Application of Intelligent process decision in CAPP

LI Shan, LI Jinle, MA Yiming, LIU Guanyu
Faculty of Mechanical and Electrical Engineering, Kunming University of Science and Technology,
650500,Kunming, China

Abstract: *With the development of artificial intelligence and the appearance of concurrent engineering, new requirements for traditional CAPP have been put forward, and the intelligent process decision making problem has attracted more and more attention. Because of the complexity of process design, it is difficult to make theoretical analysis and decision with simple mathematical model, and the CAPP system is dependent on the processing environment, which makes the intelligent development of CAPP have some problems in the system structure, application and management. In order to further improve the applicability of CAPP, this paper adopts the idea of hierarchical planning, establishes the process decision model and gives the decision implementation plan. An intelligent process decision system is designed by the integration of expert system and neural network, and it is realized in practical application.*

Keywords: *CAPP, Process Decision, Neural Network, Expert System.*

1. Introduction

Process design is an important part of product development, but also a bridge between engineering design and manufacturing. Computer Aided Process Planning (CAPP) is a technology that uses computer technology to assist process personnel to design parts from blanks to finished products, and is a technique to convert enterprise product design data into product manufacturing data [14]. The research of CAPP technology theory and application has made some important achievements since the 1960s, but with the complexity of product technology and the changeable production environment, there are still many problems needing further study in CAPP technology. Especially the development of artificial intelligence, as well as the appearance of concurrent engineering work mode, has put forward the new request to CAPP. How to apply artificial intelligence to CAPP, make CAPP have better practicability, and have great significance to the development of manufacture.

The application and development of CAPP has always been a hot issue in research. G.van Zeir [15] proposed the concept of interactive process design, and developed a CAPP prototype system based on interactive. J. F. Wang [12] in order to optimize the process scheme of complex parts generation, the traditional particle swarm optimization algorithm is improved and the process planning problem in Capp is solved effectively. Recently, the integration of Computer Aided Design（CAD）, Computer Aided Manufacturing(CAM) [7] and CAPP has been concerned, some scholars [1,11] have used artificial intelligence technology such as neural network, machine learning, intelligent inference, etc., developed integrated CAPP system, can be used to identify the

design and production parts of various features and geometrical information, their research has achieved good results in the application. For different industries, researchers have developed different CAPP systems. X. Jiang [4] based on the theory of bearing forging and rolling process design, the CAPP system for the forging process of bearing ring is developed. W. Fan [2] adopts the object-oriented design method, develops the CAPP system of ball screw machining, realizes the process file query, edit, save and print function. M. U. Junqiang [5] According to the feature similarity of parts, the CAPP system of high-speed train bogie assembly is developed, and the rapid deformation design of the assembly process of high-speed train bogie is realized. C.grabowik [3] presents a method for the representation of body structure and technical knowledge with expert system. M. Milosevic [9] a distributed collaborative system based on internet and distributed technology, which enables engineers to communicate and share resources in a timely and effective way during product development. Although many achievements have been made in CAPP research, there are still many problems to be solved in the aspects of intelligence, integration and flexibility of CAPP at present [10].

Based on the above analysis, this paper, from the perspective of improving the applicability of CAPP, using Visual Basic for Application development tool, researched and developed an intelligent process decision-making system based on expert system and neural network integration.

2. The Implementation Plan of Intelligent Process Decision

2.1. Analysis and Assessment of Evidence Gathered

The process decision making problem belongs to the unstructured decision problem, and the factors that influence the decision result are numerous. Therefore, the idea of hierarchical planning can be used to establish a suitable decision model, and a complex decision system is decomposed into several levels of sub problems, and various influencing factors are dispersed into different decision making levels, and the refinement is solved by layers.

According to the idea of hierarchical planning, a Top-down decomposition method can be used to decompose process decision making into process decision making, processing method selection, process parameter selection and so on. Thus, the basic process decision model is established (see Figure 1).
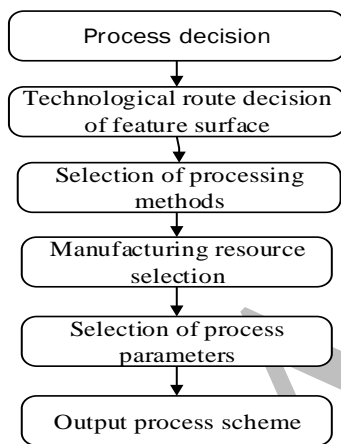

Figure 1. Basic process decision model.

