The research on construction and application of machining process knowledge base

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Abstract. In order to realize the application of knowledge in machining process design, from the perspective of knowledge in the application of computer aided process planning(CAPP), a hierarchical structure of knowledge classification is established according to the characteristics of mechanical engineering field. The expression of machining process knowledge is structured by means of production rules and the object-oriented methods. Three kinds of knowledge base models are constructed according to the representation of machining process knowledge. In this paper, the definition and classification of machining process knowledge, knowledge model, and the application flow of the process design based on the knowledge base are given, and the main steps of the design decision of the machine tool are carried out as an application by using the knowledge base.

1. Introduction

Process knowledge is an important intellectual capital of the manufacturing industry. It is a process-related knowledge that runs through the product's full life cycle in the product design, production preparation, manufacturing and operation and management activities of the enterprise[1]. In the face of complex and diverse knowledge of enterprises, the traditional process knowledge resource management has not adapted to the development of modern enterprises, which has affected the accumulation, communication, use and innovation of enterprise process knowledge[2]. In recent years, knowledge base construction technology developed rapidly, many scholars, experts have put forward new research results[3-5]. From the current construction and expression of process knowledge, the process knowledge in the knowledge base and knowledge expression model has no uniform standards, and the process of knowledge representation and knowledge model is the key to decide whether the knowledge can be shared and reused [6-8]. Based on the analysis of the knowledge of machining process, this paper classifies the knowledge of machining process and studies the expression of machining process knowledge in knowledge base. The process knowledge model, including the machining scheme, the machining processes, the manufacturing resource and the cutting parameter, is established, which is beneficial to the reuse and sharing of the machining knowledge in the enterprise.

2. Definition and Classification of Machining Process Knowledge

Machining process knowledge refers to all the process knowledge involved in the process of forming blanks into products[9]. The classification of machining process knowledge can be described from different levels. According to the product process, the machining process knowledge can be divided into process level knowledge, working procedure level knowledge and step level knowledge. The process level knowledge includes process route knowledge, processing method selection knowledge,

mold and blank design knowledge and so on. The knowledge of working procedure level includes the selection knowledge of machine tools, the mode of workpiece clamping, step design knowledge, process inspection knowledge and other knowledge. The knowledge of step level includes machining margin determination, cutting parameter knowledge and tool selection knowledge, measuring tool usage knowledge, etc[10]. According to the application mode of knowledge in machining process design, machining process knowledge can be divided into three categories. They are process rule knowledge, manufacturing resource knowledge and cutting parameter knowledge. In this paper, the knowledge of machining process will be discussed according to the application pattern division.

Process rule knowledge is used to express the corresponding relationship between part feature information and process decision method. It can support intelligent process decision. This kind of knowledge includes the processing scheme knowledge, processing method knowledge and process constraint knowledge. Process constraint knowledge includes sequence knowledge in the processing phase, generally follow the first face after the hole, the first base after the other, the first rough after the essence of the principle.

Manufacturing resource knowledge refers to the selection of tools and equipment used in the process of manufacturing, including the selection of common manufacturing resources, such as machine tools, tools, clamps and measuring tools.

Cutting parameter knowledge refers to the relationship between cutting tools, parts design information, machining methods, machine tools and cutting parameters, which can be used to guide the knowledge of cutting parameter intelligent decision making.

3. Representation of machining process knowledge

Knowledge representation is the process of expressing knowledge as a data structure that computer can obtain and process. Common knowledge expression methods include heuristic rule knowledge representation, semantic network representation, predicate logic representation, object-oriented representation, artificial neural network representation and ontology representation, etc. Each kind of knowledge expression method has its superiority as well as the certain limitation. Different kind of knowledge representation method are used in this paper in view of the application characteristic for the three kinds of knowledge mentioned above, by which the complication of simple problems as well as the incomplete definition of complex problems could be avoided simultaneously.

An important part of the intelligent process decision is to determine the processing chain, namely, the machining scheme, for each machining feature of the parts. Each machining scheme contains one or more machining methods. The knowledge expression of process rule includes the expression knowledge for the selection of machining scheme and machining method, and the expression knowledge for clustering rules and sequence rules considered in process sequencing. The factors that affect the selection of machining methods include the workpiece material, the size and accuracy of the machining features, surface roughness, hardness, the structure of the part, and production lot sizes and so forth.

