Knowledge Representation for Knowledge-based Generative CAPP

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Abstract—**In this paper we discuss the features and knowledge representation issues involved in knowledge-based generative CAPP because CAPP is not only related to CAD and but also knowledge about manufacturing. As many forms of knowledge are needed in knowledge-based generative CAPP, with the features we defined based on the cutting tools for the feature machining, we discuss the knowledge representation about the part description, and manufacturing resources knowledge which are manufacturing operations, cutting tools, machine tools. All this knowledge is connected by the features defined to help knowledge-based generative process planning and also this knowledge can have a link to the feature-based part modeling. With the features defined， all knowledge is no longer stand alone knowledge so that it can support knowledge-based generative CAPP well.**

Keywords-knowledge; generative CAPP; feature

I. INTRODUCTION

Computer aided Process Planning (CAPP) is a means to automatically develop the process plan from the geometric image of component. The key to the development of such CAPP systems is to structure the data concerning the part design, manufacturing facilities and capabilities into categories and logical relationship. In generating a process plan for a part, the process planner must interpret engineering drawings, determine the best sequence of operations, make decisions about how cut should be executed, specify which tools, machines; fixtures are needed, and so on. CAPP thus integrated CAD and CAM.

There are two basic approaches to computer aided Process Planning. That is variant and generative. The variant approach can be regarded as an advanced manual approach in which the planner's memory retrieval process is aided by the computer. In generative approach, a process plan is created for each component automatically. A large database and complex built-in decision logic would certainly be required to generate a process plan for arbitrarily complex parts. To date the generative approach has been restricted to special classes of parts that have a limited set of part feature [1, 2]. These systems are designed to automatically synthesize the information to develop a process for a part. Knowledge-based generative CAPP system has received much effort in recent years because the process generating depends on planner's knowledge of manufacturing capability, tooling, materials, and machine tools. The solution to the process planning task depend mainly one the empirical knowledge relevant to the organization based on the existing facilities. Fig. 1 shows the structure of knowledge-based generative CAPP system. We can see that the process is generated based on the knowledge.

In this paper we propose a series of "work in progress features", which can be used for both part modeling and for connecting knowledge about manufacturing operations, cutting tools, machine tools. In addition to these, as many forms of knowledge are needed in knowledge-based generative process planning, we discuss the knowledge representation about the part description, and manufacturing resources which are manufacturing operations, cutting tools, machine tools. All this knowledge are connected by the features defined to help implement knowledge based generative CAPP. This paper introduces how the knowledge about manufacturing operations, cutting tools, machine tools are extracted, connected and represented.

(1) The Components of Manufacturing Resources

Manufacturing resource can be classified into three levels according to the role the manufacturing resource plays in the process planning: workshop level, equipment level, knowledge level. The fact that taking workshop as a resource level is very important. The definition varies in different factories. Usually each factory has its own way to divide workshops. Some factories do this by the different kinds of work pieces, such as crank cylindrical surface workshop, spindle workshop, etc. Some factories do this according to the machining phase, such as rough machining workshop, finish machining workshop, This classification method for workshop not only represents the way the enterprise organizes its production, but also it affects the process plan for each part. When process plan engineer plans for a part, firstly he will take into account overall information of the part, then decide what workshops the part should go through. This will determine the general picture of the part machining process. The equipment level contains various machine tools and process equipment, such as tools, jig and fixtures and measuring tools. The machining knowledge level contains machining parameters, working hours and machining allowance, etc. In this paper the manufacturing resources contains only the equipment level and knowledge level.

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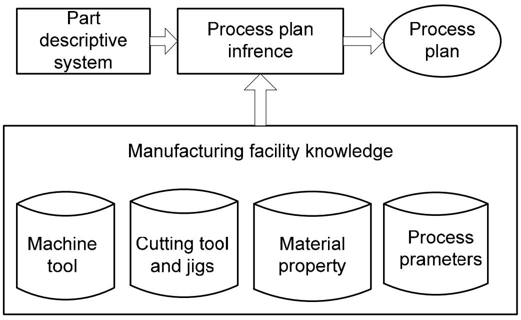

Figure 1 Knowledge-based generative CAPP

(2) Manufacturing Resource Knowledge and CAPP

Concurrent engineering is a business strategy which replaces the traditional product development process with one in which tasks are done in parallel and there is an early consideration for every aspect of a product's development process. This strategy focuses on the optimization and distribution of a firm's resources in the design and development process to ensure effective and efficient product development process. Manufacturing resource modeling is a important part in the research on the CAD, CAPP, CAM, many efforts have been on how to realize concurrent engineering [1,3].

Process planning is the function in a manufacturing facility that establishes which process and parameters are to be used, as well as the machines performing this process. The goal is to convert blank to a part in desired shape as specified in the engineering drawing. As for CAPP, all the process is planned based on a specified manufacturing environmental, so the manufacturing resource knowledge is important. But it is very hard to find a mathematical model for the process planning. As the complexity of the manufacturing resource, the success of CAPP relies much on the method for manufacturing resource representation. On the other hand, in the planning process, the decision is made much on expert knowledge. With the development of knowledge engineering, knowledge-based CAPP system has received much effort, and is moving towards intelligent knowledge-based CAPP system [3, 4].

