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# FEATURE BASED MODELING AND AUTOMATED PROCESS PLAN GENERATION FOR TURNING COMPONENTS

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**Abstract:**
Feature based modeling is an indispensable tool for integrating design and manufacturing processes in CAPP system. Present work proposes a new approach to generate process plan from feature-based modeling, based on an integrated geometric modeling system that supports both feature-based modeling and information storage. This feature based modeling approach eliminates extraction of features from the programs of the already drawn components. As a result, feature information is directly available to downstream activities. The system comprises of three modules for different tasks such as feature-based modeling module, feature information storage module and process plan generation module. The proposed feature based modeling system provides a graphical environment for solid modeling in AutoCAD. The system is user friendly, flexible, expandable and reduces over all lead time. Present system is developed only for turning components and limited to selective machining features. To generalize the system, it can be extended to prismatic components and for more machining features. Generalized system can be used in manufacturing industry for automated process plan generation.

**Key Words:** Machining Features, Feature Based Modeling, CAPP

## 1. INTRODUCTION

Present manufacturing industry demands more automation from design stage to manufacturing stage. There is much interest in manufacturing firms to automate the task of process planning using computer-aided process planning (CAPP) systems. CAPP is usually considered to be part of Computer-Aided Manufacturing (CAM). However, this tends to imply that CAM is a stand-alone system. In fact, a synergy results when CAM is combined with computer-aided design to create a CAD/CAM system. In such a system, CAPP becomes the direct connection between design and manufacturing. Process planning includes identification of the processes, machine tools, cutting tools, setups and fixtures to produce the desired product, along with geometric information. Even today, the activities of process planning are partially based on the skill of experienced process planners, which results in time-consuming procedures. As process planning is very complex, it would be desirable to use computer-aided approaches to relieve the process planner from routine activities and reduce the time and cost of the task. Because of the need to respond quickly to highly variable market demands, the development of computer-aided process planning (CAPP) systems is necessary.

To achieve this computer integrated manufacturing (CIM) system, information about machining component is must. In terms of integrating CAPP systems, the feature-based approaches have been recognized as essential tools for eventually integrating process planning and design. Feature-based approaches are divided into two groups, namely, feature recognition and design by feature. The feature recognition approach examines the topology and geometry of a part and matches them with the appropriate definition of predefined features. The design by feature approach builds a part from predefined features where their attributes are attached.

## 2. LITERATURE REVIEW

Several research efforts over the last two decades have been focused on feature-based approaches to integrate design and automated process planning. Li [1] presented a methodology for recognizing manufacturing features from a design feature model. A feature recognition processor first translates the design feature model of a part into an intermediate manufacturing feature tree by handling design features and then final manufacturing tree is updated with some interpretations. Yan [2] proposed algorithms based on progressive Z-maps for recognizing the machining features and feature topologies by analyzing NC programs. Lee and Kim [3] presented a new approach to extracting machining features from a feature-based design model, which supports both feature-based modeling and feature recognition. Feature recognition is achieved through an incremental feature converter. Jung [4] has given a novel feature finder, which automatically generates a part interpretation in terms of machining features, by utilizing information from a variety of sources such as nominal geometry, tolerances and attributes, and design features. Martino [5] presented system architecture for feature-based modeling which is founded on integration that is obtained through the definition of a common feature library and an intermediate model, which plays the role of communication link between the geometric model and the feature-based model. Timo [6] proposed a novel feature-modeling system which implements a hybrid of feature-based design and feature recognition in a single framework. During the design process of a part, the user can modify interactively either the solid model or the feature model of the part while the system keeps the other model consistent with the changed one. This gives the user the freedom of choosing the most convenient means of expressing each required operation.

Duan [7] proposed a feature based solid modeling tool in which geometry is associated with knowledge. Generalized sweeping has been developed as a unified method for defining various features with a dual representation schema of a CSG index and a B-rep index. Anthony and Lin [8] presented a systematic approach using Autodesk Inventor to design assembly drawings with geometric dimensioning and tolerance (GD&T). Through the use of position tolerance in GD&T and the parameter data file in Auto Desk Inventor, this approach can generate the assembly drawing when specified with maximum material condition (MMC). Ismail [9] introduced a technique called edge boundary classification (EBC) for recognition of features from B-rep solid model to support integrated manufacturing. In EBC features are interpreted from patterns formed by identifying the solid and void sides of a boundary entity using the spatial addressability information of solid models. Different type of Feature- based techniques [10, 11, 12] have been developed, which represent the 3D object as a set of features. Some of these techniques appear to be promising for cost estimation domain. Application-independent feature based approaches based on Skeletons [13, 14], Shock graphs [15], Reeb graphs [16] and Slope diagrams [17] have also been developed. However, these approaches tend to filter out important geometric details in machined parts. Gupta [18] presented algorithms for identifying machined parts in a database that are similar to a given query part based on machining features. In this algorithms feature vectors are used to assess the similarity of the parts that are machined on 3-axis machining centers.

