Intelligent Approach for Part Family Searching and Cutting Tool Matching in FMS

Jun WANG\textsuperscript{a} and Zong-Chong ZHANG\textsuperscript{b}

College of Mechanical Engineering, Yanshan University, Qinhuangdao, China, 066004
\textsuperscript{a}Jun64@ysu.edu.cn, \textsuperscript{b}1142502913@qq.com

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Abstract. Flexible Manufacturing System (FMS) is an automated manufacturing system which is suitable for small and medium batch production. Usually FMS can not only satisfy existing parts machining, but also have the ability to adapt to new parts machining when the products changes with the market demand. The automation of new parts process planning is hard to achieve because of the limitation of the current CAPP technology, the complexity of FMS, and diversity of parts. To solve the problems above, this paper proposes an intelligent approach to determine machining family and cutting tool for new parts using case-based reasoning method which is based on artificial intelligence technique and artificial neural network, part family search and tool matching are the important part of CAPP especially for variant CAPP. In this new approach, first, the existing parts are considered as cases, the relationship among parts information, machining families and cutting tools from the existing parts in FMS is established by means of artificial neural network and the relational model is obtained after ANN is trained with the cases, then the two key problems, searching the machining family automatically and matching tool set from huge cutting tool group intelligently for new parts machining can be realized in FMS. This paper aims to make the existing FMS adapt to the new parts machining when market demanding changing, improve the intelligent level of FMS and the enterprise's ability to response market rapidly and provide technical support for intelligent manufacturing.

Introduction

The core of FMS technique is flexible manufacturing, FMS is not only able to complete the machining of the existing parts, but also have the ability of machining new parts. The primary problem to complete the new parts machining is process planning. So far, as mathematical model to describe the decision-making process is difficult to establish and flexible manufacturing system are diverse and complex, the process generating ability of computer aided process planning (CAPP) software is limited currently and CAPP is far from automation and generalization. The intelligent CAPP system combined with artificial intelligence technology has become a hot spot in today's research as the traditional CAPP can not satisfy the requirements of today's manufacturing. In this paper, Case-based reasoning and artificial neural network (referred to as ANN) are used to seek the solutions for related problems in new parts process planning in flexible manufacturing system.

The objective of this research is to study how to make use of existing parts process information to do the process planning for the new parts, when new parts is to be machined in the flexible manufacturing environment, namely the new approach should be able to search parts family for new parts and choose a set of processing cutting tools in the vast FMS tool group, so achieving the target to choose part family and cutting tools automatically on the basis of new part code.
Part Families Search Based on Neural Network

Configuration and production organization of flexible manufacturing systems are usually based on group technology and FMS should be capable of adapting itself to produce a new set of product. When group technology is used in FMS, parts are usually classified into groups by similarity of the parts process according to some rules, and then the medium and small-sized production can be converted into larger group production which can reduce production lead time, improve economic effects closer to that of mass production. When a new part is needed to be machined and produced in the flexible manufacturing system, we must first solve the problem about how to determine the machining families the parts should belong to, and we should also modify and improve the standard process of part families. Therefore, part families search and tool intelligent matching both are important issues in process design.

Essentially, group technology is the reuse of the existing parts manufacturing knowledge, namely “knowledge reuse”. The amount of data involved in knowledge is enormous, data type is diverse, and the links between the data is usually unstructured. Currently, there is no effective method for data processing and retrieving. Those problems make people seek a new approach in the development of the group technology itself. Therefore, application-oriented information classification, identification and processing of information, similarity theory, cluster theory and classification retrieval have become the research focus in this field[1-6].

Grouping the existing parts is a key step in the implementation of group technology and the methods of grouping usually affects the way of part family search. Existing group methods mainly include coded method and production flow analysis (PFA). Code classification is based on certain coding system (OPITZ, KK-3, JLBMI-1 systems, etc.). To encode parts, coding the information of the parts, then group the parts according to the feature bits or signature fields of the part-code matrix, this method makes the relationship between parts and machining family by coding directly, but the method for determining signature bits or signature fields is not mature, it often requires human determination. In addition to this, as many classification symbols does not have manufacturing process features during coding, it causes that the parts with similar structure but different process are divided in the same group, but the parts with similar process and different structure can not be divided in the same group.

Production Flow Analysis

For reasons above, the production flow analysis (Production Flow Analysis, referred to as PFA) has been widely used in parts grouping. The principle of this method is that the parts are grouped directly by the similarity of machining process of existing parts, those with similar process are combined into groups, therefore, we usually need to build part-machine matrix at first, and then cluster the parts into groups according to certain cluster analysis methods. Usually we can get satisfying classification result by means of PFA method, and it is suitable for flexible manufacturing cell configuration and group process design. The disadvantage of PFA method is that the part code is not directly related to the part families, but directly related to the manufacturing process for each part. Due to the part code of a new part is usually is used for part family searching, it is difficult to determine part families according to new part code. Furthermore, due to the complexity of the FMS system, the differences about configuration and machined parts between different FMS system exists, family searching is not automated, although there are a number of algorithms, but they can only meet certain machining system and has great limitations.

When part code is used, part family’s characteristic parameters should be determined (characteristic matrix) first. When production flow analysis is employed for part grouping, we should first establish the part families according to manufacturing process similarity, then, the characteristic parameters of the part families can be obtained. As the procedure does not follow a mature algorithm, it is difficult to establish a relational model between part families and code which is also the current difficult problem of CAPP. It should be noted that the code of the parts is identification of feature; it’s also a qualitative and coded description about geometry and manufacturing information of the parts.
There is an implicit link between the code of the parts and the process of part families, but this link is indirect, implicit and difficult to use mathematical expressions to describe.