The heuristic representation of knowledge index is adopted to express machining scheme knowledge. The index structure are used as the IF entry while the knowledge content as the THEN entry. Taking the machining method selection of a hole feature as an example, the knowledge index instance can be expressed in the form of IF-THEN as follows:

IF "Feature type = HOLE" AND "Machining accuracy (IT) = 11" AND "Surface roughness (Ra)= 12.5" AND "Workpiece material = CAST IRON" AND "Heat treatment type = QUENCHING" AND "Batch = LARGE",

THEN "Machining method = DRILLING".

The characteristics of the wide variety of enterprise manufacturing resources are the difference of parameters that describes resource capabilities. Therefore, object-oriented representation are involved in the process of knowledge representation of manufacturing resources. The basic attributes of each layer are defined in terms of the hierarchical structure of the manufacturing resources. And as a result, the storage management of manufacturing resources could be facilitated efficiently. Taking machine tools for example, machine tools are divided into machining centers, CNC machine tools and other sub classes. Sub class can further be divided, such as horizontal machining centers. Each class layer has its

corresponding attribute information. For instance, the knowledge expression form of machine tools is as follows:

Object class:: =<class>[numerical control machine tool]

Object attributes:: =<attribute>[name]

Object attributes:: =<attribute>[detailed description]

Object sub-class:: =<sub-class>[CNC milling planer]

Object sub- attributes:: =<sub- attribute>[machine tool version]

Object sub- attributes:: =<sub- attribute>[spindle speed]

Object sub- attributes:: =<sub- attribute>[power]

The selection of cutting parameters needs to meet the constraints of positioning ability, clamping ability, machining capacity and workpiece quality requirements that are provided by the process and the system. In the representation of cutting parameters knowledge, the heuristic representation of knowledge index is adopted. Five factors, including machine tool, cutting tool, feature type, workpiece material and process strategy, should be considered comprehensively.

4. Construction of knowledge model for machining process

The knowledge base eventually stores structured knowledge in the form of a database. However, the difference from the traditional database is that the knowledge base contains not only a large number of simple facts, but rules and process knowledge as well. In the model construction of process rules knowledge, according to the heuristic rule knowledge representation, the reference result of machining method and machining scheme knowledge is taken as the content of process decision. Figure 1 shows a typical knowledge model of machining scheme and machining method. This knowledge model includes heat treatment method, production batch, material, roughness, dimension precision, feature type and so on.
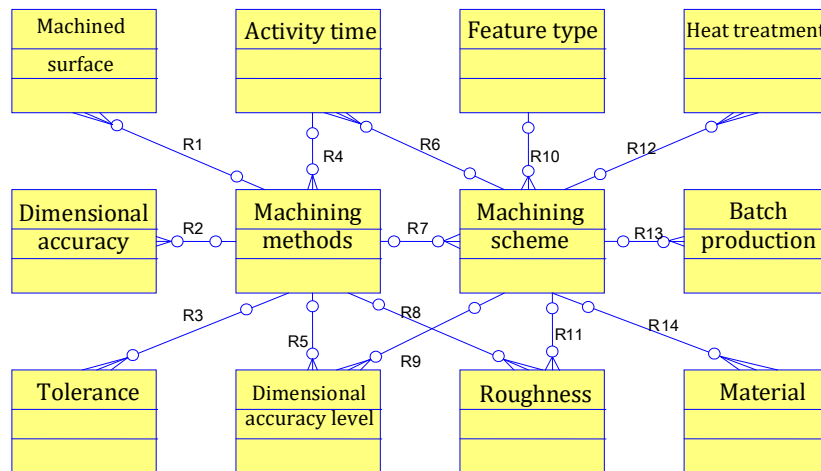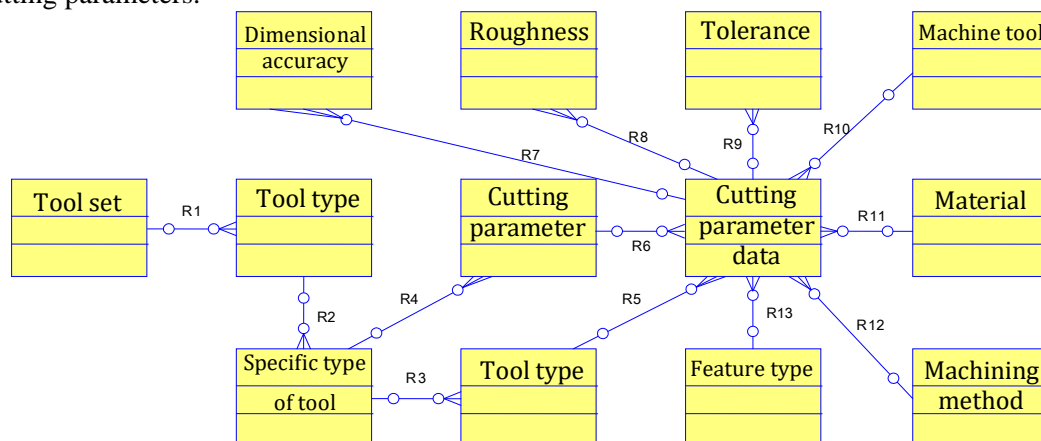

