Emerging Trends in Applied Research

Volume - 1

Chief Editor

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Integrated Publications

New Delhi

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Chapter - 5

Manufacturing Feature-Based CAD Management and Intelligent Process Planning

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Abstract

In a traditional manufacturing environment, a process plan is generated by a process planner, who examines a part drawing to develop an efficient and feasible process plan to produce the part. This manual approach of process planning depends heavily on the knowledge and experience of the process planner. In order to prepare new process plan, the process planner must be able to manage and retrieve a great deal of documents for a similar part and make necessary modifications to the plan to produce the new part.

Keyword: CAD, 3D technology, APPS

I. Introduction

A recent article on the subject of process planning and scheduling D.N. Sormaz and Ganduri] gives a good review on integration of rule-based process selection. Computer-Integrated Process Planning and Scheduling (CLIPPS) [Aldakhilallah and Ramesh] system consists of integrated modules namely for automated feature recognition, for determining an efficient and feasible process plan and to generate production schedule plan. The system provides feedback to design and manufacturing to engineers to fully evaluate design and ensure that the product can be manufactured in a cost-effective manner. Hierarchical and Intelligent Manufacturing Automated Process Planning (HI-MAPP) [Berenji and Khoshnevis] is another AI based process planning system developed by University of Tokyo. In this system knowledge base consists of 45 production rules that are classified into 4 categories. These are rules that define process, type of cut, type of machine and rules that can select any other miscellaneous action that the planner wants. HI-MAPP then applies the hierarchical and non-linear planning concepts. Turbo-CAPP [Wang and Wysk] is an intelligent process planning system in which a problem-solving knowledge is represented as production rules and is stored in three planning layers: layer of facts, layer of inference rules and layer of meta-knowledge. The system starts with extracting geometric entities in terms of surface features from the part description provided by the 2D CAD system. Then based on the features and the qualification data, the system generates sequence operation and NC code.

From the preceding discussion it is clear that process planning is an information intensive task which requires significant amount of time and experience. Manufacturing Knowledge Management System is designed keeping in view the requirements of manufacturing industry. Thus, system provides intelligent functions for automatic generation of process plans. Intelligent process planning system attempts to automate the process planning task by modelling human kind of intelligence. This includes gathering of expert knowledge from individuals (employees, customers and suppliers) and making it available to the entire organization to create a culture of knowledge sharing. Also save time and cost in the transition between design and manufacture. It also provides an XML based Data Exchange interface to integrate CAD/CAM system with other life cycle issues such as PDM, ERP etc. The remaining sections will give details about system architecture and its implementation details.

II. Manufacturing knowledge management system

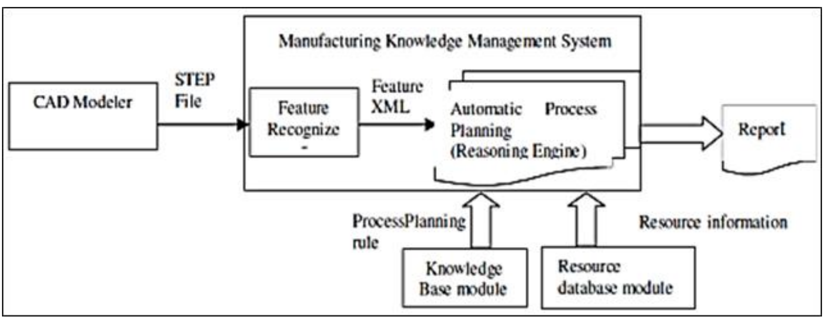


Fig 1: Architecture of Knowledge Management System

The goal of Manufacturing Knowledge Management System is to automatically generate a process plan according to design information and manufacturing knowledge available in an enterprise. Its focus however, is on improving work efficiency and quality by integration, intelligence and information management. The key modules of Knowledge Management system are shown in Figure. 1.

