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THE INFLUENCING MECHANISM OF MANUFACTURING SCENE CHANGE ON PROCESS DOMAIN KNOWLEDGE REUSE

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ABSTRACT

It is necessary for a enterprise to reuse outside process domain knowledge to develop intelligent manufacturing technology. The key factors influencing knowledge reuse in digital manufacturing scene are manufacturing activities and PPR (Products, Processes and Resources) related to knowledge modeling, enterprise and integrated systems related to knowledge utilizing. How these factors influence knowledge modeling and utilizing is analyzed. Process domain knowledge reuse across the enterprises consists of knowledge reconfiguration and integrated application with CAx systems. The module-based knowledge model and loosely-coupled integration application of process domain knowledge are proposed. The aircraft sheet metal process domain knowledge reuse is taken as an example, and it shows that the knowledge reuse process can be made flexible and rapid.

Keywords: Knowledge reuse, Knowledge reconfiguration, Integrated application.

1 INTRODUCTION

Modern manufacturing technology is becoming intelligent to make organizations respond rapidly and perform flexibly. To modern enterprises, it is necessary to develop intelligent manufacturing technology by integrating computer-aided system with knowledge-based system based on process domain knowledge reuse. Effective reuse of enterprise knowledge is a key strategic component of product development (Rezayat 2000). Design reuse in product design is typical research direction (Alizon et al. 2006). Knowledge reuse framework in digital manufacturing consists of correlated knowledge modeling and knowledge utilizing (Liu et al.2012). The knowledge-intensive aircraft manufacturing processes are divided into different process domains such as metal cutting, metal forming, and assembling and so on. Correspondingly, process domain knowledge has the characteristics of various types, different sources and complicated structure, and is different from the knowledge of solving a single problem. Knowledge reuse is influenced by many factors in certain manufacturing scene.

Process knowledge reuse is based on the determination of knowledge classification and composition. To various types and complicated structure knowledge, knowledge needs to be described from species and population. Knowledge is organized by process or task (Han et al.2009, Baxter et al. 2008 and Guerra-Zubiaga et al. 2008), but the minimum granularity is not described. As manufacturing knowledge is used to support solving problem of manufacturing tasks in product fabricating or assembling processes, classifying the knowledge by three dimensions of products, fabricating processes and manufacturing tasks meets the requirements of information definition in product manufacturing of certain process domain (Liu et al.2012). The knowledge is further classified into basic types of minimum granularity. Different granularities of knowledge bases can be not only reused in the same enterprise ,but also reused by other enterprises to make them perform better in terms of low-time and high-quality output. Current research is focusing on knowledge reuse in the same enterprise to support certain manufacturing activity. For instance, knowledge is reused in product design (Baxter et al. 2008), manufacturability analysis(Cochranea et al. 2008), process planning, product assembly (Alizon et al. 2006) etc. Similarity match algorithms are presented by many researchers. Many research organizations and enterprises have established different kinds of knowledge base and knowledge-based system. The process domain knowledge reuse across various enterprises is a new research direction. As the biology fits to environment, existing process knowledge in database needs to fit the changes of manufacturing scene to make the reuse more efficiently and effectively. These factors in manufacturing scene are required to be considered in knowledge modeling and utilizing. The reuse process and influencing mechanism of these factors on the knowledge reuse needs further research.

In this work, the influencing mechanism of manufacturing scene change on process domain knowledge reuse is built to aid the engineer during knowledge reuse across the enterprises. This paper will first establish the digital manufacturing scene and analyze the key factors in process domain knowledge reuse across the enterprises. Then, knowledge reuse framework influenced by manufacturing scene change across the enterprises is proposed and examples are given. The final section discusses the influencing mechanism.

2 KEY FACTORS INFLUENCING KNOWLEDGE REUSE IN MANUFACTURING

The information in manufacturing can be classified into product manufacturing information and manufacturing knowledge. The first one is the all kinds of information of manufacturing elements including products, processes, resources (PPR); and the second one is all kinds of knowledge, which support the design or definition the information of manufacturing elements. Digital manufacturing scene consists of the information defining and the material processing. In information defining, the engineers use knowledge to define the PPR information models, and represent the models in some information carrier. In material processing, product manufacturing is driven by PPR information to transform material into products. Different persons, parts or products, time, place, software, hardware and manufacturing tasks form different manufacturing scenes, where the inputs of information and material are transformed into outputs of parts or products. The definition, management and application of PPR information is the key to digital manufacturing or E-manufacturing.

