Incremental Expansion of Manufacturing Knowledge Base

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ABSTRACT

Recognition of manufacturing features from a computer aided design (CAD) model is vital to generate manufacturing processes in computer aided process planning (CAPP) systems. Usually CAPP systems (and CAM systems) have their own libraries for supported features. In this paper we demonstrate a methodology for expansion of existing manufacturing knowledge base by introducing a new feature type into CAPP prototype system called IMPlanner. The IMPlanner system is currently capable of mapping Holes, Pockets, Slots and Feature sets/Feature instances from feature based design (CAD) model and it generates manufacturing operations for those feature types using a rule based reasoning. This paper focuses on applying the same methodology, but extending it for identification of chamfer features from a CAD model, extraction of the feature information, development of chamfer processing rules, and generation of manufacturing processes for chamfer feature of varied dimensions. The methodology has been developed for interaction with Siemens NX CAD system and it has been developed in Java to be compatible with existing IMPlanner system. The results have been verified for several complex industrial parts, and possible applicability to other feature types. Savings in development and engineering time of this incremental approach are also addressed in the paper.

1. Introduction

Recognition of features of a CAD model has a direct relationship with other downstream activities such as automatic manufacturing and process planning and many researches have been done in past decades in the area of automatic feature recognition and integration with CAPP. Manufacturing companies need to produce customer's parts at low cost with high quality and they need more flexibility in modification of a part according to the customer requirement. In order to fulfill these requirements, companies need automated systems to link CAD and CAM with CAPP. It is necessary to identify and extract feature information from a CAD model in order to define machine, cutting and tolerance parameters in the CAPP. There are many CAPP systems in both industry and academia and we used the Ohio University CAPP test bed, IMPlanner for our case study. We discuss methodologies of recognizing chamfer feature and extracting details from CAD model which is designed in Siemens NX CAD system for CAPP. In this paper, section 2 discusses previous work on automatic feature recognition methodologies for CAM and CAPP and section 3 shows overview of IMPlanner system. Using chamfer feature as a manufacturing feature in CAD systems and chamfer rules which are used in extended knowledge base are discussed under section 4. Section 5 explains a case study of chamfer as extended feature for IMPlanner system while section 6 explains conclusion.

2. Literature review

Feature recognition or feature mapping from a CAD model is vital for the CAPP and many researches have been done in the area of automatic feature recognition and its integration with CAPP. In the area of feature recognition, many papers focused on various approaches with different algorithms in order to recognize features. Some of these methods are the graph base method, volume decomposition, pattern recognition, and hints based method.

Joshi and Chang [1] presented the graph based feature recognition procedure, Attributed Adjacency Graph (AAG), and also discussed implementation of feature recognizer. AAG considers relationships between faces and edges of a CAD model and classifies all consecutive two faces as concave or convex. Then the feature recognizer sub-graphs the completed AAG through its algorithm and the sub-graphs are analyzed to identify correspondent features. This approach recognizes many varieties of polyhedron features. However, this method is unable to recognize the hole feature and it has difficulty recognizing intersected and nested features.

The hint based feature recognition approach is introduced in the paper by Vandendrande and Requicha [3] and they focused hints from the B-Rep of a model. Hint is identified by characteristic pattern in the B-Rep and for instance, hole-hint is represented by cylindrical surface. Identified hints are tested for presence, non-intrusion, accessibility and other dimensional constraints. This approach addressed both interactive features which are not addressed in most of previous work and also the non-interactive features.

A similar hint based feature recognition approach was proposed by Sormaz and Tennety [2] to recognize features using hints in 2D space from a CAD object which is built in sweep solid modeling operation. Swept profile in 2D is analyzed at the initial sketch level of the CAD model due to simplicity of computation when compared with 3D. Each hint is tested for presence which is at least one face that makes up the extrude operation, non-intrusion and for both 2D and 3D verification process. Suggested method is computationally efficient but limited for the CAD objects which are designed by sweep (extrude) operation.

