Knowledge-Based CAD/CAPP/CAM Integration System for Manufacturing

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Abstract: Integration of CAD/CAPP/CAM is a natural result of scientific advance; such integration fulfills an overall automation and intelligence from product design to manufacturing in enterprises. In the paper, a new CAPP system is involved in and some new methods are introduced. The CAPP system is based on UG software, which is used as a platform of CAD/CAM system. A new way adopting the UG/API function to develop an interface between CAD and CAPP is employed to make feature extraction that can be transferred from CAD to CAPP. Then part information is sent to a knowledge base in the CAPP system. Process planning can be automatically generated through reasoning processes. The architecture of integration system and design methods are presented.

Key words: CAD/CAPP/CAM, API, feature extraction, Intelligence Manufacturing Systems.

1. INTRODUCTION

Integration of CAD/CAPP/CAM is a natural result of scientific advance; such integration fulfills an overall automation and intelligence from product

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design to manufacturing in enterprises. Productivity, quality, and manufacturing capacity are greatly improved by such integration. [Wang, 1991] Besides, the management methodology of an enterprise is also heavily influenced. However, the integration is a complex systematic project. The cost may be rather high, and if not implemented accurately, the benefits coming from CAD/CAPP/CAM integration will be compromised. Thus, one of the current trends in mechanical manufacturing area is to implement such an idea effectively with light investment, which is also our general rule when implementing the integration. CAD/CAPP/CAM integration is also required by the production and supported by the technical advances.

As separate systems, CAD, CAPP and CAM have been widely used in enterprises. However, due to the different historical backgrounds for these three systems, there are some limitations for the current application methods. Although these three systems are widely used in industries, there is limited information sharing among them, which reduces the efficiency of the system. Since these systems are separated in nature, resources in each system are also not fully utilized. With the advance of networking technique, information exchange among these three systems is highly desired. Processing information and knowledge should also be put on the first priority in development of integrated systems. In practice, different enterprises have different views of CAD/CAPP/CAM integration, but there are some common aspects related to system integration:

1. Parts information from CAD system has to be extracted and transferred to CAPP system completely and then CAPP system should generate the corresponding process plans automatically.
2. The CAPP system has to offers functions to manage information and knowledge. It means that the system provides mechanisms for users to acquire, share, utilize and create the knowledge in process planning.
3. In CAPP/CAM integration, the process planning information that generated by the CAPP system, should be transformed into NC codes in order to control NC machines.

It is very necessary to manage all data, information and knowledge related to manufacturing processes, such as, product data, CAD information, resource information, CAPP knowledge and so on.

Based on above principle, NTNU together with Xpalno developed an intelligent system for manufacturing companies to implement CAD/CAPP/CAM integration. The system was based on the UG software as CAD/CAM platform. It successfully extracted the design feature with UG/API method. It can automatically generate process planning using a knowledge base which users are able to create and modify all the reasoning rules in the system. [Wang, 2000]

2. THE AIM OF THE SYSTEM

2.1 Integration

The integration of CAD/CAM/CAPP is very important for improving efficiency of manufacturing and sharing production information. In order to take advantage of sharing information, the integration with PDM, ERP is also requested.

2.2 Intelligence reasoning

How to utilize the design and manufacturing information from CAD system to generate the process planning in CAPP system is a complex problem. Our aim is to generate the process planning based on feature information from CAD automatically. In the process of manufacturing planning, intelligence approaches are used to develop reasoning processes.

2.3 Information and knowledge management

The complex process planning is related to many data, factors, information and knowledge of product and production in manufacturing environment. Managing knowledge is very important, imperative and valuable in order to generate a perfect process planning. How to offer an efficient environment to user and how to organize, manage knowledge is also our tasks in the development of the integrated system.

3. THE PRINCIPLE OF SYSTEM DESIGN

The integrated system is intended to provide practical solutions to the enterprise, but not a general system used for all enterprises. The following rules are followed during the system development:

3.1 Usefulness and practicability

The designed system should provide practical and useful functions to user, which can be used to solve practical problems.