Process domain knowledge reuse across the enterprises is to build knowledge base by reconfiguring knowledge base and integrating intelligent design tools with its existing software systems to retrieve the knowledge to form the solution to support information model definition. In order to adapt to knowledge reuse across the enterprises, knowledge modeling and utilizing approach need to respond rapidly. There is same knowledge including process terms, material data, operation descriptions etc in some process domain knowledge, and there is close or different knowledge because of different technique level, machinery, etc in manufacturing scene. Process domain knowledge is reused for different manufacturing activities in different enterprises by integrating with different software systems. On the analysis of the manufacturing scene, products, machinery, tooling, tasks, operations, software systems, persons, etc. are the factors influencing knowledge reuse across the enterprise. These factors can be classified by knowledge modeling and knowledge utilizing as follows:

(1) Factors related to knowledge utilizing: Two factors of enterprise and integrated systems determine the main scene of different departments or enterprise and integration mode separately. All tasks or activities in digital manufacturing are completed by computer-aided application systems. Knowledge base is used through integrating with software tools in knowledge-reuse enterprise. To certain task in product manufacturing, engineers utilize knowledge to solve manufacturing problems and utilize application systems to edit the information model. he knowledge is required to be composed of standard domain concepts and used in distributed environment. The knowledge-based system is required to be integrated with changing software systems across the enterprises.

Application systems are gradually implemented to meet different function requirements in enterprise, and there are variances at developing technology, data structure, operating environment in different enterprises. Different modules of the same application system require different kinds of knowledge and reasoning mode. This leads to variance at integration scheme. Through analyzing all elements in integration and integration relationships, the flexible integration application mode is required to be established.

(2) Factors related to knowledge modeling: Two factors of manufacturing activities and PPR determine the knowledge types and knowledge population or content. Knowledge is correlated centering on the product information which is constituted of three kinds of manufacturing element information of products, processes and resources in process domain and serves for all tasks or activities. When products, processes and resources change, knowledge types and elements is required to reconfigure. The classification is required to be clear and easy to be cut. The organization or structure is required to be flexible and reconfigured rapidly.

On the one hand, the enterprise to reuse process domain knowledge has established some knowledge bases including work type, process file and other manufacturing resources. The knowledge will be merged with the new selected knowledge to form process domain knowledge base. On the other hand, not all the knowledge elements need to be modified. Firstly, process domain terms can be used without modification. Secondly, typical PPR information or knowledge elements can be updated and need a few modifications. Thirdly, case PPR information or knowledge elements need to be added according to the changing conditions of PPR.

3 KNOWLEDGE REUSE INFLUENCED BY MANUFACTURING SCENE CHANGE

The process domain knowledge reuse in target enterprise A is along two routes of knowledge reconfiguration and knowledge integrated application. Firstly, on the analysis of the enterprise, the processes and manufacturing activities are determined; then the types of knowledge are selected and knowledge elements are adjusted to form the target knowledge base. Secondly, the interfaces of information integration and user are developed. In the target enterprise, the knowledge can be reused to design the parameters and information model intelligently, rapidly, and qualifiedly, and the knowledge can be best used to perform efficiently.

(1) Knowledge reconfiguration: Manufacturing activities, processes, and products that the knowledge supports are different with the enterprises to reuse knowledge. This decides that different types or granularities of knowledge will be reused. To knowledge population, the variance of PPR that constitutes knowledge leads to the changes of content of knowledge base. Knowledge reconfiguration includes top-down knowledge type selection and bottom-up knowledge population configuration. After the knowledge types are selected, the knowledge elements are changed by adding, modification and deletion to form the new knowledge population. It is a knowledge base transplantation process customized by the target enterprise demands.

(2) Integration application: The knowledge utilizing process can be divided into problem definition, design inference and solution revision. The integration of intelligent design tools with CAX systems and knowledge bases in the target enterprise concerns about heterogeneous databases, knowledge utilizing logic, process planning systems, process information base, manufacturing resource bases from database to software interface upward. Through knowledge integration application, the knowledge is utilized to define the manufacturing information more rapidly and qualifiedly.

3.1 Knowledge reconfiguration

(1) Modular process domain knowledge organization model orienting to reuse: Knowledge model is built from the viewpoint of classification to describe the layers and components in every layer and from the viewpoint of population to construct knowledge elements. Firstly, knowledge of complex product manufacturing is classified into tribe of top layer by manufacturing activities, into genus by fabricating processes, and into group by products. The three classification standards are taken as three axis, and knowledge classification coordinate system is established. The point in this coordination system represents some kind of knowledge, which is named by z, y and x coordinates. For example, the point in Fig.1 represents ribs part rubber hydro-forming flow planning knowledge. A group of

knowledge is classified into basic type by abstract degrees of manufacturing elements information. Type is the bottom classification unit and minimum granularity of knowledge, which includes special, typical and general knowledge. Knowledge element is decomposed into information elements that are made up of known features and solving features. So there are two kinds of data item in knowledge model. One is knowledge element, and the other is information element.

