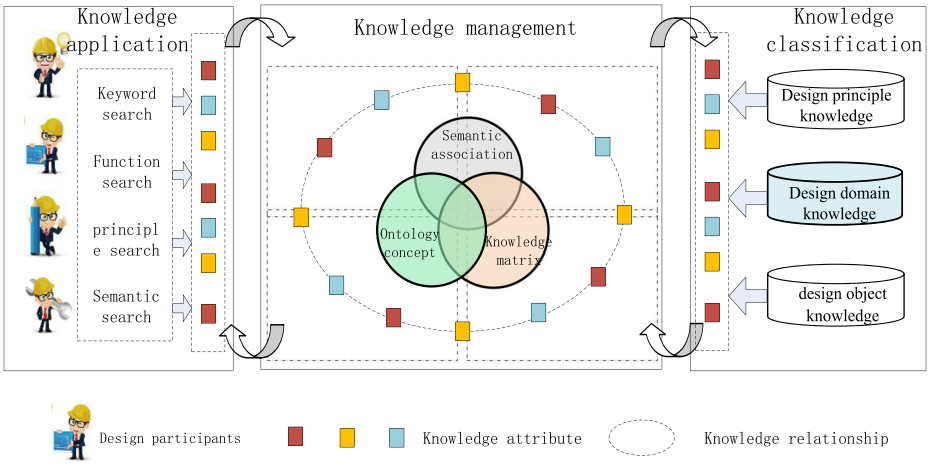

Fig. 2 The management framework of design knowledge collaboration

among different domain. The third part is knowledge classification. The design knowledge of enterprise is divided into principle knowledge, domain knowledge and object knowledge and to extract the operation attribute, relationship attribute and physical attribute from design knowledge. A unified knowledge expression model is established based on the knowledge attributes extraction. The design knowledge matrix is used to establish a unified knowledge organization model is which can achieve and storage the structured, unstructured and semi-structured knowledge. Meanwhile, the knowledge ontology is used to manage the knowledge attributes among different knowledge. This design knowledge management model can build the design knowledge bridge among different design domains and departments.

The detailed implementation process of the knowledge management framework is described below.

4 Knowledge management realization and implementation

4.1 Classification of design knowledge

Modern products have become more and more as the result of the integration of multi-disciplinary knowledge. Different categories of knowledge abound and always exist in the structured, unstructured or semi-structured knowledge carrier. In order to extract the required knowledge from a large amount of design knowledge resource, it is necessary to summarize and classify the design knowledge in a suitable way. Based on the different demands during the design process of mechanical products, the design knowledge is divided into three categories, including design principle, design domain and design object knowledge, as shown in Fig. 3.

The design principle knowledge refers to the design principles, methods and design specifications used in the design process. They include not only all kinds design principle achieving the product function, scientific effect and design standard, but the enterprise general methods, such as design, analysis, evaluation, and the optimization methods. Because they are not limited by the design domain, it is possible to support the product innovation through