**Part Family Searching Using Case-based Reasoning with Neural Network**

In this paper, we combine case-based reasoning method with neural network technology, the existing machined parts and processes are regarded as cases, digging out the implicit relationship between the code of the parts, part families and the link between the code of the parts and tool groups by neural network technology, building relational model among code, machining family and tool group by learning function of neural network, and making use of this model to achieve the mapping between the code and part families, the code and tool group, thus solving the problem of the new part families search and tool matching, and matching with each procedure.

The Principle of this approach is shown in Fig 1.

**Elements and Workflow of Searching System**

The new system for part family search based on the new principle above is shown in Figure 2.

The following introduces the principle and process of using neural network method to establish the relationship among the code, the process and part families to implement part families search. ANN-based intelligent search technology is actually to establish links between the code and part families by ANN, this links is no longer in the form of feature matrix, but in the form of the network topology and weight matrix, the overall flow is shown in Fig 2.
Flowchart mainly consists of two parts, the first part of which is the data processing section, the functions are as follows:

(1) Data prepared, the main purpose is to establish part-machine tool matrix.
(2) Grouping the parts based on production flow analysis.

Grouping parts includes defining similarity coefficient of the process, then clustering parts so as to forming part families based on this coefficient, part families is considered as neural network training samples. The second part is to search part families by neural network; the part families the new parts belong to can be determined just after the part code is input.

The flow chart shows:

(1) Part-machine tool matrix are regarded as the input data of parts grouping based on the principle of process similarity,
(2) The result of grouping is seen as the basis of FMS equipment planning, as well as a learning sample of neural networks.
(3) Grouping results are regarded as a learning sample of neural networks to train the network.
(4) Part families for new parts can be obtained based on the trained neural network.

The factors directly involved in the grouping of parts are process, the code of parts which is used as identification of parts. After the parts are grouped, trained ANN is considered as search device as the ANN has build implicit links between the code and part groups so as to achieving part families search.

The simplified ANN can be illustrated as in Fig 3 for building implicit links between the code of the parts and part families by using neural network in order to deal with the search problems of part families.

![Figure 3. Neural Network Models.](image)

In Fig 4, \(i_1, i_2, \ldots, i_m\), are the input data of neural network , \(o_1, o_2, \ldots, o_n\), are the output data.

After analyzing a variety of network mapping functions are, we finally use BP neural network because this network has excellent input-output mapping ability, and it can simulate any mapping relation.

The transfer function of the neural network is an important parameter; the difference among the various models of neurons is that different transfer functions is used and that they have different information processing characteristics. During training, we compare multiple transfer functions, seeking an appropriate one in it. The transfer function determined in this paper is a non-linear one. As shown below.

\[
y = f(s) = \frac{1}{1 + e^{-s}}
\]

**Cutting Tool Intelligent Matching Based on Neural Network**

Cutting tool system is the core of FMS system and cutting tool requirements planning is needed in process planning. The cutting tool selection is difficult for the follow reasons: (i) material of cutting tool are diverse, (ii) types of cutting tool are diverse, (iii) workpiece materials are diverse, (iv) the
Cutting tool and workpiece matching depends on the the existing cutting tools, (v) geometry of cutting tools are different, (vi) usually a tool set is need for workpiece machining. In addition to this, manufacturing process requires the FMS to provide a variety of cutting tools; on the other hand, it requires the FMS to reduce types and categories of cutting tools. Usually, FMS and FMC all have vast cutting tool systems, because there are differences in the structure and manufacturing requirements between the new parts and existing parts, so it is very necessary to determine the tool set for new parts.

**Using ANN to Establish the Relationship between Existing Parts and Cutting Tools**

As it is difficult to build the mathematical model of relationship between parts and cutting tools, here, the ANN is used based on the existing parts and corresponding cutting tool. First, the features of parts are defined and each feature corresponds to a cutting tool, so one part is composed of some surfaces, and each surface can be seen as a feature, and each feature means that when the part is machining, the is evoluting to its final shape, and the final intership can be seen as a sub-feature. The schema is shown in Figure.4

![Figure 4. Mapping Model between Parts Code and Tool Set Based on ANN.](image)

**Elements and Workflow of Cutting Tool Matching System**

The structure and work flow of the tool searching system based on ANN technique is shown in Figure 4. In Figure 4, we can see that the inputs and outputs of ANN are the part code and cutting tool respectively. The manufacturing process of existing parts and cutting tools are taken as training samples to train neural networks, the trained neural network parameters can be stored in the form of ANN topology and the weight of the network. When cutting tools intelligent matching is need to be done, first the part code should be input, then trained neural network will mappings out the cutting tool set.

**Summary**

1. Neural network technology is used to manage and reuse the machining parts family data obtained by production flow analysis, the nonlinear mapping relationship between parts code, parts family is obtained, and then the parts family is determined for new parts effectively by means of the ANN.

2. BP neural network can be used to realize nonlinear mapping between part codes, parts family, and expected mapping accuracy can be achieved by adjusting the number of hidden layer of network after a variety of neural network types are tested.
Artificial neural network can solve the problems such as cutting tools matching and part family searching for flexible manufacturing system using the information of existing parts in flexible manufacturing systems, therefore, this approach can reduce the types of cutting tools in the whole process and the diversity of manufacturing process, and make the process more standard and reasonable.

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