'95 KACC (1995. 10. 23 ~ 25)

A GT-Based CAPP System Using A Decision Tree

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Abstracts Computer Aided Process Planning(CAPP) has been emerged as playing a key role in Computer Integrated Manufacturing(CIM) as the most critical link to integrate CAD and CAM. A modified variant CAPP system based on process planning rule base is developed in this paper. This CAPP system generates process plans automatically according to the GT code data provided as input. In order to execute process planning, various process planning rules are constructed in the form of decision tree and the inference engine that extracts the process plan based on the tree-structured rules are implemented.

Keywords CAPP, Group Technology, Rule Base, Decision Tree

1. INTRODUCTION

Process Planning is a procedure to select the manufacturing processes to transform a raw material into a finished part based on the design requirements. In this paper, it is defined as two levels. One is the process planning level, and the other is the operation planning level[1]. A CAPP (Computer-Aided Process Planning) has been emerged as playing a key role in CIM(Computer Integrated Manufacturing) as the most critical link to integrate CAD(Computer Aided Design) and CAM(Computer Aided Manufacturing). Therefore, much effort has been dedicated to development of CAPP systems. Two approaches for computer aided process planning are currently being pursued : variant and generative. Generally, a variant type CAPP system is based on the classification and coding, deciding part families and standard process plans[8].

A modified variant CAPP system using GT(Group Technology) and decision tree rule-base is developed in this paper. This CAPP system generates process plans from GT-codes by inferring from process planning rule-base without any kinds of standard process plans. To implement this CAPP system, the preparatory stage and the process analysis were performed, and the decision tree structured rule-base was constructed[5].

2. THE PREPARATORY STAGE

2.1 The GT-Coding System

The TS coding system is developed for the CAPP system implemented in this paper[4]. The TS coding system is a general purpose classification and coding system for the general mechanical, it consist of 15 digits and no limit for the number of the items for each digit. This coding system allows multi-pick codes for a digit, so flexibility can be obtained. Furthermore, this TS coding system is very good for process planning because it can deal with all the combinations of the features of the subject parts[5]. The structure of TS coding system is shown in <Table 1>. All TS codes and process plan of each subject part are stored in manufacturing database which is developed using a commercial relational database management system.

2.2 The Process Analysis

The process analysis is performed to construct process plan rule-base based on GT-codes. This task is done for the various sample parts of the subject company and the basic knowledge of process plan using decision tree is obtained from the result of this job[5]. The procedure of process analysis is shown in <Fig 1>.

Several basic manufacturing processes are defined to perform the process analysis procedure. Generally, manufacturing processes are divided into several process groups, which are 'Basic Process', 'Principal Process', 'Auxiliary Process', 'Supporting Process'(3). 'Basic

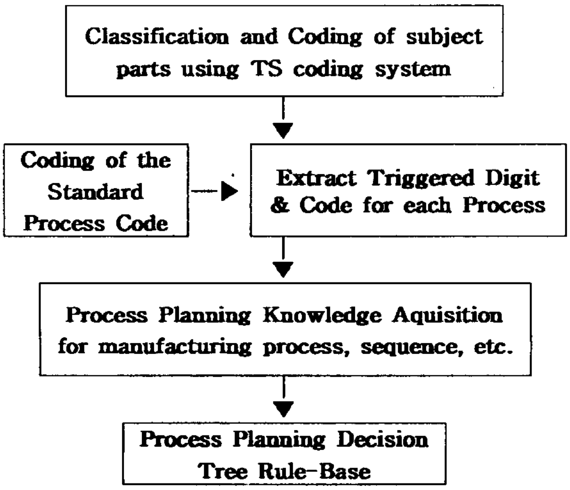
Process' is a pre-process to make a basic from an input material. 'Principal Process' is a core process of manufacturing such as drilling, milling, grinding. 'Auxiliary Process' is the process which are added on the principal process, like heat treatment, welding and press working. 'Supporting Process' is a final process to complete products, such as inspection, painting and others[3].

Digit	Rotational Parts	Non-rotational Parts
1	Name	
2		
3	Materials	
4	Main Dimension	Main Dimension
5	Dimension and Ratio	Weight and Ratio
6	Main Shaped External	Main Shaped External
7	External Surface, Groove	Auxiliarly Shaped External
8	External Surface, Gear and Thread	Bending
9	Hole Size and Accuracy	
10	Main Hole	Main Hole
11	Main Hole - Special	Main Hole - Special
12	Auxiliarly Hole - Direction	Auxiliarly Hole - Direction
13	Auxiliarly Hole - Special	
14	Non-Machining	
15	Accuracy	

<Table 1> The Structure of TS Coding System

In this paper, 2-Digit standard process coding system is defined for process analysis. This coding system is used to make process database, programming algorithms. The standard process code is shown in <Table 2>[5].