Among them, the process route decision mainly solves the processing scheduling problem of each characteristic surface, and the manufacturing resource selection mainly selects the available resources such as machine tool, tool, fixture and so on in the operation of each processing sequence. In accordance with the decision model shown in Fig. 1, the search space can be limited to a smaller part on different levels, so that each link is easy to find the corresponding solution, the solution is gradually refined.

2.2. The principle of process route decision

Whether the process route design is reasonable, determines whether the product can be processed smoothly, so how to design the process decision making route is a very important problem. According to the principle of feature surface description method, no matter how complex the parts are, it can be regarded as the composition of various characteristic surfaces. Under the specific production conditions, the processing accuracy, surface roughness, size, material

and heat treatment of each characteristic surface are certain, and the processing method sequence of the conditions should be satisfied. That is, there is a specific mapping relationship between the part feature surface, the processing method and the equipment resources (see Figure 2).
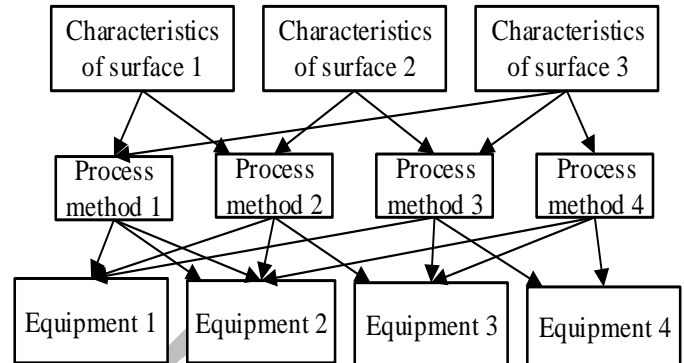

Figure 2. The mapping relation of characteristic surface, processing method and equipment resource.

Therefore, the paper adopts the process route decision method based on the surface characteristics of parts. The principle is that the first assumption is that the order is a feature surface unit, that is, through a processing method sequence to complete a feature surface processing, and then start the next feature surface processing. Each feature surface is generally subject to different processing processes to meet all aspects of its requirements. The choice of processing method is actually the selection of processing sequence. After the accumulated experience of the predecessors, the craft staff summed up the processing sequence principle of the revolving parts: the principle of benchmarking, the principle of first and the latter, the small principle after the first, the principle of ease of section.

2.3. Processing methods and selection of manufacturing resources

In process decision process, the processing method selection is to determine the processing method chain for each processing feature on the part. The so-called processing method chain is a sequence of processing methods used to complete a machined surface. In doing this work, the following factors need to be considered:

1. The properties of the materials used in the workpiece;
2. The precision, surface roughness, hardness, etc.
3. The shape of the parts and the dimensions of the machining characteristics;
4. The production outline quantity.

The choice of manufacturing resources is the important content of process decision, it is always as a constraint condition, which restricts the development of each link

of the process plan. The choice of manufacturing resources is to select a set of processing equipment which can complete the processing task according to the quantity, state, processing ability, manufacturing cost and availability of the processing equipment under a certain workshop layout. When choosing manufacturing resources, first of all, the most basic is to consider the processing capacity of resources. Secondly, we should consider how to achieve optimal resource allocation and utilization.

2.4. Selection Of Process Parameters

A complete process design plan, in addition to including processing routes, processing methods, but also should include each of the process parameters of the selection of detailed content. The selection of process parameters of each process will directly affect the manufacturing cost and efficiency, and also be constrained by the processing accuracy. In the traditional processing, it is based on experience to determine the process parameters, but in a more complex situation, the parameters determined by experience are difficult to ensure the best economic benefits. Therefore, the process parameters should be determined from two aspects: the first is the determination of the process dimension chain, followed by the determination of the process parameters in the process, including cutting depth, feed quantity, cutting speed and other related parameters.
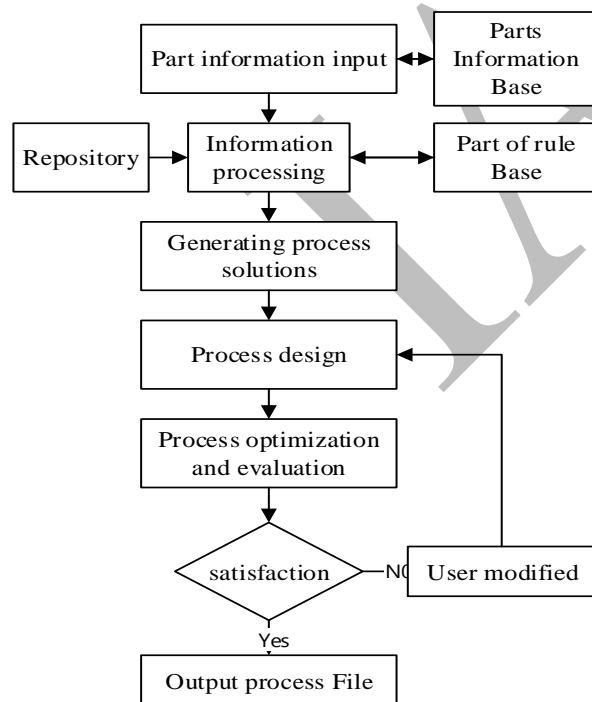