Figure 1. Knowledge model of machining scheme and machining method.

The knowledge model of manufacturing resource is built according to the object-oriented knowledge representation, as shown in figure 2. The manufacturing resource knowledge model describes the relationship between the specific types of manufacturing resources and the factors that influence manufacturing resource decisions as a bridge linking manufacturing resource types and manufacturing resource models.
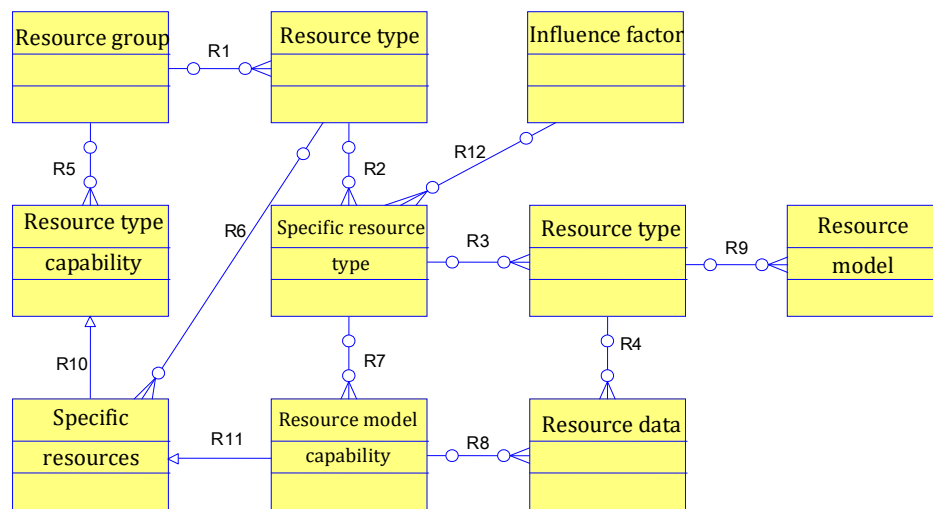
Figure 2. Knowledge model of manufacturing resource.

The knowledge model of cutting parameters mainly considers five factors: machine tool, cutter, feature, workpiece material and processing strategy. The cutting parameter knowledge model is shown in figure 3. Based on the hierarchical classification of manufacturing resource knowledge model, cutting parameters model establishes the knowledge of cutting parameters based on the tool type as the link. At the same time, the model describes the relationship among tools, parts design information, machining methods, machine tools and cutting parameters, which can be used for intelligent decision of cutting parameters.

Figure 3. Knowledge model of cutting parameters.