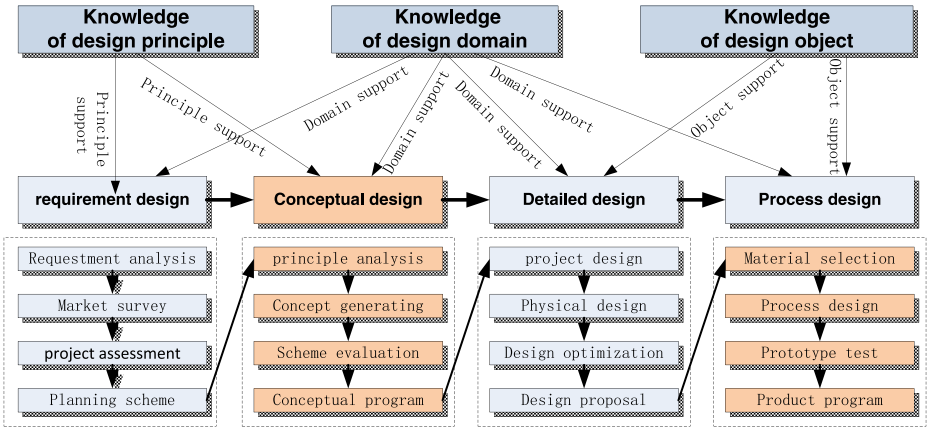

Fig. 3 Knowledge classifications base on product design process

cross-domain migration. The design domain knowledge refers to the design knowledge oriented to a specific design domain. They are the professional design knowledge within particular design domain. They have obvious domain characteristics and can assist design participants in specific design domains to complete the design tasks quickly. The design object knowledge refers to the knowledge of a certain type of product. They can be divided into direct knowledge and indirect knowledge about the product. The direct knowledge includes the material, structure and process of the designed product and the indirect knowledge includes the market survey, product planning and so on. The design object knowledge has three levels, including parts level, components level and whole machine level. The design participants can access to the knowledge in different levels based on the different design objects. For example, the part designer can rapidly get the kinematic and dynamic conditions of the parts from the part level knowledge. Likewise, the designer who charges with the component design or whole machine design can quickly carry out parameter test and performance simulation by means of component level knowledge or whole machine level knowledge.

4.2 Design knowledge attribute extracting

According to the different supporting functions to the design process, different knowledge attributes are extracted from design knowledge. The knowledge attributes are defined as the operation attribute, relation attribute and physical attribute. A hierarchical knowledge representation model is created based on the knowledge attribute, as shown in Fig. 4. The model can be expressed as M (knowledge) = (KT, KC, FT). Where, the physical attribute KT is the specific design data which is distributed in different design domains and design departments. Most of these data exists in the semi-structured form or unstructured form, such as Word, Excel, PDF, ADS, Genesys, Systemvue, C/C++, M document, dll(Dynamic link Library), Catia, UG, Proe, Ansys, Delmis and so on. The relational attribute KC is to establish a link between different knowledge. The knowledge relationship includes functional relation, principle relation and structure relation. Through these relationships, knowledge appeals can be analyzed and expanded, and relevant design knowledge can be pushed to design participants. In addition, the relationship attribute can establish a bridge between different design participants, which can be used for communication and collaboration between different design

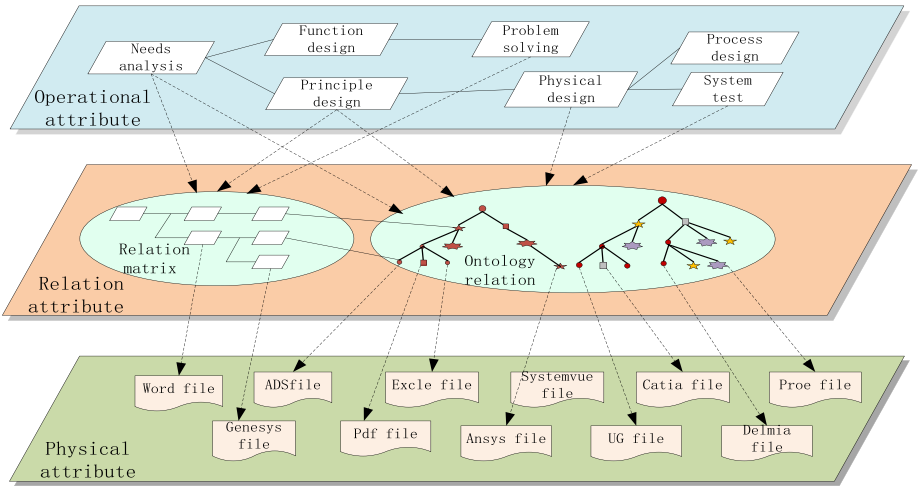

Fig. 4 Knowledge attributes extracting and hierarchical representation

participants. In this paper, ontology concept and knowledge matrix are used to correlate various knowledge relationship attributes. The operation attribute PT represents the searching attribute of knowledge. The knowledge searching attributes includes keywords, functions, principles and natural semantics. Multifarious knowledge searching attributes are provided for different design participants in different design stages. It can meet the different knowledge needs for different design participates during product life cycle. With the hierarchical knowledge representation model, i can realize not only the knowledge reuse in the same domain, but knowledge migration across domain.