An overview of automatic feature techniques are discussed by Subrahmanyam and Wozny [4]. Convex hull method, cavity volume, delta volume decomposition and decomposition by slicing laminae methods are discussed under volume decomposition approach. Further this paper discussed many approaches in automatic feature recognition such as Attributed Adjacency Graph, Frame-based feature extraction, Hint-based feature recognition, CSG/BREP for feature recognition.

3. IMPlanner overview

Intelligent Manufacturing Planner, IMPlanner , is a CAPP prototype which is under development and it makes test-environment for many researches in the department of industrial engineering at Ohio University. Development of the prototype is based on object oriented software platform, Java. The architecture of the IMPlanner system with related modules is shown in Figure-01. Three main data models, machining feature model, process plan model and the process network serve the purpose of representing the part, feature and the process plan data between execution of different modules or applications.

Applications of IMPlanner system includes feature recognition from 2D data, feature mapping and interaction, rule based process selection, process visualization (slot, pocket, hole), process network generation and integration of process planning and selection.

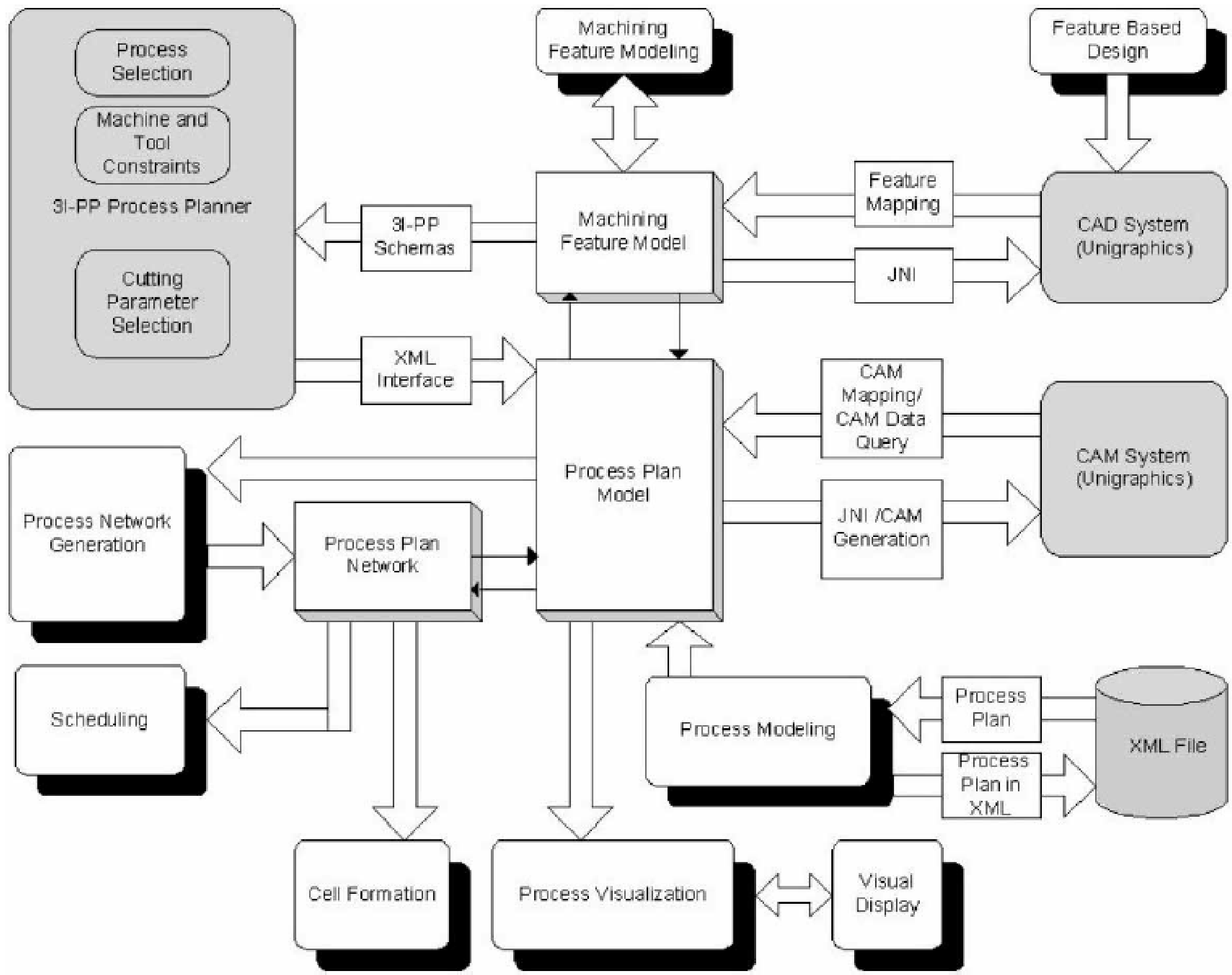

Figure-01: System architecture of IMPlanner prototype (Ref. [5])

4. Knowledge base extension

The procedure for extending the existing knowledge base in IMPlanner system is explained in this section. The steps in the procedure include: CAD feature definition, manufacturing feature definition, process planning rules extension and database extension.

4.1. CAD Feature