Figure 3. Overall decision making plan.

In the process of intelligent decision-making, imitate the process personnel to develop the process plan, first get the part of the characteristics of information, including geometric information, process

information. Then, the process rules and process knowledge in the rule base are used to deal with the information, and the preliminary process scheme is obtained. In order to make the decision making system more practical and open, the user can modify the obtained process plan, including revising the process route, processing method, process parameters, processing equipment and so on. In the process of generating the process plan, the time and cost indexes of the scheme are estimated, and the evaluation of the process scheme is realized, Figure 3 shows the schematic diagram of the decision implementation plan.

3. Intelligent Decision Making Technology of Expert System and Neural Network Integration

3.1. Expert System Structure

The expert system is a complete description of the computer model between the data and artificial intelligence, human experts with long knowledge and experience can describe and record with a third party model, and apply their knowledge to the real industry, and solve the contradiction between age and experience, field problems and seeking experts. The expert system usually includes the knowledge base, the inference machine, the interpreter, the database, the knowledge obtains, the human-machine interface six parts composition (see Figure 4).
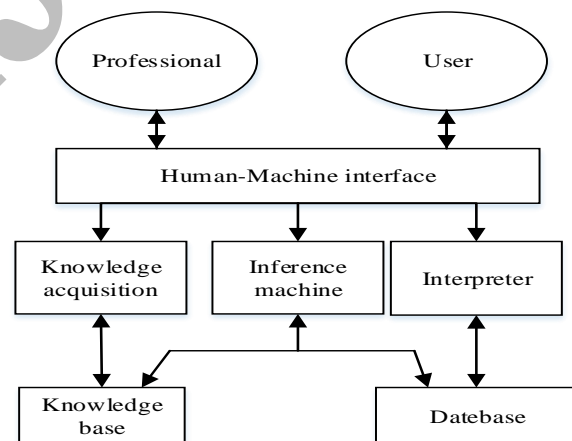

Figure 4. Expert system structure diagram.

3.2. Process Knowledge Base and Inference Machine

The role of the process knowledge base is to represent the process information as a pattern that the computer can recognize. In this paper, the process data adopts the frame pattern, and the rule adopts the production description. The knowledge representation process is not necessarily definite, for example, fuzzy computation is introduced into the Knowledge base, which indicates uncertain knowledge, and the

knowledge is human-computer interaction input, which is a definite type knowledge. The knowledge base not only includes process knowledge, but also can be understood as the database of knowledge theory organization, the concept of Knowledge base and database is very similar, but the knowledge base not only stores the data, the organization form of the knowledge base is not limited to the storage form, its expression concept and rules can have different representation methods.

Inference machine is the core of intelligent decision-making system, it is actually the control center of the whole system, the whole system depends on it, the knowledge base is not the program, the inference machine is the real computer program, relies on this kind of procedure to run the Knowledge base and other organization, solves the question which the current user raises. In the expert system, the data and rules in the knowledge base should be used to match, restrain, generalize and calculate the inference and decision.

3.3. Basic Theory of Neural Network

Neurons are the basic processing unit of neural networks. It is generally a multiple input single output nonlinear valve value device, its general structure model (Figure5).
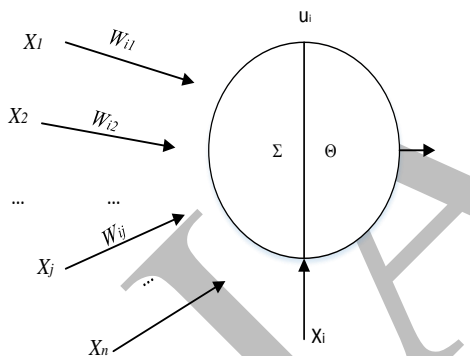

Figure 5. Neuron model.