4.3 Design knowledge representation method

The goal of design knowledge representation is to represent design knowledge in proper form. At present, the common knowledge representation methods mainly include the semantic network representation, production representation, predicate logic representation, frame representation, object-oriented representation and artificial neural network representation [28]. Knowledge representation includes two aspects, one is the external presentation for design participants and the other is the internal digital data for computer storage. For the external presentation, a cognitive science based information-processing model has been proposed. The working memory of design participants is a processor in which design information can be temporarily processed and stored. The information stored in the working memory is only 5 to 7 units. In order to improve the knowledge processing efficiency of the design participators, a hybrid image blocks was developed in this paper to represent the design knowledge. They include the representation forms of text, table, pictures, 3D model, and engineer drawing and so on. This hybrid representation can be realized by the knowledge frame. A frame representation can be constituted by a number of structures called groove. According to actual needs, each “groove” can be divided into several profiles. The groove is used to describe the one attribute of the design knowledge and the affiliated profile is used to describe individual aspect of this attribute. The contents of the groove and profile are called groove value and profile value respectively. A project case is shown in Fig. 5 to illustrate this frame representation.

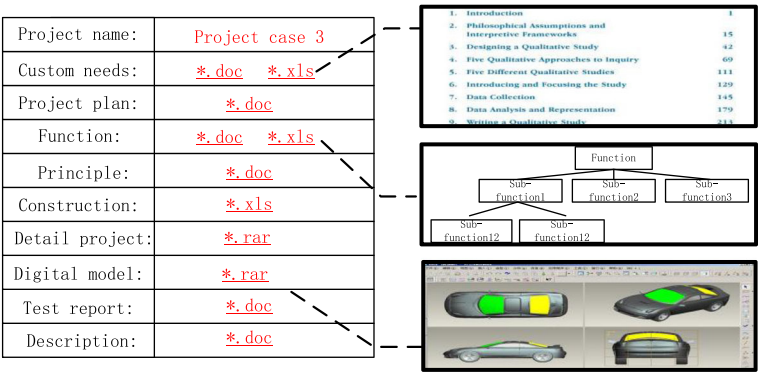

Fig. 5 Design knowledge frame representation example

Through the form of groove and profile, the design knowledge can be decomposed in accordance with the abstraction degrees of knowledge attributes, and different design participators can open the knowledge in different groove and profile based on their needs.

Because the design knowledge in external representation is existed in the semi-structured or unstructured form, it is impossible to store them with single standardization format. Therefore, the knowledge matrix format was used to represent the design knowledge. The different categories of design knowledge can be managed by the knowledge matrix based on the knowledge attribution, as shown in Fig. 6. The columns of knowledge matrix denote the different knowledge attributes and the rows is the different knowledge units. The knowledge unit are allocated different classification based on the knowledge attribution characteristic. They include the function character, principle character, structure character, process character and so on. The expression format of each knowledge unit is certain. If one knowledge unit has no any attribution characteristic, the representation will be NULL. The same attribution characteristic unit will be linked with specific knowledge carrier and the different attribution characteristic unit will be linked through ontology concept. As shown in Fig. 6, the relation

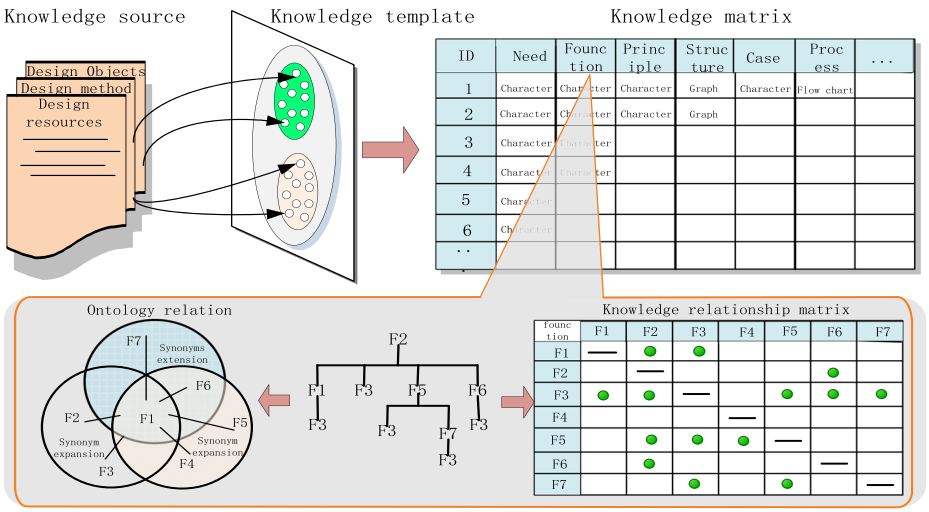

Fig. 6 The knowledge matrix and knowledge relations

matrix describes the relationship among the function attribute of F1, F2, F3, F4, F5, F6, F7. The attribute ontology relation can be built with the software of protégé which can establish the ontology relations cross-domain. Based on the ontology relations cross-domain the co-reference relation including synonyms, near synonyms and related words, the design knowledge units with relevant concepts can be obtained according to the semantic relevance which can assist participants implement design knowledge migration across different fields.

