Research and Application on Typical Process Knowledge Discovery in Mechanical Manufacturing Enterprise

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Abstract

The source and composing of process planning knowledge is analyzed based on the state of art in discrete mechanical manufacturing enterprise. On the basis of the widely application of computer aided process planning system (CAPP) in mechanical manufacturing enterprise, the concept of process planning knowledge discovery (PPKD) is proposed for product process planning database. CAPPFramework (a CAPP development platform that is developed by Northwestern Polytechnical University supported by China) is taken as a basic development platform, the technology architecture of process planning knowledge discovery is founded based on object-oriented model driven technology, and the process planning knowledge discovery script is designed. Elementary application research in typical process summarization is described in detail. The technology of PPKD has been used in mechanical manufacturing enterprise to support the automatically knowledge acquisition in CAPP system, and it shows good application effect.

1. Introduction

With the coming of knowledge economic, knowledge resource becomes the most important resource in discrete mechanical manufacturing enterprise. The competition superiority of enterprise comes from the effectively development and management on knowledge resource. Nowadays, with the rapid application of enterprise information software, knowledge resource in manufacturing enterprise is changing from employee's brain and written document into digital data [1]. These data are the foundation and source of knowledge management. How to make these data change into knowledge is the process of knowledge discovery. The process of knowledge management in manufacturing enterprise can be divided into three part, they are creating knowledge, finding knowledge and spreading knowledge. Figure 1 shows the basic process of knowledge management.

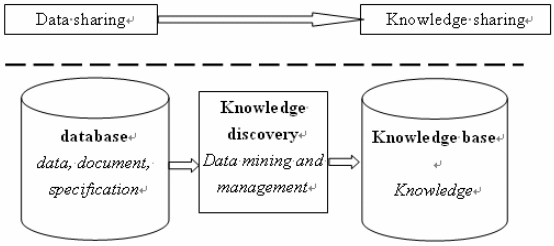

Figure 1 Knowledge management basic process

Process planning knowledge (PPK) in mechanical manufacturing enterprise includes foundation data, process planning specification, experience of expert etc. in process planning work. For the complexity of PPK, the PPK acquisition in process planning instances of papery documents needs knowledge engineers to accomplish. With the application of CAPP system, digital process planning data is accumulated rapidly. How to accomplish knowledge discovery on technique, experience, data, principle, and specification in engineering practice has been the key problem in manufacturing enterprise. With the in-depth application of CAPP system, how to discover new knowledge and enriching process planning knowledge base (PPKB) based on the accumulated product process planning database (PPDB) is regarded significantly. It is a new technology as we called process planning knowledge discovery (PPKD). Research achievement in expert system (ES), artificial intelligence (AI), knowledge management (KM), data mining (DM), data base (DB) etc. have established abundant foundation for PPKD. Nowadays, data discovery technology has been widely used in finance industry, communication industry, retail industry etc., but in mechanical manufacturing industry, especially

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in CAPP application system, it has less report and research [2].

2. Process planning knowledge discovery and management in mechanical manufacturing enterprise

Process planning knowledge in mechanical manufacturing enterprise includes foundation data, process planning specification, experience of expert etc. in process planning work. All kinds of PPK are synthetically used generally, for example, selecting manufacture method, designing fixture, arranging route etc. In commonly, PPK can be divided into four types.

(1) Handbook knowledge: It includes data and knowledge in process planning handbook and engineering standard, for example, tolerance, material, cutting feed and process planning specification etc.

(2) Manufacturing resource knowledge: It implies data and knowledge that has close relation with manufacturing environment, such as machine, cutter, fixture and process planning database etc.

(3) Decision-making knowledge: It is compose of experiential rule, procedure algorithm and control knowledge in process planning.

(4) Model knowledge: It includes process planning data model and process planning knowledge model, for example, product, part, process planning, operation, step, fixture, machine etc.

PPKD is the procedure of mining and formalization domain process planning knowledge in manufacturing enterprise. Nowadays, the main method of PPKD is done by knowledge engineer assisted by domain expert from literature, document, handbook, process planning file etc. in papery. The method costs vast time and depends on domain expert, these problems result in the poor implementation.