3.2 Reliability and safety

Since implementation of the integrated system will be related with some low-level techniques of CAD/CAPP/CAM system and database system, reliability and safety are key factors for the success of the integrated system.

3.3 Expandability

Since the system is not a general solution to every enterprise, expandability will be considered during development in order to accommodate potential, specific requirements from different users.

3.4 Adaptability and Flexibility

Parameterized design concept and OOP technology are implemented in the system development. These techniques will ensure the adaptability and flexibility of the system when those items are actually changed during operations.

4. THE ARCHITECTURE OF INTEGRATION SYSTEM

To integrate CAD/CAPP/CAM, the key factor is to implement data sharing and exchange among individual system, which ensures sharing of design information, process information and manufacturing information. Figure 1 shows the CAD/CAM/CAPP integration architecture.

UG II software, from EDS, is applied in the system. Besides providing various supports for design (part design, 3D feature design, feature recognition, assembly and division etc.), UGII also provides support for automatic generation of NC codes and drives NC machines directly. Thus, UGII is chosen as CAD, CAM platform in the integrated system. The main aim for UG/CAD is to provide users with powerful part design functions. Besides, the system also provides 3D feature design functions, feature recognition functions and data exchange interface. [EDS Unigraphics]

The CAPP system are generating part process planning automatically through design information transformation interface and process reasoning procedure, and providing users with process editing and managing supports. At the meantime, it also manages related information and feeds the process planning back to CAM module to generate NC codes through manufacturing information interface and driving NC machines directly.

The interface between UG (CAD/CAM) and CAPP system is a key to the system.

Figure 1. the CAD/CAM/CAPP integration architecture.

5. THE APPROACH TO IMPLEMENT

5.1 CAD/CAPP Integration

In order to implement CAD/CAPP integration and transform part design information into process information for manufacturing the part, the following procedures are employed.

With the information exchange supports provided by UGII software, UG part design information (including geometric information and part feature information) is extracted from UG system through design information transformation interface, and stored (according to certain self-defined format) in transformed information database.

The transformed information is further processed by feature extraction, recognition and classification etc. to obtain original information for generating process plans.

On the basis of the original information, process plans are generated automatically by inference engine and are stored in CAPP process information database.

As we known, there are some criterions to use for information exchange, for

example, STEP standard, XML and open XT format standard in UG. The UG/CAD also supports the standard. But the standard is too complex to use efficiently. In our system, a simple method called UG/API to extract information from CAD is applied.

Through the UG/API method provided by UG software for supporting the secondary development, we can develop the interface to extract the feature information and attributes. Based on analysis of information exchange, we need to get the following information from UG/CAD system to achieve the integration of CAD/CAPP. The most important information extracted from UG is listed in fig.2

Figure 2. The most important information extracted from UG

5.2 CAPP System

Application system in CAPP can then be used to process planning (edit, manage, and dispatch etc.) The CAPP system provides functions for automatic process generation, manual generation, process editing, process management, information combination, process dispatching, resource management and process information sharing etc. providing user interface for PDM is desired. The system includes following major modules:

Figure 3. CAPP models

- **Knowledge base:** The reasoning rules for generate process planning is stored in the knowledge base. The main function of which is to collect the experience and knowledge from experts and operation engineers in the

company. [Riley, 1989]

- **Resource database:** All resources of the manufacturing environment, including machines, cutting tools, fixtures, etc can be stored in it.
- **Process planning:** To make templates, edit the existed the process planning and monitor planning status.
- **Automatic Process planning:** To generate the process planning based on knowledge base and resource database; offer the manual function to edit process planning. Template function is offered to share process planning information, offer tools to get correlative knowledge of process planning. In this module, the integration of CAD/CAPP/CAM is implemented and realized. The reason process in the module is key to make the system intelligent.

