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A Bit of Factory Automation: Manufacturing Cost Estimation Using Group Technology

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공장 자동화에 관한 소고 : 그룹 테크놀로지를 이용한 생산원가 추정

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Abstract

A fully automated cost estimation system(FACES) has been developed. Since speed, accuracy, and consistency are essential factors in automating a cost estimation, the use of computers in cost estimation system(CES) has grown rapidly in the last few years.

FACES is a micro computer based cost estimation system that employs a manufacturing knowledge base. A Group Technology(GT) based part classification and coding(C&C) scheme is used to automate the process planning aspects of cost estimation. Variant process planning methods are employed to generate workstation routings from form features of the part.

The system has been tested for an assembly of six machined parts. Results indicate that the system could provide a substantial improvement in accuracy, productivity, and performance over the more traditional full dialog approach to cost estimation. It also provides a good foundation for a factory automation by using a common GT based database through design to production.

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1. Introduction

Manufacturing cost estimation is the process of determining the cost of making machined parts. Complex and time-consuming characteristics of this task require the use of a computer. Although many commercial cost estimation packages provide relatively accurate estimates they have been slow in adopting techniques to automate the cost estimating process[2].

Therefore, to fully automate cost estimating activities, a cost estimating system was developed to incorporate the process planning activity. The system consists of a collection of database files, file manipulation programs, and independent CES software. A manufacturing knowledge base has also been created to support process planning aspects of cost estimation.

Selection of an appropriate machining operation to produce one or more form features is of major concern to the process planner. Therfore, for the machining operations, a library of matches between form features and operations has been built. That is, a preferred operation is automatically chosen by the computer to produce a given form feature.

2. Features of the Developed System

2-1. Manufacturing Knowledge Base

A sample manufacturing knowledge base has been created to support and demonstrate the activities of the FACES. The database contains manufacturing information concerning the active parts population.

The initial step in creating the manufacturing information database is to use the C&C system to assign each part an appropriate code. Part families are then formed based on similarity of the assigned codes. For each part family, at least one standard routing sequence is assigned. The routing sequence is expressed as a list of work center numbers which represents the types and locations of the various machines or processes.

The database basically consists of two levels. The first level is a library of standard routings. It consists of family code, standard routing number or numbers, list of parts belonging to the part family, a routing sequence represented by work center numbers, operation description, setup and run time. Table 1 shows an example of the standard routing.

The second level is a set of files which contains costing parameters(i.e., user prompts and default responses of the CES). For each work center in each standard routing, the responses required to estimate the work center costs have been stored in conjunction with a part family number, a standard routing number, a work center number, and form feature name in the database. The user prompts and responses are required to estimate a specific work

Table 1. An Example Standard Routing for the Part Family Code H36233D1

PART FAMILY # : 1 FAMILY CODE : H3623D1

STANDARD ROUTING # 1

PART LIST : 69B60047-3, 69B60047-4

OPER NO	W CTR ROUTE	FORM FEATURE	OPERATION DESCRIPTION	SETUP (HR)	RUN (HR)
10	850	HOLE 1	ISSUE BAC1520-1668 EXTRUS	.000	.000
20	482	SAW.	SAW TO .75+OR- .02 LENGT	.500	.030
30	510	SKIP.	INSPECT	.000	.000
40	806	HOLE 2	69B60052-3 (ARBOR) SHOP T	.330	.050
50	815	THREAD 2	TOOL MCX 69B60047-3	1.000	.100
60	895	DEBURR.	REMOVE HANGING BURRS & DY	.050	.100
70	500	OTHER	INSPECT	.000	.000
80	3130	DEBURR.	VAPOR DEGREASE PER PS4050	.000	.000
90	555	OTHER.	PENETRANT INSPECT PER BAC	.000	.000
100	3130	OTHER.	VAPOR DEGREASE PER PS4050	.000	.000
110	3131	DEBURR.	ALKALINE CLEAN PER PS4050	.000	.010
120	3110	DEBURR.	ALODINE (1200) PER PS4050	.000	.020
130	500	SKIP.	INSPECT	.000	.000
140	1021	DEBURR.	MASK OFF TO PREVENT APPLI	.010	.020
150	1025	OTHER.	CLOCK NO. REQUIRED FOR EA	.000	.020
160	1075	OTHER.	STAMP "69B60074-3" ON	.040	.000
170	540	SKIP.	INSPECT	.000	.000
180	410	SKIP.	STORE	.000	.000
				1.930	.350

center in a routing while operating the CES. The default responses are optimum and proven parameter values required to produce a form feature through a given work center operation. This feature provides default values for the user prompts required to estimate the work center operations for the new part whenever the operations are to be performed at the same work centers as the ones in the associated standard routing. This feature would significantly reduce user's response time and improve the accuracy of inputting data by showing all related costing parameters on the same screen. See Fig. 1 for an example of the file.