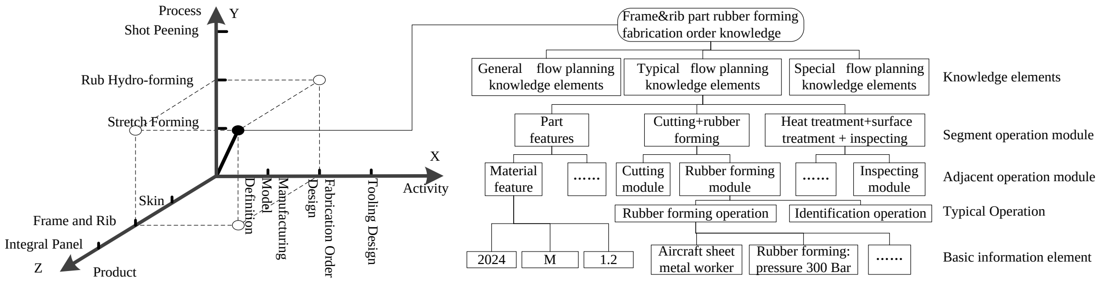

Figure 1: Aircraft sheet metal forming process domain knowledge organization model

Fig.1 shows the example of process domain knowledge organization model. Traditionally, knowledge organization is lack of flexibility and leads to the low efficiency in knowledge reconfiguration. For example, typical part fabrication process flow design knowledge is composed of dozens of separate operations. The influence of key factors has shown that knowledge organization is required to be flexible to adapt to the knowledge reuse across the enterprises. A kind of knowledge organization based on modular information elements is established. The operations in process flow can group into two layers of typical general information elements: adjacent operation module and segment flow module. The first one is membership of second one.

Module is a big granularity of information element. In the knowledge reconfiguration, module can be used to construct knowledge elements rapidly. The process domain knowledge reconfiguration is that data items are adjusted to adapt to the target enterprise. Information elements contents of operations are changed, but the fabricating flow can be constructed by the unchanged operations modules. That is to say, typical part fabrication process flow design knowledge elements can be utilized directly after the bottom operations are changed. This decreases the steps of knowledge elements reconfiguration and improves the efficiency.

(2) Knowledge reconfiguration process: Process domain knowledge types are selected to be reused based on the top-down knowledge classification tree according to the processes that the target enterprise uses and activities to support. The source knowledge population is stored in database, and database management system (DBMS) may be different from the target one. For example, the source DBMS is Oracle, but the target DBMS is SQL server. The difference should be considered to transplant the knowledge from source database to the target one.

The source data items of knowledge population are reconfigured to adapt to the changes of PPR from bottom to up. The changes consist of adding, modification or deletion of PPR information elements. The data items to be changed and the influencing paths are determined by comparison. The reconfiguration process is from bottom basic information elements, medium granularity of information elements to up knowledge elements layer by layer. Firstly, Adding new basic information or domain ontology. The terms of product, processes, work type, machine data, material data etc are acquired and supplemented into knowledge base. Secondly, Adjusting information elements. Typical parts, typical operations, operation modules, fabricating parameters etc are reconfigured by adding and modifying new elements with basic information or deleting some information elements that will not be used any more. Thirdly, Reconfiguring knowledge elements. To selected knowledge types, check and modify each existing knowledge elements; construct new knowledge elements. For example, the influences of change of processes on the knowledge base lead to changes of the operation types, contents, modules and fabricating flow from bottom to up. New processes terms are added to the basic information base at first. Then new typical operations are added and the contents of existing operations are adjusted to adapt to the target enterprise. New operation modules are constructed based on operation modules and added to the flow table of knowledge base. Finally, a part fabrication process flow design knowledge element is constructed by selecting the part and fabricating flow information elements.

3.2 Integrated application

The manufacturing engineering chain includes the design of fabricating order, tooling and manufacturing model and process parameter, numerical control code programming and other activities. Knowledge-based system for some manufacturing activity consists of knowledge base and knowledge handling logic. The integration application concerns about knowledge base, knowledge handling logic, manufacturing database and engineering design system. Process domain knowledge base contains new reused knowledge base built by reconfiguration and existing one, and it is the source of knowledge. Manufacturing database stores the engineering design information such as fabrication order, process parameters, die model and so on. Knowledge handling logic includes knowledge retrieving, inferring and updating. Engineering design system is performed by application systems and provides the environment of information display, editing and computing. The difficulty in integrating them is due to the differences of data format, development technology and DBMS etc. The integration relationship includes integration between engineering system and new reused knowledge handling logic, heterogeneous knowledge handling logic and existing knowledge base, knowledge handling logic and manufacturing database.