There are many design features bundled with commercial CAD packages such as hole, slot, pocket, groove, chamfer, boss, pad etc. for designer's convenience. Even though we consider boss and pad as features in design point of view, those are not manufacturing features because these features add material for a modeling object. We consider a feature as a manufacturing feature, when the relevant feature is made by a material removal process.

4.2. Chamfer as a manufacturing feature

If an object represents any manufacturing feature, relevant feature should be achieved by a machining process which removes material from stock. Such processes, at least require a separate tool, process and machining time. Here we consider chamfer as a manufacturing feature and to clarify, let us consider the following example. Objects, (a) and (b) of Figure-02 have chamfer feature with their own characteristics. In order to machine chamfer of part (a), a separate tool is not required and it can be machined in the process which is used to machine a slot (S-1) with chamfer milling tool. Now we consider the chamfer feature of part (b). Even though we use same tool for slot (S-2) and slot (S-3), we have to use a separate tool to machine the chamfer edge.

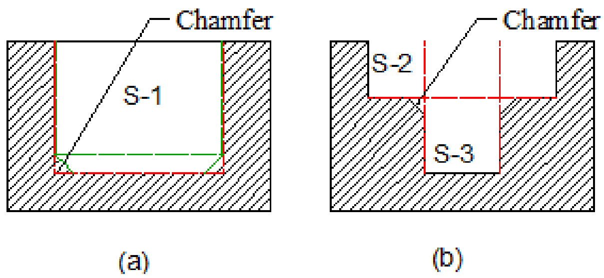

Figure-02: Illustration of chamfer feature in a CAD object

4.3. Process planning rules

We defined new rules to map chamfer information with knowledge as a part of the expansion of manufacturing knowledge base. There is a relationship between knowledge subsets and it is illustrated in Figure-03. For instance, the feature information of chamfer maps with the operation knowledge and if the mapped process is a chamfer-end-milling process, then the operation rules check the required tool from the tool base according to the chamfer angle and lengths. Then, a machine is selected as compatible with both tool and operation. Finally, related information is conveyed to IMPlanner system.