Where

u_i is the internal state of neuron i ,

θ_i is the closed value,

x_j is the input signal,

w_{ij} represents the weight of the Neuron x_i connection, and s_i represents the control signal of an external input.

Because of the limited function of individual neurons, a large number of neurons are now being constructed into neural networks through interconnection (Figure 6), to improve computational power.
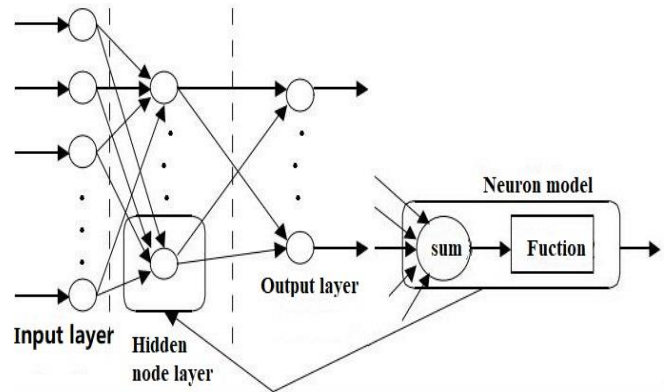

Figure 6. The structure of neuron network.

3.4. Integration of Expert System and Neural Network

Both the expert system and the neural network hope to obtain the approximate human intelligent machine system by simulating the human reasoning process, but the two methods are very different. The expert system infers knowledge according to the knowledge and facts provided by the outside, and the neural network sums up the data in a parallel way, and extracts the facts and knowledge. With the combination of expert system and neural network, the large-scale parallel processing and knowledge acquisition automation of neural network overcomes the difficulty of reasoning complexity in expert system, realizes parallel association and Self-adaptive Inference, improves the intelligence of expert system, has real-time processing ability and high stability. The hybrid system architecture of expert systems and neural networks is shown in Figure 7.
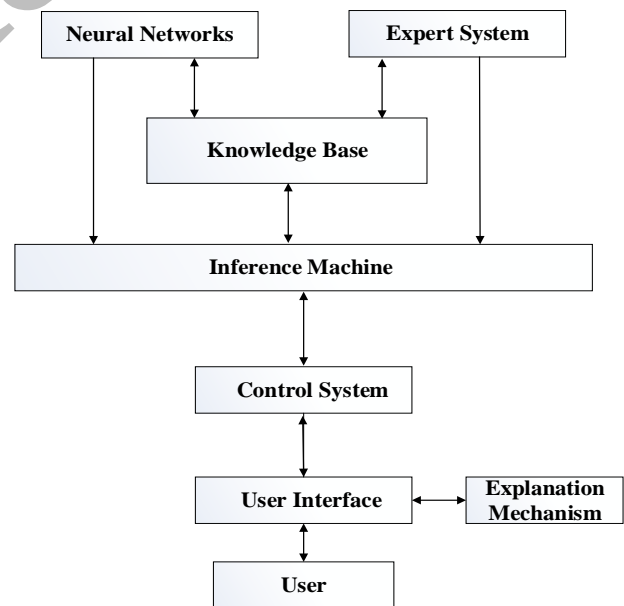

Figure 7..Hybrid system structure diagram.

4. Design of Intelligent Process Decision System

4.1. System Functional Structure

The system function module is divided into five parts (see Figure 8), part information management, process design, process document management, process resource management, System Management function module, each module is divided by function independently.
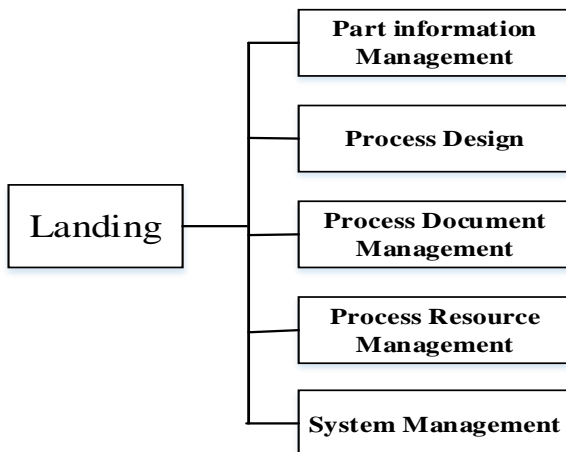
Figure 8. System functional structure.