The job of the Feature Recognizer module is to extract and translate the design information given in the CAD model into manufacturing information. The input to the Feature Recognizer module is a STEP file containing CAD model generated by some external solid modeler. The 3D Viewer helps in displaying the CAD model as well as recognized manufacturing features. The output of the Feature Recognizer is a set of manufacturing features encoded in XML format, which serves as an input to the process planning module. The Knowledge Base consists of reasoning rules definition for different manufacturing phases and covers the whole rules for manufacturing process. The Resource base contains manufacturing database information, such as raw material stock, production machine capability, tooling, fixtures, and time standards etc. After all the manufacturing rules have been defined in the knowledge base, the reasoning engine of the Automatic Process Planning Module uses these rules along with resource database to generate the process plan. Automatic Process Planning Module which contains manufacturing Knowledge base specified in term of if-then-else production rules. Each production rule contains a detailed set of instructions as to what resources are required to manufacture each feature. These rules are compiled by the knowledge engineer by interacting with manufacturing expert.

III. Implementation

In this section we shall discuss in detail different modules of the Manufacturing Knowledge Management System that we have implemented as a part of process planning system. Basic flow chart of the implemented process planning system is shown in figure. 2. This system takes as input STEP AP203/AP214 file defining geometry and topology of the part. After the module "reads-in" the STEP file, it goes through the file to check geometry representation issues.

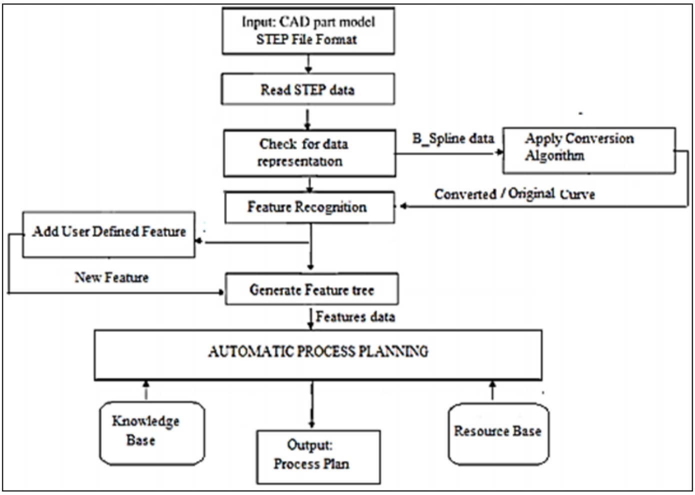


Fig 2: The basic flowchart of Automatic Process Planning System

If the shape represented using B Spline data i.e. curve/surfaces, then it goes through B Spline Curve/Surface conversion step. It sends back the output curve/surface to proceed with next step i.e. feature recognition. At this point if feature recognition process fails to recognised some features due to some reason (complex design/data loss), user is allowed to add unrecognised feature using Add User Defined Feature option. Finally feature tree is generated and this recognised manufacturing features data is send to Automatic Process Planning step. With help of Knowledge base and Resource base a final output i.e. optimum process plan is generated.

IV. Feature recognition module

Automated recognition of features from CAD models has been attempted for a wide range of application domains in mechanical engineering. However, the absence of a clear mathematical formalism for the feature definition has made it difficult to develop a general approach and thus most of these methods are limited in scope. In this work we recognize a class of machinable features expressed in neutral STEP format and feature recognition is done using the rule-based recognition technique. The feature recognizer module extracts and translates the design information given in the CAD model into manufacturing information. Input to the feature recognizer consists of a STEP file containing CAD model generated by some external solid modeller. Basic idea is to build a library of elementary manufacturing features. Each different design feature, read out from the CAD system, will be broken down and listed as corresponding manufacturing features. On completion of the feature recognition task, the Feature Recognizer outputs all the recognized features in a XML file along with their feature parameters. The list of manufacturing features presently recognized by the feature recognizer includes: Cylindrical Holes/Solids, Chamfers, Fillets and Edges Rounds, Slots and Steps, Pockets, Cones, Tapers and Spheres, Ribs, Threads, Grooves, Bosses, Irregulars and Voids. More details of the feature recognition algorithm will be discussed in chapter five. On completion of feature recognition, other subtasks involved is defining manufacturing parameters and then generating a XML file with recognized features tree. These are important tasks as it will form an input for process planning module. Following section gives details of these tasks.