By analyzing GT-codes and process database, triggered digit and code for each process are extracted. The relation obtained from the above analysis makes basic knowledge, which decides relation of digit/code and process. This knowledge is used for the decision-tree-structured process plan using rule-base system. The process analysis procedure are shown in <Fig 2>.



<Fig 1> Procedure of Process Analysis

Digit \ Code		0	1	2	3	4	5	6	7	8	9
0	Pre-process	Part Input	Sawing								Others
1	Drilling	General Drilling	Reaming	Tapping	Center - Drilling	Counter-Boring Counter-Sinking Spotfacing	Deep Holing (Gun-Drill)				Others
2	Turing	Turning	Boring	Facing	Groove, Cutting	Thread	Forming	Copy Machining			Others
3	Milling	Slab Milling	Face Milling	Grooving (End-Mill)	Wide Slant	Narrow Slant (Chamfering)	Gear	Planing	Copy Machining		Others
4	Special Machining	broaching	hobbing	Jig-boring							Others
5	Grinding	External Cylindrical Grinding	Internal Cylindrical Grinding	Face Grinding	Gear Grinding (Spline)	Slant Grinding	centerless grinding				Others
6	Special Grinding	Super Finishing	Honing	lapping	polishing						Others
7	Non-Machining	Heat Treatment	Bending	Welding	Painting	Coating	Surface Treatment	Assembly	Press Work	Reform Eccentricity	Others
8	Post-process	Finishing	Sandpaper	Washing	Cut-Off	Inspection	Part Out				Others
9	Others	Centering for Turning	Positioning								Others

<Table 2> Standard Processes and Their Code

3. THE PROCESS PLAN RULE-BASE

The knowledge about GT-codes, manufacturing processes, feature informations, processes, machines and other informations is obtained by process analysis. Based on this knowledge, the decision-tree-structured process planning rule-base is constructed. This rule-base contains knowledge about the GT-code and its corresponding processes, process sequence, available machines and others. On the other side, this knowledge can be divided into several categories as follows.

* Knowledge about TS-code and its corresponding geometry
* Knowledge about TS-code and manufacturing processes needed
* Knowledge about process sequence by precedence, machine layout and others
* Knowledge about special processes and its operations

3.1 The Decision Tree Structured Process Planning Rule-base using TS code as Input

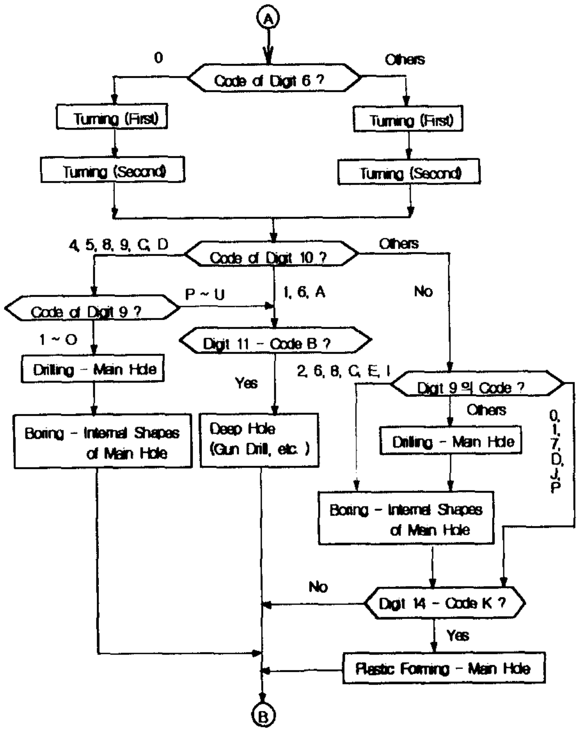
Generally, manufacturing processes of parts can be divided into pre-processes, main external shape processes, auxiliarly external shapes processes, internal shapes of main hole processes, internal shapes of auxiliarly hole processes and post-processes on a large scale[3]. The pre-processes are concerned with digit 14 and main external shape processes can be extracted from digit 6, 7, 8 of the TS-coding system. The information about the processes for internal shapes of main hole and the internal shapes of auxiliarly hole is represented in the digit 9, 10, 11, 12, 13, and the processes for the post-process are represented in the digit 14, 15. There can be more then two processes for one shape. In this case, all alternative processes are offered and user can choose an appropriate process.