4.4 Knowledge migration based on ontology concept and relation matrix

Ontology is a description method for concepts and their relations. Because the ontology description has the features of stable, easy to understand, repeated using and independent existing, are often used. it is often used to describe the design knowledge relationships among different domain. The concept ontology of design knowledge has been built according to the abstract hierarchical of knowledge attributes in this paper. During the product design process, the design participants analyze the design requirements and translate them into ontology concepts firstly. Then, the matched design knowledge can be obtained base on the domain ontology relation and knowledge relate matrix. If the needed knowledge cannot be obtained the knowledge through domain ontology relations, it need to transform the domain ontology into other domain ontology and gain matched knowledge with the cross-domain ontology relations, as shown in Fig. 7. The knowledge management mode based on ontology technology provides the method and technical support to realize design knowledge migration and restructuring among different domains.

5 Design knowledge management platform

5.1 Model analysis of knowledge management platform

A design knowledge management platform was established based on multi-knowledge collaboration. The Systems Modeling Language (SysML) is used to conduct an analysis the platform function modeling. The SysML requirement diagram is shown in the Fig. 8. The

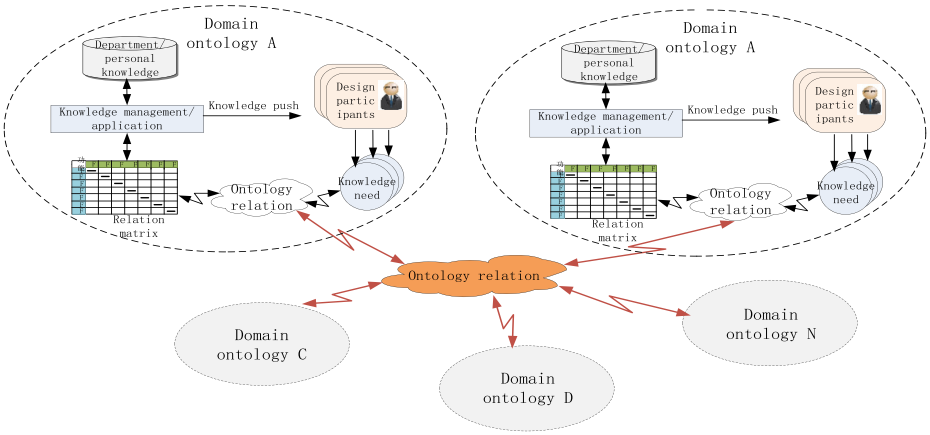

Fig. 7 Knowledge migration based on ontology concepts and relation matrix

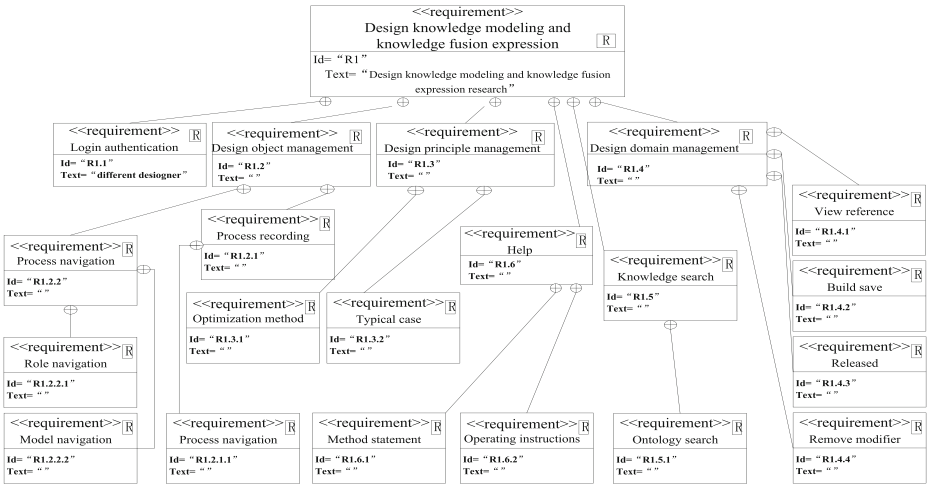

Fig. 8 The requirement diagram of knowledge management platform

overall requirements of the knowledge management platform include six sub-requirements. Which are login authentication module, design object management module, design method management module, design resource management module, design knowledge search module and help module. Each sub-requirement can be divided into lesser sub-requirements. The login authentication provides different permissions for different design participants. The tree diagram and flowchart are given to implement the navigation of the whole product design process. Which includes the requirements design, conceptual design, detailed design and process design modules. The implements are provided to check, build, preservation, storage, modify and delete the design