2-2. GT Based C&C Scheme

An existing GT based C&C scheme has been customized and incorporated into the developed estimation system. The customized C&C scheme is basically used to develop the part routing sequence that is a major costing factor in cost estimation. Based on the customized C&C scheme,

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FILE NAME : P5856.1
    USER PROMPTS
OPERATION-DESCRIPTION              : DRILL .125 HOLE
'MATERIAL CHOICE : 22.. 17-4 PH
MATERIAL SIZE     : .62 X 2
MACHINE CHOICE   : WORK CENTER - - - 0856
     9..BRIDGEPORT SERIES II MILL 3 2J (2HP)
BO OF PARTS PRODUCED OPTION : 2..MORE THAN 1 PART PER CYCLE.
NO OF PARTS/CYCLE OPTION     : 1..2 CLAMPS PER FIXTURE
CLAMPING METHOD              : 1..1 CLAMP ON THE FIXTURE
MAX RPM                        : 1500
PART WEIGHT                    : .0324
NUMBER OF PARTS PER CYCLE      : 2
BRINELL HARDNESS               : 180
OFF STANDARD AS A DECIMAL      : .18
SHOP RATE ($)                  : 50
TOOL CHANGE VALUE              : .15
TABLE INDEX TIME FOR 2 CUTS    : .05
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(a) Generic Prompts and Responses for Work Center 856 of Part Family Number 5