3.1.1 Rotational Parts

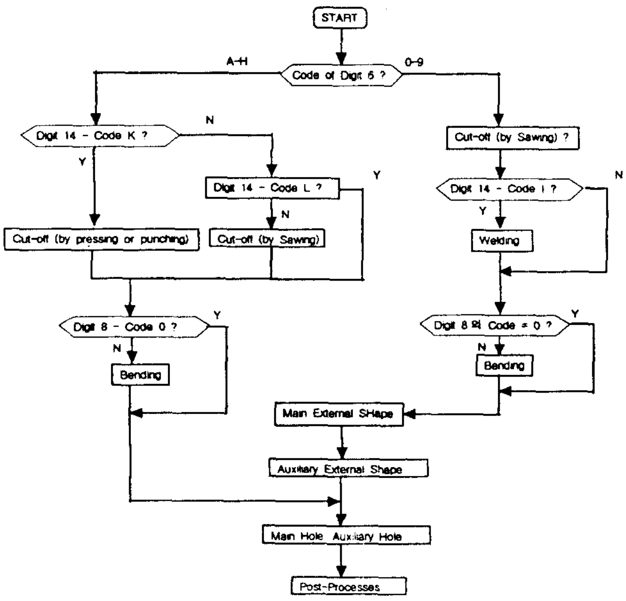
The decision tree for rotational parts is relatively not so complicated as non-rotational parts because many processes can be performed in a lathe. A part of decision tree algorithm for rotational parts is shown in <Fig 3>.

3.1.2 Non-Rotational Parts

A part of decision tree algorithm for non-rotational parts is shown in <Fig 4>.



<Fig 3> A part of decision tree algorithm for rotational parts



<Fig 4> A part of decision tree algorithm for non-rotational parts

3.2 Implementation of Decision Tree Rule-Base

The inference engine and rule-base for process planning rules are implemented in this research. The data structure of a node is shown in <Fig 5> and the search algorithm for inferencing is shown in <Fig 6>.

Node_ID
Node_Type
Parent Node ID
Child Node ID
Number of Parent Node
Number of Child Node
Condition Code
Condition Digit
Process Code
Process

Node Type C : For Branching by Condition
Node Type P : For Resulting by Digit and Code

<Fig 5> Data Structure of Node

```
a) 3 LIST : S_OPEN_LIST, M_OPEN_LIST, REGIST_LIST

b) Selection of  node to be expanded
    S_OPEN_LIST → M_OPEN_LIST
    Parent Node(P.N.) more than 2 and
       firing_count=number of P.N. → expand
    If there exist only one node in OPEN_LIST, search
       from the other OPEN_LIST

c) Expansion of the node
  expanding node is in S_OPEN_LIST
    child node(C.N.)
      single node : S_OPEN_LIST (Breadth First Search)
      multi  node : M OPEN LIST (Breadth First Search)
  expand node is in M_OPEN LIST
    child node(C.N.)
      single node : S_OPEN_LIST (Breadth First Search)
      multi  node : M_OPEN_LIST (Depth First Search)
  ---> If fire_count of expanding node more than 2,
        C.N. (Breadth First Search)
  ---> Each C.N. registered in REGIST_LIST, default
        node state=LIVE

d)  Disposing of the node
   State of P.N (Expanding node) more than one LIVE,
   node cond_digit & cond_code ↔ Part GT Code
       Same , expanding node process output
       Not Same, expanding node → DEAD
   ---> cond_digit=16 : User Selection
   ---> cond_digit=17 : User define node state
   ---> State of P.N. (expanding node) are all DEAD
        node state→ DEAD
```

<Fig 6> Search Algorithm for Inference Engine

4. CONCLUSION

A CAPP system using GT-code and decision-tree-structured rule-base is implemented in this research. This system can generate process plans for general mechanical parts. TS coding system, a GT-coding system for the target company system are developed. Various databases, rule-bases, algorithms and a inference engine are developed in this research[5]. Finally, this CAPP system is adopted to the target company, and the result process plan is very satisfactory. Special features of the CAPP system developed in this paper are as follows.

* The CAPP system generates process plan directly from the input GT-code, without the retrieval of the standard process plan.
* More detailed output than the other variant type CAPP systems are obtained.
* Many related manufacturing database are constructed, which are very useful for other production and management purposes.

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