V. 3D Viewer

The 3D Viewer module displays input data and identified feature data in the viewer and supports displaying of 3D object in major views. Viewer also displays object in wire frame mode with/without hidden lines. Transparency can be set as per user's requirement. See figure 3. Dimensioning features is incorporated in the visualizer. Manual as well as automatic dimensioning can be performed on the step file displayed in the viewer.

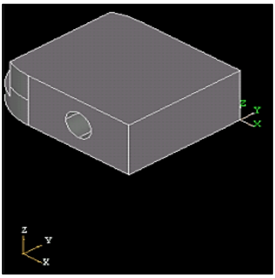


Fig 3: 3D Viewer

VI. Solid model geometry information

The Solid Model Geometry Information Tree View shows the solid model information of the STEP file. The solid node of the tree displays the information in terms of low-level geometric entities like Vertex, Edge, Wire and Face, see figure. 4. On selecting a Face, Wire, Edge or Vertex in the Viewer the corresponding entity is highlighted in this Tree view. Similarly, selecting a node item in the tree view, the corresponding Face, Edge, Wire or Vertex is highlighted. The auxiliary node shows all the vertices corresponding to the centre of circular edges. Selecting the auxiliary vertex displays the corresponding vertex in the 3D viewer with blue colour selection. These are generated at runtime and are not the part of the STEP file opened in the viewer.

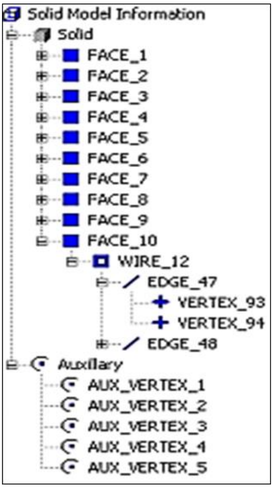


Fig 4: Geometry Information Tree View

The Geometry Property Panel gives details of the object primitives shown in the geometry information tree view. Geometry Property Panel describes various properties of the entity selected in the Geometry Information Tree View. For example in figure. 5, FACE-13 as highlighted in viewer and corresponding face properties are shown in property panel view.

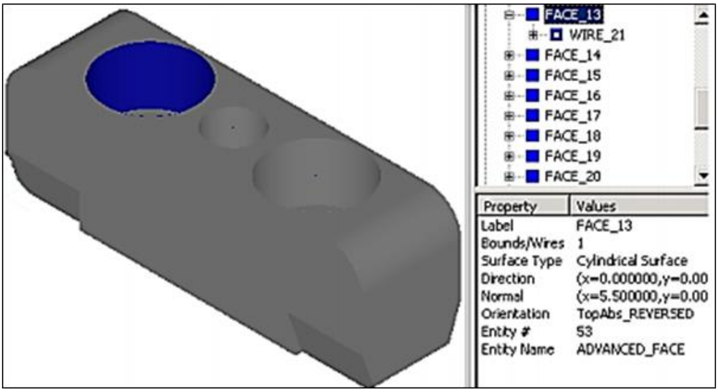
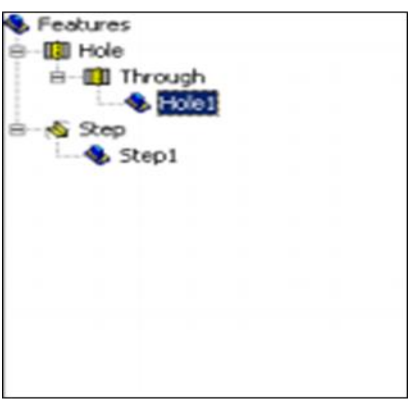
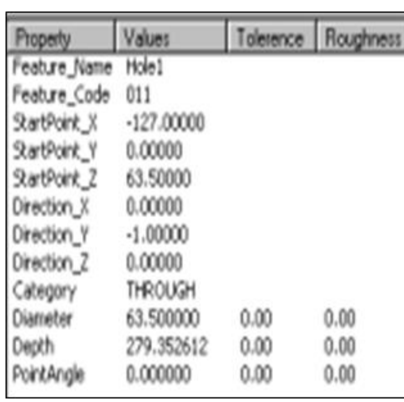


Fig 5: Highlighted face and corresponding properties

VII. Recognised features tree view & defining manufacturing feature parameters

When the feature recognition task is performed the recognised features tree view shows all the features found. Figure 6 shows a tree view of list of recognised feature. On selecting a particular feature in this tree view the corresponding feature is highlighted in yellow colour in the 3D viewer. Also selecting a face in the viewer, selects the feature tree view item if the selected face is a part of the feature that is found. If no features are found the tree is empty.