knowledge in platform module. Multifarious knowledge search methods including keywords, function principle and semantic are provided for different design participants in different design stages. It can meet the different knowledge needs for different design participates during product life cycle. The form of words, charts, cartoon, multimedia and instance are adopted to introduce the usage of different function-modules.

5.2 The framework of knowledge management platform

A framework of knowledge management platform was built based on the platform demand analysis, as shown in Fig. 9. It provides not only the knowledge management and application service for the design process of electro-mechanical products, but the cooperative design platform for different design participants during product life cycle. Three levels of platform module, knowledge organization and physical data are included in the knowledge management platform.

All kinds of function modules are provided in platform module layer. The project management module manages all kinds of projects in this platform. The platform portal module provides fast access for product design. The knowledge management module is used to collect, add, modify, approve and download the design knowledge of different sources. The knowledge searching module includes keywords, function, principle and natural semantic searching method. Knowledge support can be obtained for different design participants corresponding to the platform modules.

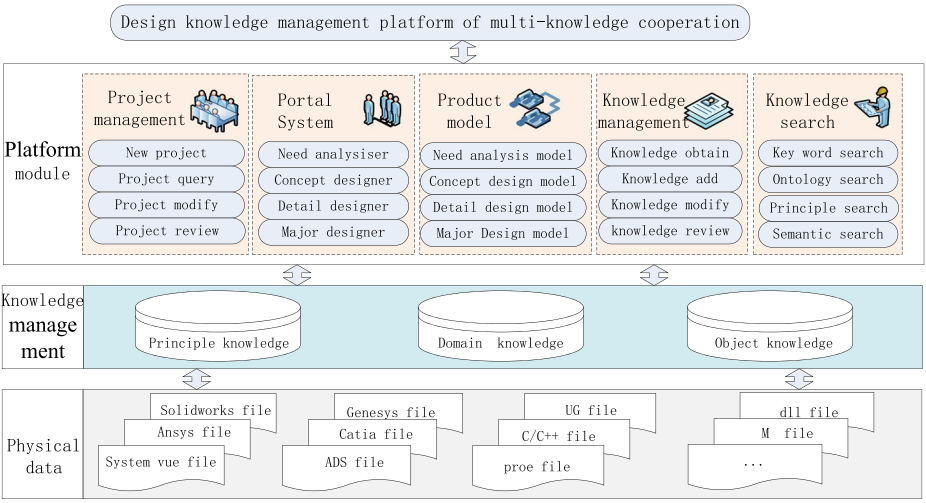

Fig. 9 The framework of knowledge management platform

The task of knowledge management is to express and store all kinds of design knowledge, and to establish the relationship between various design knowledge. A representation form of mixing multi-information block is adopted to build the expression templates of design knowledge. By means of the attributes extracting of design knowledge, the hierarchical framework is used to establish the attribute relations of design knowledge. The knowledge matrix and ontology concept are adopted to classify and management all kinds of design knowledge.

The physical data layer is responsible for organizing and managing the specific design data distributed in different design fields, literature platforms and expert minds. Those data are always existed in the form of semi-structured and unstructured and showed in the form of multi-information block of text, table, picture, 3Dmodule and engineering drawing.