In fact, with the application of CAPP system in enterprises, process planning knowledge is involved in digital process planning data. It becomes a main PPK source in manufacturing enterprise. Based on representation of process planning knowledge model, technology and method, discover knowledge from digital process planning data can be an effective method to solve the bottleneck in PPKD.

3. Mechanical manufacturing enterprise process planning Information model and PPDB

In order to represent the commonness of PPK in enterprise, process planning information model (PPIM) is founded based on the overall analysis of process planning information in enterprise. PPIM is the foundation of PPKB and PPDB. PPKD is founded on the analysis of PPKB and PPDB based on PPIM. PPIM includes all fundamentals process planning object (product, part, process planning, manufacturing resource, route etc.). PPIM establishes the protocol on PPKD in CAPP system by the standard description of concept, item and model for the sharing on PPK. PPIM in manufacturing enterprise can be denoted as table 1.

Table 1 Description of PPIM

Name	Description
ProdM	Product model, it includes product no, product name, version and assembly relation etc.
PartM	Part model. it includes part name, part no, version, fixture, cutting elements etc.
PPM	Process planning model, it describes the relation of process, operation, step, product, part, manufacturing resource etc.
MRM	Manufacturing resource model, it includes machine, fixture, cutter and measure etc.
MOM	Manufacturing object model, it includes manufacturing object such as Material, blank etc.
PPDM	Process planning decision model, it describes methods and rules based on object class.
PCM	Process card model that is used to define process card based on process planning data model.
PFM	Process file model that is used to define the relation of process planning files.
WFM	Work flow model, it includes approval workflow model, process planning assignment model, process planning change model etc.
OM	Organization model, department and organization in manufacturing enterprise associated with CAPP are defined in OM.
UM	User model, user, role and right in manufacturing enterprise associated with CAPP are defined in UM.
FCM	Function configuration model, system configuration, function choice etc. are defined in FCM.

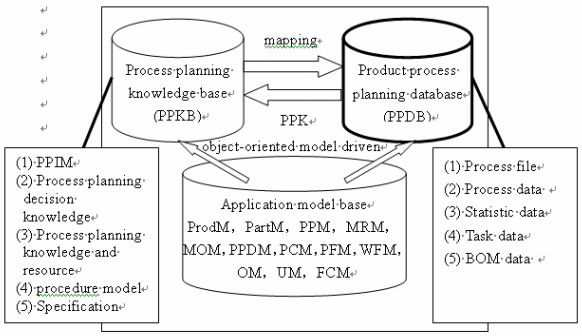

Figure 2 Product process database based on object-oriented model

4. Process planning knowledge Discovery technology based on PPDB

4.1. Process planning knowledge discovery

The application of CAPP system can be divided into three phases, they are foundation implement, accumulation of process planning data, process

planning knowledge discovery. PPKD can be implemented in the third phase. Based on the PPIM, the concept of process planning knowledge discovery (PPKD) is presented, it combines software technique and PPDB based on PPKB to realize the computer aided knowledge analysis and acquisition, it provides support to the standardization and specification for PPK [4]. The application foundation of PPKD based on PPIM is the foundation, application, maintenance of PPKB. PPKD based on PPKB and PPDB is showed in figure 3.

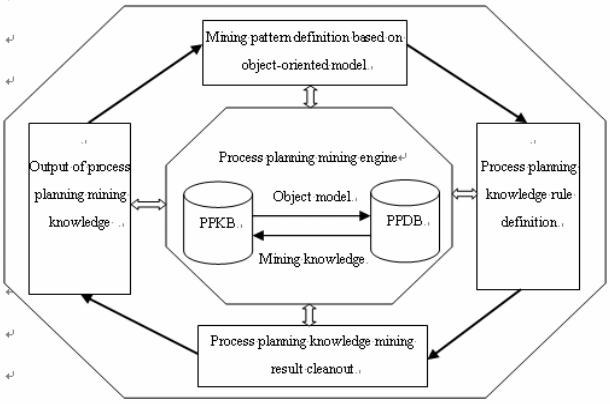

Figure 3 Process planning knowledge mining

4.2. Process planning knowledge discovery

In PPKD, the pattern of PPKD needs to be defined and make the knowledge discovery on the interest of users. Based on the PPIM, the PPKDS is designed to define knowledge discovery pattern, communication of PPDB and PPKB, support the procedure of PPKD. The realization of PPKDS helps the application standardization of PPKD. PPKDS can be used by user for defining interest dataset, data mining task, process planning type, mining procedure, evaluating and display mining result etc. PPKDS can realize the communication of PPKD engine with other software system to support the data and procedure integration. The main content of PPKDS includes the relative data of task, knowledge type for mining, background knowledge, evaluation of interest threshold value, representation and visualization of mining knowledge.