The above analysis shows that manufacturing resource representation is very important in intelligent CAPP. In this paper we propose a new concept “transitional feature” based on the feature modeling theory in order that we can use this concept for both products modeling, and establishing the connectivity for part specification, machine tool, tooling, jig and fixture, and measuring tools. With this technology, all the knowledge of the manufacturing resource can be well-organized for supporting intelligent CAPP well.

II. FEATURE AND TRANSITIONAL FEATURE

A. *Feature definition*

The definition for feature varies in different applications; even the same “feature” has different forms. From the view of design process, feature is the corresponding geometric description for functions and structures. But from the view of process planning, it is for structures and process, thus from machining point, feature is the corresponding description to process planning, machine tools and cutting tools. Feature-based product modeling is the combinations of features which include design and machining information. In the specific system, features will be defined as a parametric shape unit which has geometry attributions, manufacturing attributions.

B. *Product design process, manufacturing process analysis and the concept “transitional feature”*

(1)Analysis of the Manufacturing Process

From the blank to the final part, parts need to go through different operations that gradually remove the excess materials and evolve to the final state; therefore, this process can be considered as the fact that the blank pass different working procedures and states. The initial state is the raw material or work piece from which the part is to be produced and the goal state is the finished part. The set of operators comprise the available machine tool, etc. Processing of the part involves proceeding from the raw material to the finished part. Applications of operator (machine and cutters) and the various stages represent the work ‘in progress’ condition.

Sinitial→S1→S2→…→Sfinal

These process parts gradually increase the accuracy and surface finish to the design requirements. The manufacturing precision that the process parts get has corresponding final processing methods, in other words, each of the processing methods corresponds with the geometry shape can be achieved and the accuracy can get. We describe the link of processing methods, its corresponding geometry shape and attained accuracy by using the conception of transitional feature. “transitional feature” not only describe the part’s final forming state, it can also describe “process parts” .Transitional feature is a manufacturing process-oriented classification. For example, in the machining chain of cylindrical surface “rough turning--semi-refined turning—refined turning”. After rough turning or semi-refined turning, there will present a different state of part(geometry shape, manufacturing accuracy), which describe the evolution process of part , more over, each state has the corresponding machining and tools. Because of the relationship between the tool and machine, the links of machining process, tools and machine tools corresponding to the state can be built.

(2) The analysis of product design process

Based on the function requirements of product, product design process normally design the geometry that constitutes the part’s surface, as well as the geometrical shape, tolerance, dimensional accuracy and surface finish corresponding to the different geometrical shapes. The part’s geometry, dimensional accuracy and surface finish vary in he different functions of products, in other words, one product’s intermediate state may be the other’s final state, and vice versa. As a result, it enabled us to use the conception of “transitional feature”, which not only describe the part’s features with respect to manufacture process, but also it can be used to describe parts in the course of design, and the modeling approach based on the transitional feature. All design data can be connected with the machining process and manufacturing resources, thus in the course of design, some related machining process and information could be given and the design for manufacturing will be implemented.

C. The definition of transitional feature

This paper proposes the concept "transitional feature", and the concept is used to descript and define the part from the blank, semi-finished product and the final part with a common modeling system. With this technology, it is easy to implement CAD or CAPP integration, it also simplifies the intermediate database structure in the process, accordingly reduce the space of data files.

Transitional feature can be defined as the surface of part, and has the following meanings:

1) Transitional feature is one surface or several surfaces

2) Transitional feature is not only applicable to the description of the final parts, but also applies to the descriptions of semi-finished products; thereby a common information model can be constructed.

3) The classification method for transitional feature is closely related to the machining process and cutters.

4) The attribution of a transitional feature includes manufacturing precision information, machining process information, material information, geometry information and its constraints, etc.

Transitional features not only are attached with the information of dimensional accuracy and finish to geometrical shape, but also with the corresponding machining process and cutter. Accuracy and finish are the important factors affecting machining process; therefore, we usually divide the part characteristic into various stages of machining by the accuracy and finish. Each corresponding characteristic is called transitional feature.

Table 1 shows only cylindrical feature for rotary parts modeling and this cylindrical feature is divided into some sub-features according to surface finish, tolerance, material, and the corresponding cutter. For rotary part feature modeling, there may be cylinder, taper, hole, gear feature etc. For these feature we can do as we do for cylindrical feature following the same rule. For the fourth one, and the corresponding machining process is refined turning or coarse grinding (quencher), refined turning tools or grinding wheel as the cutting tools are used. Thus we can establish the connection among the surface specification, cutting tools and machine tools.