Property	Values	Tolerence	Roughness
Feature_Name	Hole1		
Feature_Code	011		
StartPoint_X	-127.00000		
StartPoint_Y	0.00000		
StartPoint_Z	63.50000		
Direction_X	0.00000		
Direction_Y	-1.00000		
Direction_Z	0.00000		
Category	THROUGH		
Diameter	63.500000	0.00	0.00
Depth	279.352612	0.00	0.00
PointAngle	0.000000	0.00	0.00

Fig 6: Feature Tree View **Fig 7:** Feature Properties

The parameters of the recognized feature are displayed in the Feature Property Panel, see figure 7. When recognition is performed and a feature is selected from the tree view the panel displays the corresponding parameters of the feature. Feature definition includes parameters which give geometric information about the feature. These parameters are sub-divided into two categories, dimension type and non-dimension type. Dimension type parameters specify measurements of the physical structure of the feature using Length-Mass-Time measurement. Attributes/Parameters like radius, diameter, length, breadth, height, depth, width, and angle belong to the dimension type. In addition, dimension type parameters contains tolerance and roughness information which specifies the possible upper limit and lower limit of the parameter value and the surface roughness respectively.

The rest of the parameters such as the start point, direction of the feature belong to the non-dimension type. Each feature comprises of one or more faces. The information about feature faces is stored for each feature along with its parameter. Figure.8 displays a entire 3D viewer with solid model and recognised features tree with its properties.

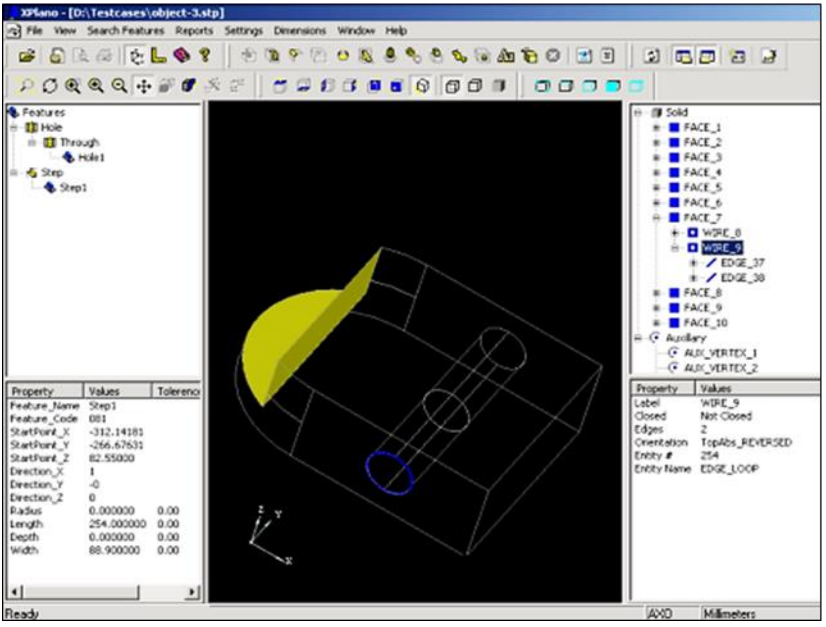


Fig 8: Solid model with recognised features and properties

Conclusion

This chapter describes Manufacturing knowledge management framework, implemented to automate process planning in manufacturing.

The framework allows manufacturing expert to incrementally specify rules in Knowledge base and gradually enhance degree of automation. It is observed that the rules in Knowledge base directly influence the quality of process plan. Over a period of time, with trial and error the system stabilizes and over dependence on expert process planner reduces.

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