In CAPP module, the intelligence plays an important role. It includes defining knowledge base, managing resource and automatically reasoning for process planning. The reason rule can be defined in knowledge base. The resource database is used for managing all manufacturing resources. In reasoning process, a reasoning engine generates process planning based on the reasoning rules and the information of resources. The reason mechanism is shown in figure 4.

Figure 4. The reason mechanism

We define following steps for reasoning process planning:

- *Manufacture method selection*

According to some design and manufacturing features extracted from UG/CAD, including feature type, feature dimension, tolerance, roughness, the finial manufacture approaches can be selected. For example, if we know a cylinder and its dimension, roughness; then we are able to get the finial manufacturing method to make the feature. The rules about how to select the manufacturing approach can be designed in knowledge base by users.

- *Raw material selection*

The rules of raw material selection define how to select raw material according to overall dimension and shape identification of the part. So, it is necessary to calculate overall dimension and shape identification. We can get the overall

dimension and shape based on dimension and location of each feature.

- *Machine selection*

The rules for selecting machine are based on manufacture methods, raw material dimension, machine parameter and performance, etc..

- *Fixture selection*

The rules of fixture selection can be defined according to overall dimension, raw material and machine interface. For example, using the rule of the chuck, chunk jaw can be selected.

- *Cutting tools selection*

Cutting tools selection refers to many options. In this phase, we not only select cutting tool material, shape and interface, but also select adapter and basic holder to fix the cutting tool. The rule is defined according to feature type, manufacture method, work piece, cutting tool parameter, adapter parameter and basic hole parameter.

- *Manufacture Sequence selection*

Based on the feature types, manufacture methods and location relation among each part feature, the sequence of process planning can be obtained. Some rules can be defined in knowledge base in order to adjust the sequence of process planning if the users want to modify the sequences generated.

- *Dimension calculation*

Dimension calculation is a complex process. It is based on the different feature type, manufacture method and model.

- *Cutting data selection*

Cutting data includes cutting speed and cutting feed. The rule is defined according to cutting method, cutting tool and work piece material.

In CAPP system, the Information management is also employed to manage all data, for example, part information, process-planning information, etc..

5.3 CAPP/CAM Integration

In UGII (CAM) system, the NC code for a manufacture part can be generated automatically. In the process of generating NC code, process planning plays an important role. It is necessary to transform the information of process planning into CAM system correctly and smoothly for generating the NC code automatically.

In the process of generating NC code, the information extracted from CAPP

includes three types:

- *The manufactures sequence of parts*

This information will guide to generate NC code sequence for a part.

- *The method of manufacturing of parts*

This information will guide to generate different NC codes for different features.

- *The manufacturing dimension and precision*

This information will guide to generate different NC codes for different dimension and precision. It can help to match the manufacture tools automatically.

Those information must be transferred from CAPP system to CAM system for generating NC code. The interface of CAPP/UGII (CAM) plays an important role in the generating NC codes. According to the interface function, the CAPP/CAM interface mainly has two functions.

1. Extracting information from CAPP system
2. Treating these information according to data format and rules, and send some information to CAM system through API functions.

6. THE FURTHER WORK

How to decide a process planning is a very complex process, there are many factors and Knowledge to be affected in the process. How to manage and utilize these knowledge becomes more and more important in manufacturing enterprises. Knowledge management about process planning is planed to involve in further work.

The integration is not only among CAD, CAPP, CAM, but also includes with PDM, ERP system. How to implement with PDM, ERP system is also considered in further work.

In order to improve the intelligence of system, the artificial intelligence, such as, Artificial Neural Networks, fuzzy logic systems and Genetic Algorithms, will be applied in futher development of the system.

7. CONCLUSIONS

In the paper, the CAD/CAPP/CAM integration system is introduced. A new approach with API to integrate CAD/CAM system is also presented. the system architecture is described in details. It is demonstrated that integrating CAD/CAPP/CAM based on the above architecture and technology is feasible, efficient and easy to implement for manufacturing enterprises. The integration, intelligence and knowledge management are an important development and application fields in future manufacturing enterprises.

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