Fig.2 shows the evolution process of cylindrical surface machining. These as the material removal has not been done, the stage can be reversed. These stages are non-reversible as the material once removed can not be added back. However in the process planning, we can easily machining chain from it. So, if we define the features like this we can not only get the machining process easily, but also get the cutter, machine tool and machining data. All these information is connected.

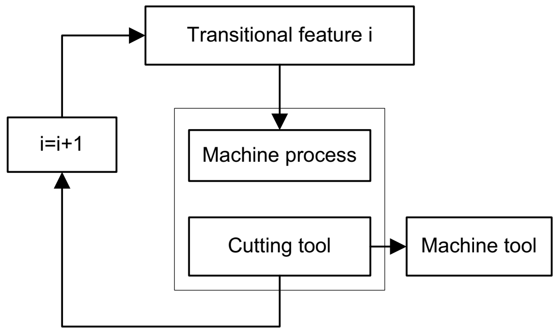

Figure 2 The evolution of transitional feature

TABLE 1 TRANSITIONAL FEATURE FOR CYLINDRICAL SURFACE

Transitional feature			Cy11	Cy12	Cy13	Cy14	Cy15	Cy16
attribution	geometry		Cylindrical feature					
	accuracy	tolerance	6-3	6-5		8-7		10-9
		finish	0.1-0.006	0.9-0.2		1.6-0.8		6.3-3.2
	Over all	material	steel	steel		steel		steel
		heat treatment	harden steel	harden steel	none	harden steel	none	none
	Machining process		lapping	fine grinding	fine turning	rough grinding	fine turning	semi-fine turning
	Cutter code		41003	41001	11002	41002	11001	11003

III. KNOWLEDGE REPRESENTATION FOR MANUFACTURING RESOURCE

In the paper above, we explain the definition of transitional feature, through which, the feature, machining process, cutting tools, machine tools are well connected. Each transitional feature has its corresponding machining process that attached with the relevant cutting tools and the data of cutting parameters. In actual machining process, we only need one machining process and the relevant cutting tools to complete the processing of transitional feature, while the cutting tools are associated with some machine tools, thus the links of feature, machining process, cutting tools and machine tools are established, as shown in Fig.3.

A. *The Relationship between the Cutting Tool and Machine Tool*

We use an object-oriented approach for representing the manufacturing resource knowledge relational entities and the relationship among them for the development of automated CAPP system The objected oriented approach views the manufacturing resource as a set of interrelated objects which during process planning exchange message. Each object carries: data identifying it through a set of attributes, functions that defines its behavior through appropriate method, and links to other objects through association with other objects. Each kind of object is represented as a hierarchy with the relationship is-a between them and instance at the bottom level. Lower objects in the hierarchy inherit common attribute and/or their values from higher level objects.

B. *Relationship among transitional feature, machining process, and cutting tool Units*

The transitional feature, cutting tool and machining process is a one-to-many relationship. A transitional feature corresponds to one or a few cutting tools and machine tools and each cutting tool can be attached to one or several machine tools.

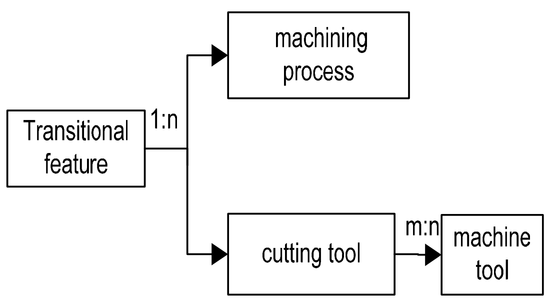

Figure 3 Relationship between transitional feature and manufacturing knowledge

The attributions for each machine process, cutting tool, machine tool are the some important parameters (like the maximum diameter can be rotated, maximum length, precision capability, lathe type etc. for lathe). Attributions and relationship of transitional feature, machining process, cutting tool and machine tool are represented, So that all the data or knowledge can be connected. This method has been proved connection of knowledge base has been proved effective in a prototype.

IV. CONCLUSIONS

CAPP is very important for CAD/CAM integration and is not well developed. Because the process planning depends on planner's knowledge of manufacturing capability, tooling, materials, and machine tools, the solution to the process planning task depends mainly one the empirical knowledge relevant to the organization based on the existing facilities, it is difficult to find a mathematical model for the process planning. For the reasons above, knowledge-based generative CAPP has been recognized as an efficient way to solve these problems, knowledge representation is very important for developing knowledge-base generative CAPP

Transitional feature is an extended concept from the conventional concept "feature"; and it can be used both for part modeling and the semi-finished product modeling. In addition to that, as transitional features have the attribution of machining process; it is an also practical approach for manufacturing resource modeling. By means of transitional feature, we can build up the knowledge connectivity among part features, machining process, cutting tools, machine tools, so this approach can support concurrent engineering and integration of CAD/CAPP. All the knowledge about the manufacturing knowledge (machining process, cutting tools, machine tools) can be organized well to support knowledge-based generative CAPP.

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