The part Information Management module automatically encodes the parts ' shape and processing features, and this module can modify the related information of the parts. Process design, according to the part description output coding information, through with the process library and process resource database interactive edit output new process. Process document management module, mainly for the completion of the process developed parts of the process to retrieve, output, in the form of documents to provide processing department use. Process resource Management module is the editing, modification and deletion of process related database, such as process library, process equipment storehouse, material storehouse, etc. System Management module is the user admin login system to other software users to delete, modify and so on.

4.2. Database Design

The system uses Microsoft Visual Basic for application as the database development tool, VBA is the Windows System Basic development tool, has the concise and efficient syntax, the simple and easy to use visual design method, can quickly compile the windows Powerful application software system in the environment, including the development of the database.

The CAPP technology transforms the enterprise product design data into the product manufacture technology, how to design the reasonable data structure according to the system analysis and the outline design request is an important step to develop the CAPP system. A successful CAPP system, the design of the process data structure should follow the following principles:

1. The principle of separating the process knowledge base from the process processing;
2. The principle of minimizing data structure;
3. The third paradigm of complex and large data-volume data.

There are several methods of designing data model, including mesh data model, ANSI/SPARC data Model, entity-contact data model, semantic object model and so on. In the E-R model（see Figure 9）, the maximum and minimum granularity are expressed, respectively, the largest and least allowable quantity relationship between the two entities, and the significance of E-R labeling is shown in table 1.

Table 1 The E-R entity meaning represented by Erwin.

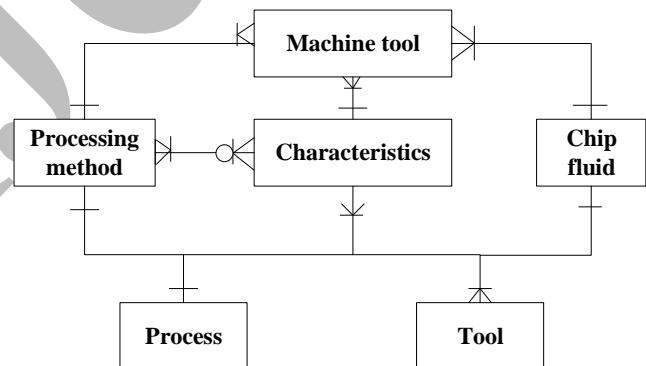| ERwin	Significance
Round and Vertical	Can have one or more entities
Vertical	Allow only one entity
Vertical and arrows	Can have one or more entities
Round、 Vertical and arrows	There can be zero, one or more entities

Figure 9. E-R model.

4.3. System implementation

Access to the main interface of the database system, the main interface contains a variety of functional modules: Part information management, process design, process information management and process resource management (see Figure 10).

Figure 10. The main interface of the database system

The part Information Management module mainly generates code for process design and converts the feature information of the part into the information that the computer can recognize. At the same time, you can maintain the part information in this module, and realize the functions of Quick View, add, change, save and delete records (see Figure 11).
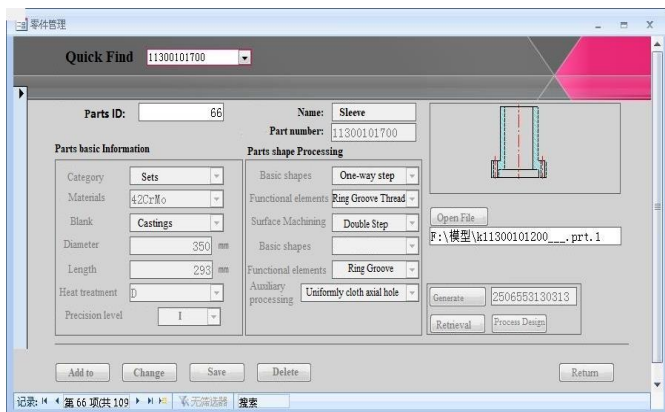

Figure 11.The interface of the parts information management.