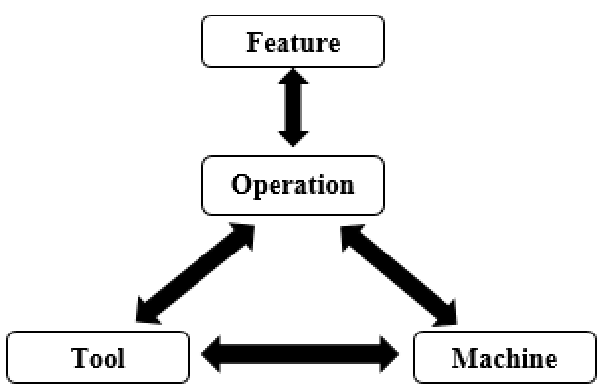

Figure-03: Relationship Illustration of knowledgebase

New rules for chamfer are defined to understand extracted details from CAD object and the feature information is executed to find out necessary machines, tools, cutting parameters and operations. Defined rules for chamfer feature in order to identify information from the extended system are shown below in Figure-04.

```
(defrule chamfer
      ?f <- (feature (name ?f1 )
            (type chamfer) (status input) (quality ?quality&: (> ?quality
30) ) )
      =>
      (modify ?f (status process) )
      (assert (operation (feature ?f1) (process chamfer-end-milling ) (cut
single) (options or)
            (machine nil) (tool nil) (setup-time nil) (op-time nil) (cost
nil) ) )
      (assert (operation (feature ?f1) (process chamfer-side-milling) (cut
single) (options or)
            (machine nil) (tool nil) (setup-time nil) (op-time nil) (cost
nil) ) )

)
```

Figure-04: New rules for chamfer feature

Existing manufacturing knowledgebase is extended for chamfer feature and new tool, process and machine data are added. For instance, TC600 tool is added to knowledge base with its specifications such as, tool diameter, length, number of teeth, chamfer-angle etc. Machine and process parameters are also added to existing knowledge base for the chamfer feature. An example data set is illustrated in Figure-05.

Tool Data	Process Data	Machine data
(assert (tool (name TC600) (material Carbide) (for-process chamfer-end-milling) (diameter 4.0) (length 10.0) (number-of-teeth 4) (chamfer-angle 45) (chamfer-length 0.5) (life-cycle 180) (cost 30.000)))	(assert (process (name chamfer-end- milling) (machine CncVMillFast)))	(assert (machine (name CncVMillFast) (type mill) (toolhead vertical) (bed-size-x 54) (bed-size-y 20) (bed-size-z 10) (setup-time 240) (power 4) (mhandling-time 0.8) (speed-efficiency 1.0) (tool-change-time 40) (unit-cost 1.3) (tool-list TC600 T601 T603 T605 T607 T609 T611 T613 T615 T617 T619 T701 T702 T703 T704 TC600)))

Figure-05: Knowledge extension for chamfer feature

5. Case studies

Existing IMPlanner system is capable of extracting holes, slots, pockets and pattern features from a CAD object which is designed through the Siemens NX CAD package. Our case study focused on extension of knowledge base which is driven by Jess rules in order to recognize chamfer feature from a CAD object and execute for process planning. We used Java, an object oriented software platform, to extract feature information from Siemens NX CAD model and extended existing knowledge based using Jess rule base software. Our CAD model is opened through Integration Panel, a module IMPlanner system, and it extracted chamfer information. Figure-06 is shown recognizing chamfer feature from the NX-CAD model.