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CUT TYPE CHOICE : 14...CHAM
OPER. DESC.        : CHAMFERRING
     DIAMETER                 : .312
     LENGTH OF CUT            : .03
TOOL CODE                     : MX
TOOL DESIGN TIME              : 0
TOOL FAB. TIME                : 0
MATERIAL COST FOR FIXTURE ($) : 0
NC PROGRAMMING TIME           : 15
```

(b) User Prompts and Responses for Chamferring Operation in the Work Center 856 of Part Family Number 5

Fig. 1 An Example of User Prompts and Responses Files.

sample manufacturing part families were formed. A set of sample standard routings have been developed for each of the sample part families.

With these arrangements, as new parts are to be estimated, they are coded instead of developing routing sequences for them. By mapping the part codes to appropriate part families, the standard routings can be retrieved and modified for the specified parts. In this way, a routing for the new part can be established rapidly, accurately, and consistently if the new part belongs to a part family in the database. The quality of the routing developed will be improved since the routings will be based on the standard routings. The standard routings are tried and proven routings that reflect efficient ways of producing the parts.

The customized C&C scheme was tested for 98 sample parts. Formed part families using the C&C scheme indicated that the customized C&C scheme is robust to capture sufficient part information to support manufacturing activities.

2-3. Preferred Work Center Operation Selections Based on Form Features

For fifty nine selected form features, a library of preferred operation selections to produce them has been built. In order to build an appropriate match between form feature and operation(s), each machine capability of each work center has to be analyzed carefully by the process planner and/or manufacturing engineer. Therefore, the library of preferred operation selection may be different in a different company. This feature contributes to more consistent routing development by eliminating the user's need to create one. It also results in automating the CES further. Fig. 2 shows an example of the file.

3. FACES Procedures

Following is a discussion of the FACES procedures to automatically estimate a cost using the GT based C&C scheme. Fig. 3 shows an overall logical diagram of the FACES. In order to see how the FACES works, an example case is described. Let's say that a set of new parts are to be estimated from blue prints. Before the system starts, the parts are coded by the user. The blue prints, a taxonomy chart with the C&C scheme, and basic shape diagrams are used for part coding. A spreadsheet must also be filled with the common part information such as a list of parts to estimate, part names and part codes.

Based on each part code on the spreadsheet, FACES examines the manufacturing database to find a part family to which the part may belong. The system takes each part code and begins by searching the database to see if a part code match can be located.

If no match can be found, the user is

NO	MACH	DRILL	TURN	OPERATIONS
M 1	1		2	... BORING
M 2	2	1	8	... DRILLING
M 3	3	3	10	... CORE DRILLING
M 4	4		19	... CENTER DRILLING
M 5	5	2	11	... REAMING
M 6	6	5	12	... COUNTERBORING
M 7	7	4	13	... SPOTFACING
M 8	8	6		... COUNTERSINKING
M 9	9	7	16	... TAPPING
M10	10			... FACE MILLING
M11	11			... END MILLING
D12		8		.. GUN DRILL (FOR GUN DRILL MACHINES ONLY)
D13		9		... BURNISH
T14			1	... TURN OR FACE
T15			3	... CUTOFF
T16			4	... FORM
T17			5	... GROOVE
T18			6	... THREAD SP TOOL OR ROLL
T19			7	... HOLLOW MILL
T20			9	... SPADE DRILL
T21			14	... CHAMFER
T22			15	... TREPAN
T23			17	... SHAVE
T24			18	... SKIVE
T25			20	... END FORM
T26			21	... KNURL
T27			22	... LOAD/UNLOAD OR ADV BAR
T28			23	... START CUTOFF OR TUBE

	PREFERRED OPERATIONS		
FORM FEATURES	MACH	DRILL	TURN
		.	
		.	
7 ... BEVEL 1	11		
10 ... BORE 1	2, 5, 1	1, 2	8, 11, 2
15 ... BOSS	11, 10		
16 ... CHF'R			14
17 ... C'BORE	6	5	12
18 ... C'HOLE	4		19
19 ... C'SINK	8	6	
20 ... CUTOUT 1	11	.	
		.	

Fig. 2 An Example of OPEROTM File.

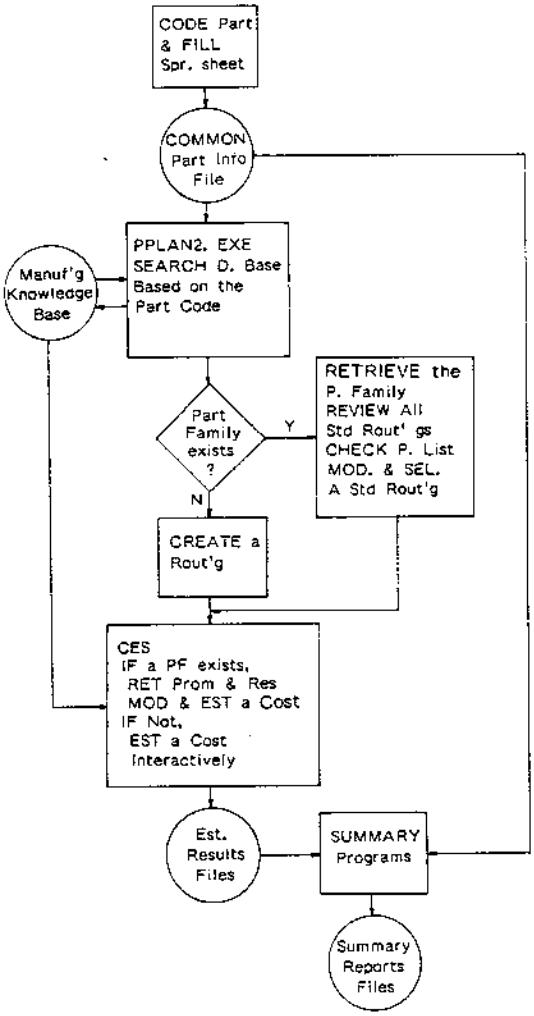

Fig. 3　Overall Logical Diagram of FACES.

prompted to create a routing for the new part. In this case, to facilitate creating the routing, the PE(IBM's Personal Editor) is used. When the user chooses the option to create a routing, the program displays a copy of the standard routing form on the screen. New routings can be readily prepared by modifying the form while in the PE editor.

If a code match is located, the system retrieves all the standard routings that are associated with that partfcular code. The user is given an opportunity to review all the standard routings associated with that part family code. Any one of these routings may be accepted as is or edited further. If none of the routings appear acceptable, a completely new routing can be constructed.