Process Design module is mainly through the retrieval and derivation of two methods to generate the required process. You can click on the part management interface of the search process or process design, or directly click on the main interface of the process design into the part of the process design interface. If the process library has the same process information as the part encoding, the process can be added after the build process is retrieved (Figure 12).
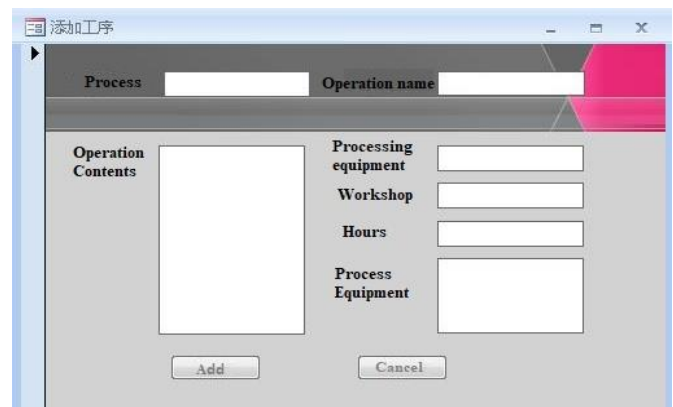

Figure 12.The interface of adding process.

5. Conclusion

By using the idea of hierarchical planning, through the analysis of the process route, the model of process decision is established, and the overall decision scheme is given according to the process of making process plan by the craft personnel, which provides the basis for realizing the intelligent process decision making.

This paper introduces the structure and working principle of expert system and neural network, analyzes the characteristics of expert system and neural network, and has better real-time processing ability and stability by integrating expert system and neural network design, and has some reference value to the application of intelligent decision technology in CAPP.

References

[1]   Deja M., Siemiatkowski M, "Feature-based generation of machining process plans for optimised parts manufacture," Journal of Intelligent Manufacturing, vol. 24, no. 4, pp. 831-846, 2013.

[2]   Fan W., Wang K., Gao C., and Zha C., "Development and Application of BGS-CAPP System of Ball Screw", Modular Machine Tool & Automatic Manufacturing Technique, 2015.

[3]   Grabowik C., Knosala R., "The method of knowledge representation for a CAPP system", Journal of Materials Processing Tech, vol. 133, no. 1, pp. 90-98, 2003.

[4]   Jiang X., Shi D., Qian D., "Research and Development on CAPP System of Forging and Rolling Process for Bearing Rings", Bearing, 2016.

[5]   Junqiang M., Yang X., Shuwen M., Ding G., "Research on High-speed Train Bogie Assembly CAPP System", Machine Tool & Hydraulics, 2018.

[6]   Kutin A., Dolgov V., Sedykh M., Ivashin S., "Integration of Different Computer-aided Systems in Product Designing and Process Planning on Digital Manufacturing,", Procedia Cirp, vol. 67, pp. 476-481, 2018.

[7] Lee K., Principles of CAD/CAM/CAE Systems, Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA ,1999.

[8] Ma H., Zhou X., Liu w., Li J., Niu Q.,Kong C., "A feature-based approach towards integration and automation of CAD/CAPP/CAM for EDM electrodes," The International Journal of Advanced Manufacturing Technology, vol. 98, issue 9-12, pp. 2943-2965, 2018.

[9] Milosevic M., Lukic D., Antic A., Lalic B., Ficko M., Simunovic G., "e-CAPP: A distributed collaborative system for internet-based process planning", Journal of Manufacturing Systems, vol. 42, pp. 210-223, 2017.

[10] Negahban A., Smith J., "Simulation for manufacturing system design and operation: Literature review and analysis", Journal of Manufacturing Systems, vol. 33, no. 2, pp. 241-261, 2014.

[11] Sun P. , Liu Q., Ding J.,Pi S., "Open CNC system design for multiple intelligent functions based on TwinCAT and .NET framework", in IEEE International Conference on Mechatronics and Automation, pp. 910-915, 2017.

[12] Wang J.,Kang W., Zhao J.,Chu K., "A simulation approach to the process planning problem using a modified particle swarm optimization," APEM Journal, vol. 11, no. 2, pp. 77-92, 2016.

[13] Xu T., Chen Z., Li J., Yan X., "Automatic tool path generation from structuralized machining process integrated with CAD/CAPP/CAM system" , International Journal of Advanced Manufacturing Technology, vol. 80,issue 5-8, pp. 1097-1111, 2015.

[14] Yang Y., Shi M., and Xiao X., "Research on the actualities and developing trends of CAPP," Machinery Design & Manufacture, vol. 216, no. 7, pp. 223-225, 2008.

[15] Zeir G., Kruth J., Detand J., "A conceptual framework for interactive and blackboard based CAPP," International Journal of Production Research, vol. 36, no. 6, pp. 1453-1473, 1998.