5.3 The application process of knowledge management platform

This knowledge management platform is not only the knowledge supporting platform for the design process of electro-mechanical products, but the cooperative design platform for different participants product life cycle. Figure 10 is the application process of this knowledge management platform. The different design participants login the platform and manage the product design project including building, checking, modification, examination, submitting etc. according to respective authority. Project manager can divide the design task to different design participants based on the design needs. The different design participants propose the knowledge requests based on their respective design task. They can use a variety of knowledge searching methods to search knowledge on the platform. Not only can they get the knowledge from their own domains and departments, but they can also get the knowledge from other domains and departments. Which can realize the knowledge migration and knowledge cooperation among different design domains. If the acquired design knowledge can satisfy the design knowledge request, the corresponding design task can be completed according to these design knowledge. Otherwise, it needs to redefine design issues and submit new knowledge requests. Meanwhile, the design participants can manage the design knowledge such as collecting, adding, modifying and examining according to their authority.

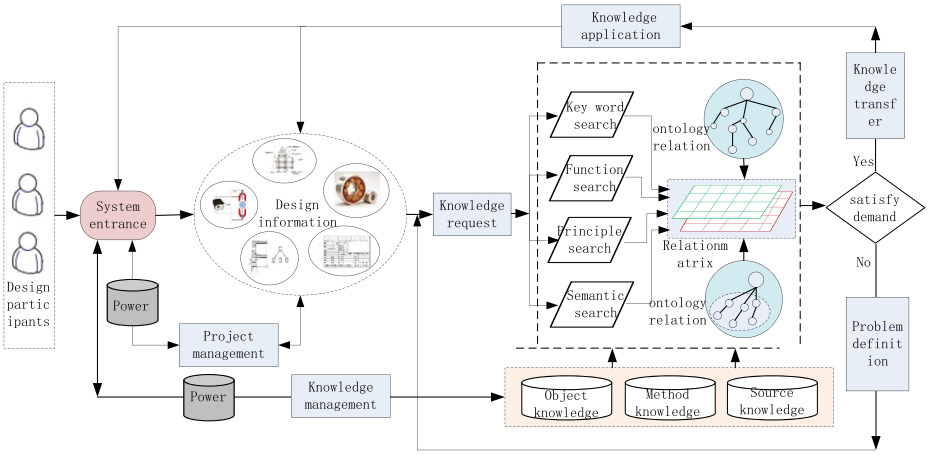

Fig. 10 The application process of knowledge management platform

6 Application case

A brief example is showed as following to introduce the application process of knowledge management platform. An automobile enterprise decided to design a light truck engine based on the knowledge management platform after the market survey. Different design participants login the platform and obtain the design knowledge they needing by different knowledge searching methods. Firstly, the requirements design participants define the design task as a structure which can convert the other forms of energy into mechanical energy. The requirement function can be extracted as conversion energy. Based on the function searching method provided in platform, various scientific principles of energy conversion can be obtained. They include mechanical energy conversion, thermal energy conversion, power conversion, magnetic energy conversion, solar energy conversion, atomic energy conversion, wind energy conversion, light energy conversion and so on. Based on the evaluation of design requirements and product development goals, the requirements designers can select a scientific principle as the development direction of the new engine.

If the scientific principle of thermal transformation is adopted as the realization form of the new engine, the conceptual design participant will complete the design of the concrete scheme under this scientific principle. The conceptual design participants can search for the design patents in different domain and the design instances in same domain through the principle searching method provided in the knowledge management platform. It can help conceptual design participants to obtain the relevant structural forms to achieve the scientific principle of thermal transformation. The conceptual design participants can complete the specific product concept based on the basis of these structural forms.

After obtaining the specific design scheme, the detailed design participants can carry out the parameter-level design tasks according to the specific structural form of the engine concept. The detailed designer participants can get the implementation parameters of the concrete structural form by keyword searching function provided in the knowledge management platform. For example, the detailed design participants can obtain the specific performance parameters of the existing engine in the knowledge base, as shown in Fig. 11. If there are