After routings are developed for the new parts, the system estimates a cost based on the routing sequence of each part. If a standard routing was found, the system retrieves and displays optimum user prompts and responses associated with the standard routing from the database. The user can edit the default responses for the specific requirements of individual work center operations. After the user accepts or modifies and accepts the responses, the system calculates a cost based on the accepted responses. Only if a completely new routing is created or a new work center is added to the standard routing, the system prompts the user interactively to input required data.

Whenever a work center has been estimated, the estimation results are saved in a file. After all work centers in parts routings of a costing project have been estimated, four summary reports of labor/machine, tooling, outside process, and routing can be generated based on the results files and the common part information file.

4. Comparison of FACES with Traditional CES

For comparison purposes, sample parts(six parts and an assembly) have been estimated using traditional CES and developed FACES respectively.

4-1. CES Estimation Procedure

All blue prints of the parts and an assembly were analyzed to extract information for routings and tools requirements. The extracted routings and tools requirements were written on separate sheets for each part and assembly. With the sheets and blue prints, a standard spreadsheet was completed. Then the parts and assembly were estimated interactively based on the spreadsheet information using a commercial CES software. Finally, four different kinds of summary reports were generated.

4-2. FACES Estimation Procedure

First, the six parts were coded by classification code. While coding the parts, form features were identified and recorded to be used when the standard routing is modified. The classification codes generated and the parts list were entered into a spreadsheet. Since the current C&C scheme can not handle an assembly part, the assembly was estimated independently using the commercial CES software. Six standard routings for six part families were prepared before hand.

4-3. Results

Table 2 shows the time required to estimate each of the six parts and their assembly. The routing sequence, material, and machine selection were taken from the previous spreadsheet which was used for the traditional method. Because the amount of spreadsheet data required by the program was reduced, the time required to complete the spreadsheet has been reduced considerably. Since the routing for each part was developed by modifying the standard routing, the routing development time(column 4) has also been reduced remarkably.

FACES provides default values for the user prompts for each work center. FACES also automatically selects a preferred individual work center operations for form features of the part. As a result of these improvements, the time required for entering data(column 8) has been significantly reduced.

As long as the database provides standard routings for the parts to be estimated, FACES can generate accurate estimates in a short time. The estimates can be more accurate and consistent than the ones produced from the traditional CES because the routings were developed from standard routings. If no standard routing exists, a

Table 2. Time Consumption in Analyzing the Blue Print & Estimation

(Unit: minutes)

Part No.	Part Name or Job Description	Routing Development Time		Time to Operate Program		Improvement (%)
		CES	FACES	CES	FACES	
	Coding	-	15	-	-	-
	Filling Spreadsheet	-	-	15	5	66.67
Part #1	PIN, PIVOT	25	5	20	5	77.78
Part #2	PIN, ROLLER	20	2	10	2	86.67
Part #3	ARM CENTER GUIDE	40	5	20	3	86.67
Part #4	SPRING REATAINER CTR GUIDE	25	5	20	2	84.44
Part #5	WEAR PLATE	30	5	8	3	78.95
Part #6	FRAME-CENTER GUIDE	30	5	15	5	77.78
Assembly	747 CTR GUIDE ASSEMBLY	40	40	30	30	0.00
	TOTAL TIME	210	82	128	55	59.47 (%)

routing would need to be created and will virtually require the same amount of time required in traditional CES. The number of standard routings in the database will grow with time. It is estimated that after two years, a 60% reduction in the total time required to make an estimate will be realized.

5. Conclusions

A fully automated cost estimation system has been developed. The concepts of Group Technology and Manufacturing Form Features were used to automate the process planning aspects of cost estimation.

In order to evaluate the developed FACES, an assembly of six parts has been estimated. The results indicated that FACES could provide a substantial improvement in accuracy, productivity, and performance over the more traditional full dialog approach to cost estimating.

Although FACES has been customized and used for the manufacturing environment of a specific company in this study, the conceptual approach used in this system provides an essential base for the batch oriented production companies which want to fully automate cost estimating activities using GT. The system can also be used in teaching as well as in industry to illustrate the benefits of GT in the cost estimating process as a bit of factory automation.

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