Based on the PPDB and PPKB, PPKDS can realize knowledge discovery in RDBMS. The syntax of RDBMS has an analogy to SQL, it is adopts BNF definition and easy mapping to SQL.

- **RULE 1:** The object class in PPKDS is mapped into a corresponding database table in PPIM. PPKDS transforms it into SQL statement and is mapped into the operation of database table.
- **RULE 2:** Generic attributes of object class in PPKDS is mapped into database section, the section type is defined by PPIM in PPKB.
- **RULE 3:** Complex attributes (such as object and object list) of object class in PPKDS is mapped into several corresponding database table in PPIM. PPKDS can be accomplished by the joint operation from main table to secondary table.
- **RULE 4:** Sorting, grouping, including operation in PPKDS is mapped into order by, group by, having operation in SQL statement.
- **RULE 5:** Fuzzy matching rule in PPKDS is mapped into such SQL statement as like_, like% etc.

5. Typical process discovery based on PPKDS

Based on PPIM, in the development of CAPPFramework (a CAPP development platform that is developed by Northwestern Polytechnical University which was supported by China), PPKD application tools are researched that takes PPDB as the core in CAPPFramework. The PPKD application tool based on CAPPFramework uses PPIM to realize knowledge model of CAPP system, and PPKD is optimized in CAPP application procedure to support the stepwise implement and development of CAPP system.

In the application of PPKD based on PPIM, PPKD technology was used to solve process planning standardization and specification by the analysis of PPDB, concept, item, typical operation, typical step, typical process and optimization of process planning can be achieved.

Typical process discovery based on CAPPFramework takes the group coding (GC) and process flow analysis (PFA) as technique foundation[5]. On the basis of operation code (OPC) matrix based on PPIM, and analysis of typical operation, typical step, similarity model of process planning knowledge is defined. PPKD in CAPPFramework is a clustering procedure, the knowledge discovery procedure and method is the same in different classes. In this section we use a machining process model as an example to explain the typical machining process knowledge discovery procedure [6],[7]. The machining process class model is showed as table 2.

Table 2 Machining process model

NO	Attribute name	Attribute alias name	Value type
1	PPLAN_NO	Process NO	String(64)
2	USE_SHOP	Using workshop	string(64)
3	PLAN_ID	Process identifier	string(64)
4	PART_TYPE	Part type	string(64)
5	PART_TYPE_ID	Part type coding	string(64)

(1) Knowledge discovery class definition: It is to define the knowledge discovery class that defined in PPKB. The object class of typical machining process knowledge discovery is machining process class. The PPKD engine in CAPPFramework can automatic find relative database tables in PPDB based on knowledge discovery class definition.

(2) Key attributes definition: Typical process knowledge discovery class definition is a clustering procedure, it needs to analysis the class attributes, define the clustering rules of machining process in PPDB, and confirm the analysis of typical machining process on specified part type.

(3) Associated support classes definition: Typical process knowledge discovery procedure needs to build OPC matrix based on part process, it needs the support of machining operation and OPC. So machining operation class and other relative classes must be defined in PPIM. By doing this, the operation in part process can be mapped into typical operation.

(4) OPC generation rule definition: Because the operation in part process can not be the same with typical operation, operation matching rules must be defined. It can be reached by the matching on key attributes. For example of table 2, key attributes can be define as shop, workshop section, operation name. Only the three attributes value is all the same, we think this matching is success.

(5) Knowledge discovery rule: Process comparability rule need to be defined on a specified part type,. Three rules are founded in PPKD of CAPPFramework. It includes MaxOPNum rule, MaxPlanNum rule and SysSynth rule.