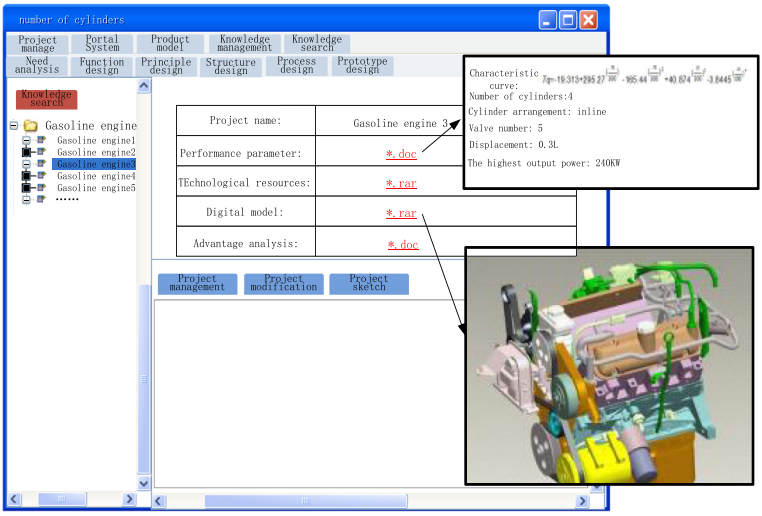

Fig. 11 Knowledge entries sketch map of target engine

multiple engine conditions in the knowledge base, the detailed design participants can also optimize the design target based on matching degree. For example facing to the design of half shaft parts, they would get the associative information in the knowledge map of half shaft parts such as the size parameters, digital model, processing technology, heat treatment, strength design criteria and so on, as shown in Fig. 12. Detailed design participants could complete the detailed design process of half shaft parts quickly based on these design knowledge. Different design participants can change the design role and browse the product design information model from different view which can realize the collaborative process among the participants of different design stages.

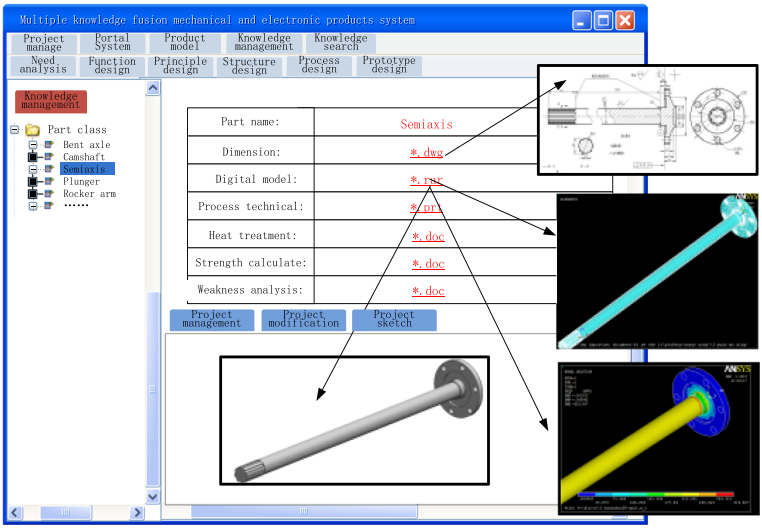

Fig. 12 Knowledge entries sketch map of half shaft parts

7 Conclusions

In view of the current knowledge management process is based on the lack of knowledge reuse, a new knowledge management model and platform for enterprise different design participants are proposed in this paper. Vast enterprise knowledge supporting product design process is divided into principle knowledge, domain knowledge and object knowledge according to their different characteristics and functions. The knowledge attributes including the operation attribute, relation attribute and physical attribute are extracted and A hierarchical knowledge representation model is established. It can standardize the design knowledge and provide appropriate knowledge representation for different design participants. Ontology concept and knowledge matrix are used to establish the relation between knowledge attributes. Multifarious knowledge search methods are provided for different design participants including keywords, functions, principles and natural semantics. This can realize the collaborative design of different design participants and the knowledge migration among different domains. The main achievements of this paper are as follow.

(1) According to the different knowledge requirements of product design process, all kinds of knowledge in the enterprise have been effectively integrated. A unified knowledge representation model is established based on knowledge attribute for different design participants. Multifarious knowledge searching methods are provided to meet the knowledge needs for different design participants. Which will improve the design efficiency and reduce the design cost effectively.
(2) The concept ontology and knowledge matrix are used to establish the relationship between various kinds of design knowledge They will break down the knowledge barriers in different design domains and realize the design collaboration of different design departments. It can provide more extensive knowledge for different design participants and improve the innovation level of product design.

A knowledge management platform based on multi-knowledge cooperation was built in this paper. The Systems Modeling Language was used to analyze the functional requirements of platform. The corresponding functional modules were developed based on Visual Studio as an integrated development environment. This knowledge management platform can assists different design participants to obtain the required knowledge support according to their respective design tasks.

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