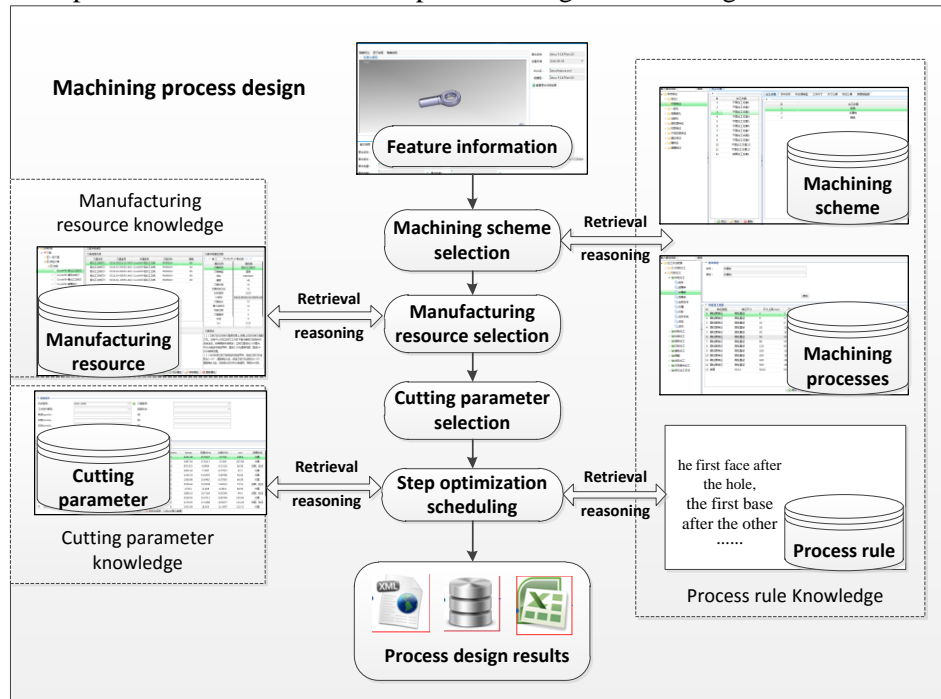## 5. Application of machining process knowledge base

This paper constructs the knowledge base as the starting point for the application, combined with machining process design system for rapid process planning. In the machining process design system, four knowledge bases are designed according to the knowledge model, which are machining scheme, machining method, manufacturing resource and cutting parameter. Taking the machining process design of the connecting parts as an example, the system interface and application flow are shown in Figure 4. And the decision-making process is as follows:

Step 1: 3D manufacturing feature information is extracted from the part. The feasible machining scheme set is generated and optimized to get the processing chain through querying the process rule knowledge base.

Step 2: The machining scheme is decomposed into a collection of machining methods. By making manufacturing resource knowledge and cutting parameter knowledge reasoning, the decision-making

of machine tools, cutting tools and cutting parameters are carried out in turn, and the manufacturing resources and cutting parameters required by the machining method are obtained.

Step 3: Through the reasoning of the process rule knowledge base, the steps are optimized according to the process constraint rules. The process design results are generated.

Figure 4. The process of machining process design based on knowledge base.

6. Conclusion

Based on the knowledge application, this paper analyzes the knowledge of machining process, establishes the knowledge model of machining process, and develops the knowledge base management system which meets the needs of enterprises. The knowledge base can support the rapid machining process design, facilitate the management of process data, adapt to the development of modern enterprises, and promote the accumulation, exchange, use and innovation of enterprise process knowledge.

References

[1]   Lu H L and Chu Z B 2012 *Microprocessors.* **33** 90-92,95
[2]   Peng X 2011 *Logist. Eng. Manage.* **33** 164-66
[3]   Koyama K, Hara N and Ohsugi I J 2010 *Int. J. Adv. Intell. Para.* **2** 49-63
[4]   Ken L D 2011 *J. Inf. Process. Manage.* **54** 243-53
[5]   Niu F Q, Liu Y H and Gao Y 2009 *Agric. Network. Inf.* **2** 112-17
[6]   Gao Y and Qiao L H 2014 *Aeronau. Manuf. Technol.* **16** 23-26
[7]   Qiao L H and Dong W 2010 *Avi. Preci. Manuf. Technol.* **2** 45-49
[8]   Gong Y Q and Lu M 2008 *Comput. Eng. Appl.* **26** 208-10
[9]   Wu J R 2016 *Mod . Manuf. Technol. Equip.* **4** 122-24
[10]   Guo C F 2011 *Coal. Technol.* **30** 3-5

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