- **MaxOPNum rule:** All{OPC} is the set of all operation coding of all part process on a specified part type. By the analysis of a part process with All{OPC}, we think the most maximum part process is the typical process of this part type. It shows as formula 1.

$$Max\{\frac{Part1\{OPC\}}{All\{OPC\}},\frac{Part2\{OPC\}}{All\{OPC\}},\ldots\ldots,\frac{Part N\{OPC\}}{All\{OPC\}}\}$$

- **MaxPlanNum rule:** Parts are divided by the rate of part process and All{OPC} based on MaxOPNum rule. So set of {Type 1,Type 2,……,Type N} can be acquired. We select the set of Type X{Part 1{OPC},Part 2{OPC},……,Part N{OPC}}, it has the most part process. In this set, we use MaxOPNum rule to select the typical machining process.
- **SysSynth rule:** We take the set All{OPC}as typical process and accord the position, frequency of every OPC in part process. By the Statistic and sorting, the operation set and sequence of typical machining process can be reached.

(6) Cleanout of discovery result: For the complexity of process planning knowledge, the knowledge discovery result probably includes invalid or repetitive knowledge, cleanout of these is essential. It includes two patterns.

- **Contrast with PPKB:** It is to contrast the result set with PPKB, if repeated instance was founded, the instance is delete in result set. Interaction is allowed between system and user.
- **Handiwork cleanout:** The result set is displayed in tree form or list form, process planning management personnel can checkup and dispose freely.

(6) Output of result set: When the result set is cleaned, it can be added to PPKB in computer memory or output as external file (XML, txt format) for more checkup and import.

For machining process class in table 2, the PPKD script is showed in table 3. The script can be stored PPKB for repeated use later. Figure 4-5 are some typical application interface of PPKD in CAPPFramework.

Table 3 Typical machining process PPKDS script

```
use PPDB: xac_ppdb;
use PPKB: xac_ppkb;
use hierarchy PART_TYPE_ID for machining process;
in relevance to machining process, all, machining operation all;
from machining process, machining operation;
mine characteristics MaxPlanNum;
analyze SHOP,WORK_SEC,OP_NAME;
display as table;
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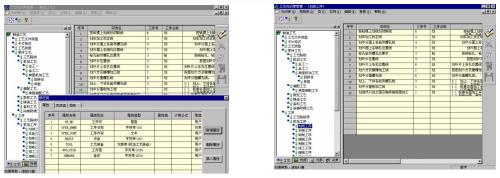

Figure 4 PPIM of a manufacturing enterprise

Figure 5 Process planning data and knowledge discovery

6. Conclusion

Process planning knowledge discovery and management is the important foundation work of manufacturing enterprise. It is the most difficult work in manufacturing enterprise knowledge management. It includes concepts, terms, typical operations, typical steps, typical process and manufacturing resource etc. Process planning discovery and management can not be success implementation by the supporting of software system. By the practice of using PPKD technology in CAPP system developed based on CAPPFramework platform, PPKD can be executed automatically in PPDB. It can solve the standardization of process planning knowledge to a certain extent and helps the standardization and specification of process planning data effectively.

7. References

[1] A.Gunasekaran, Next generation computer-integrated manufacturing strategies and techniques, International Journal of Computer Integrated Manufacturing, 14(2), 2001, 137-139.

[2] Farid Meziane, Sunil Vadera, Khairy Kobbacy, Intelligent systems in manufacturing:current developments and future prospects, Integrated Manufacturing Systems,11(4), 2000, 218-238.

[3] Industrial Automation System and Integration—Product Data Representation and Exchange, Part 28: Implementation methods: XML representations of EXPRESS schemas and data, ISO/TS 10303-28, ISO, Switzerland, 2002.

[4] Paul A.Rodgers， Nicholas H.M.Caldwell， P.John Clarkson, Managing knowledge in dispersed design companies——Facilitating context-driven design support through multiple perspectives, J.S.Gero（ed.）， Artificial Intelligence in Design, 2000, 147-167.

[5] Ciurana, J., Romeu, M.L.G., Castro, R. Optimizing process planning using groups of precedence between operations based on machined volumes, Engineering Computations (Swansea, Wales), 20(2), 2003, 67-81.

[6] M. Shakeri, Implementation of an automated operation planning and optimum operation sequencing and tool selection algorithms, Computers in Industry, 54(3), 2004, 223-236.

[7] Stephan Haberle, Karl Furst． Knowingplant—— Decision supporting and planning for engineering design. Intelligent Systems in Design and Manufacturing III, Proceedings of SPIE, 2000, 376-384.