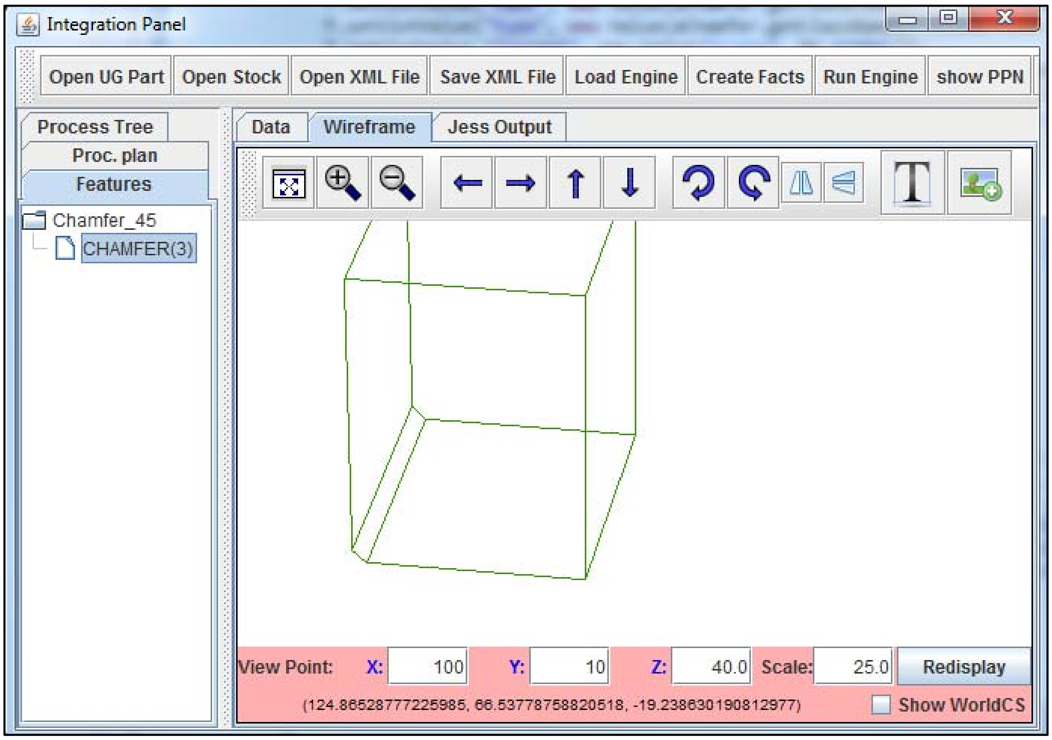

Figure-06: Recognize chamfer feature from CAD object

Extracted feature details is run through extended rules in order to map feature information with expanded knowledge base. Fired rules related to the feature information and rules firing order are shown in Figure-07. Making operation, machine and tool are identified in first three consecutive firing. According to information in the manufacturing knowledge base, machine cost is calculated via fire number 4. Fire steps 5, 6 and 7 define the feature order and steps 8 and 9 run for operation cost. Fire step 10 reports to user generated operations and in the firing steps of 11, 12 and 13, newly created processes, machines and tools are send back to the IMPlanner system from the rule engine working memory.