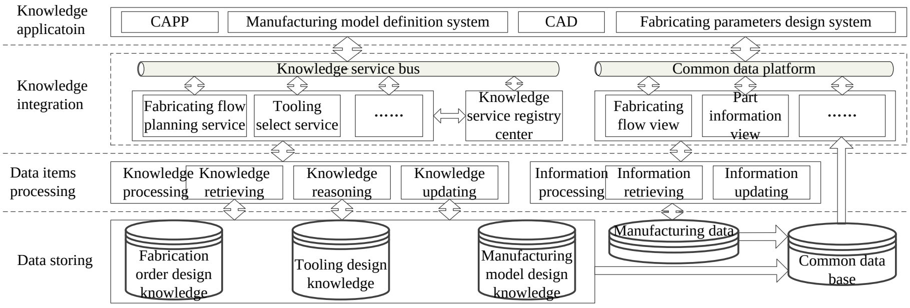

Figure 2: Loosely-coupled integration application of process domain knowledge

Tightly-coupled interfaces are usually used to integrate application system with knowledge base, and increase the dependence among the application systems and the cost of maintenance. It is not good for the system upgrade and extension. On the basis of influencing mode of integrated software and analyzing the integrated application process, a loosely-coupled mode of process knowledge integrated application was built based on process knowledge service bus and common data platform.

The framework of knowledge service bus based on service-oriented architecture is composed of knowledge service, knowledge service bus, service registry center and application systems. Knowledge retrieving, reasoning and updating are packaged as knowledge service and it is registered on the service bus. The knowledge service bus is used to connect and communicate with application systems. Application systems can inquiry and call the knowledge service. Service bus separates the application systems and knowledge service. It decreases the dependence of the integrated systems on each other and realizes loosely-coupled integration of application systems and knowledge-based system. That is to say, the flexibility of integration is increased.

The framework of this kind of integrated application is composed of knowledge bases, manufacturing database, common data platform and application systems. Information and knowledge sharing modes are specified in common data platform. The data views are built by taking knowledge bases and manufacturing databases as data sources. The inquiry users of shared data views are created on the common data platform, and application systems can get given shared data. In this mode, the data type and structure of the integrated knowledge bases and manufacturing databases need not to be modified, and only the data structure of the shared views is known by the integrated application systems, but not the original data tables and their relationships. Then a kind of loosely-coupled data and knowledge sharing mechanism is provided.

For example, the integration of fabrication order design knowledge base system is integrated with CAPP system in the target enterprise. In the target enterprise, the knowledge bases of machines, tooling and process files have been built and CAPP system is developed using ASP.NET. Part of the reused knowledge base includes typical fabricating flow design knowledge, fabricating parameters, material data etc and the intelligent design tool is developed using J2EE. The integrated application scheme presented above is used to achieve the integration of reused knowledge base, existing resources knowledge base, CAPP system and intelligent design tool. Web services are used to package the tools of fabricating flow planning, tooling selecting, machine selecting etc as knowledge service and the knowledge services are released in service registry center. The common data platform is designed on the Oracle database and provides global data sharing views which include part information, fabrication order data and typical fabrication order design knowledge. CAPP system is integrated with the reused fabrication order design knowledge-base system flexibly. The part information and fabricating process result from the common data platform. Typical fabricating process planning knowledge and resources selecting knowledge services are utilized to complete the process planning rapidly. The FO design time is reduced 30%, the content quality is assured and the dependence on the designers' experience is decreased.

4 CONCLUSION

Intelligent manufacturing can enhance the enterprise's manufacturing abilities by providing flexibility, responsiveness and high-quality. Process domain knowledge reuse can therefore be possible from the technology point of view. However, process domain knowledge base is not easy from the beginning of creating a new knowledge base to integrating with the current computer-aided enabling systems because of its complexity. This obviously shows the necessity of process domain knowledge reuse across the enterprises to better the product manufacturing. The influencing mechanism of manufacturing scene change on process domain knowledge reuse is introduced in this paper. The mechanism is built based on the analysis of digital manufacturing scene and key factors influencing process domain knowledge reuse. The factors require the knowledge model utilization flexible to reconfigure and integrate with current CAX systems rapidly. The module-based knowledge model of process domain knowledge makes knowledge organize flexible and reconfigure rapid. Loosely-coupled integration application based on knowledge service bus and common data platform makes knowledge utilize flexible and digital manufacturing rapid.

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