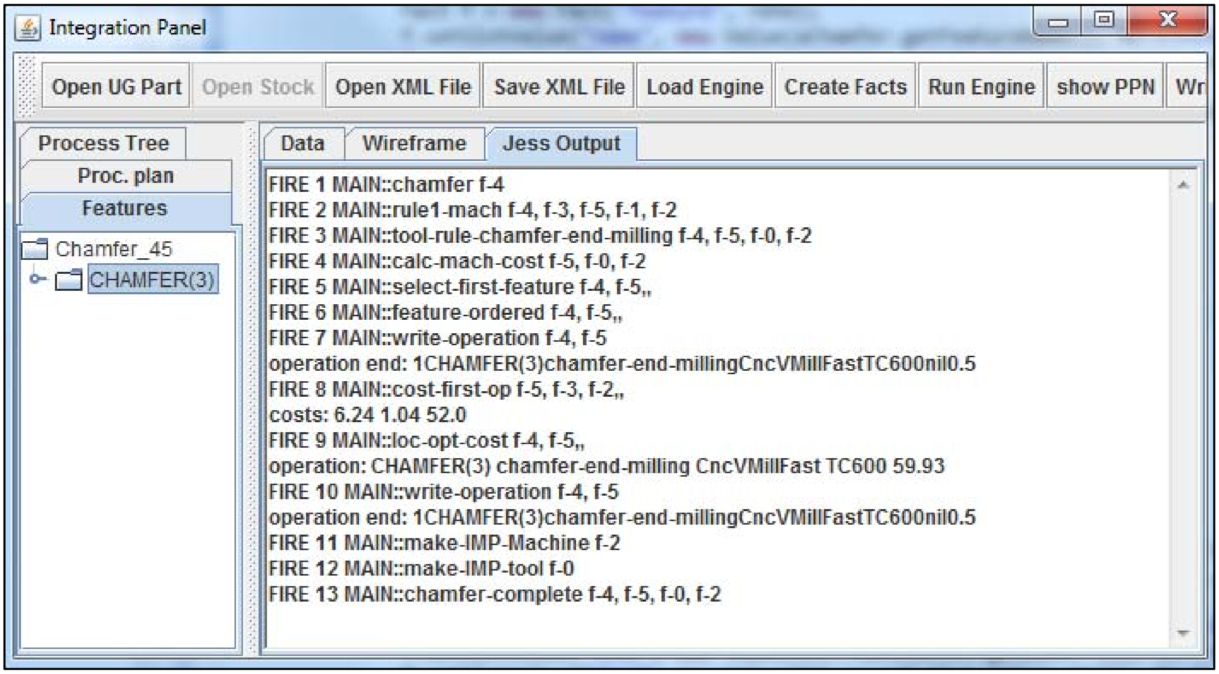

Figure-07: Fired rules for extracted feather information

After creting facts for given feature, we execute relevant fact information for the processes. The IMPlanner system then visualizes process information for chamfer feature according to fired rules information, as shown in Figure 08. For instance, the required machine for our feature is CNCVMillFast (CNC vertical milling machine) and the tool is TC 600.

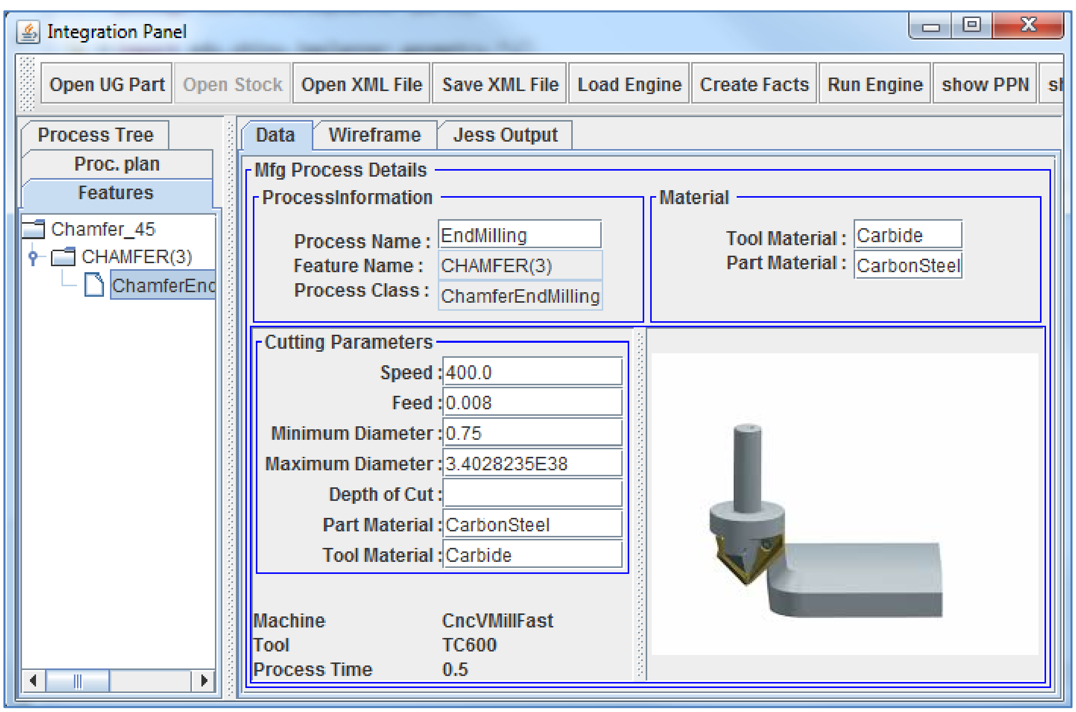

Figure-08: Process information for Chamfer feature

6. Conclusion

Existing system is expanded successfully extending the knowledge base in order to recognize chamfer feature from a CAD design object. A previous application, the Integration Panel of IMPlanner system, is used to execute new rules under this study. Additionally, further extensions can be done for additional processes of the chamfer manufacturing feature. Finally, our approach was successful to recognize chamfer feature from a CAD object which is design through the Siemens-NX CAD package and generate required processes.

References

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