Devireddy and Ghosh [19] presented a methodology of integrating the design and planning of manufacturing by utilizing the concept of feature-based modeling. Patil and Pande [20] reported the development of an intelligent environment for the feature-based design synthesis and process planning of prismatic parts. Khoshnevis et al [21] described architecture of an integrated process planning system, called 3I-PP, which is comprised of three modules: feature completion, process selection, and process sequencing. Tseng [22] developed a feature-based fixturing analysis method for machining multiple sets of features. Joo and Cho [23] presented a feature-based process planning for sculptured pocket machining. Kim et al [24] developed an automated computer-aided process planning and die design system for quasi-axisymmetric cold forged products based on knowledge-based rules. The system uses 2D geometry recognition and is integrated with the technology of process planning, die design and CAE analysis.

Alberto and Ferreira [25] described the implementation of the Web Machining system, aimed at integrating CAD/CAPP/CAM for the remote manufacturing of feature-based cylindrical parts with symmetrical and asymmetrical features through the Internet, using an approach based on multi-agent systems. Saleh and Engin [26] presented an intelligent process planning system using STEP features (ST-FeatCAPP) for prismatic parts. The system maps a STEP AP224 XML data file, without using a complex feature recognition process, and produces the corresponding machining operations to generate the process plan and corresponding STEP-NC in XML format. A hybrid approach of artificial intelligence is used as the inference engine in developing the system. An object-oriented approach is used in the definition and implementation of the system. From literature it is observed that feature recognition needs longer time and difficult task, where as in other studies based on feature based modeling include lot of constraints. While generating process plan, the entities like point, line, arc not sufficient and it is necessary to convert the CAD data into design oriented geometric entities or manufacturing related features such as plane cylinders, taper cylinders, holes, slots, pockets.

In the present work, new approach to include machining features from a feature-based solid modeling, based on an integrated geometric modeling system that supports both feature-based modeling and feature recognition is proposed. Three modules are integrated viz. design module, information storage module and process plan generation model. Design module consists of feature based modeling system, which is developed using VISUAL BASIC in integration with AutoCAD for turning components. This feature-based solid modeling based on an integrated geometric modeling system that supports both feature-based modeling and feature identification. Information storage module stores the information available in the design stage and connects both design module and process plan module. The information of the machining features available in storage module is used in process plan generation of the components. The proposed feature based modeling system provides a graphical environment for solid modeling in AutoCAD. The machining features are used as basis for automated process plan generation.

## 3. FEATURE-BASED MODELING

In the proposed system, design module provides inbuilt features such as plane cylinder, taper cylinder, blind hole, through hole and groove to generate CAD model. Algorithms are developed for individual features and these algorithms are embedded in Visual Basic forms. Required dimensions of the selected feature are specified by the user in the user interactive mode. Then the model is created in the AutoCAD window. The deimensions are automatically recognized and are stored in the Visual Basic window (information storage module). This integration is done, using a user integrated and development environment in VISUAL BASIC. The User integrated environments used in this work are VBAIDE (Visual Basic Automated Integrated Development Environment) and VLIDE (Visual Lisp Integrated Development Environment). These Environments integrate AutoCAD with Visual Basic, so that we can use them with considerable ease.

### 3.1 Algorithm for plane cylinder

The algorithm for modeling and storing plane cylinder based on the dimensions entered by the user is represented below. The model created and feature list stored is shown in the Figure 1.

- Length, radius of plane cylinder is considered in the ZX plane and stored in information storage module. Same is used to create plane cylinder from the built in function.
- If the machining feature is first operation, it is created from reference point in ZX plane. Otherwise, end point of the previous machining feature is considered as starting point for the present one.
- The starting point of the feature is computed from the previous feature history of the model. If the previous history is null then start from reference point.
- Nodes indicating the starting point of the feature, radius, and length of the cylinder are created in the information storage module. All the features are considered co-axial.
- Plane cylinder is created in the AutoCAD window and information required for machining operation is stored.
- Dimensions of the machining feature like length, radius, and reference point are displayed in a separate window.

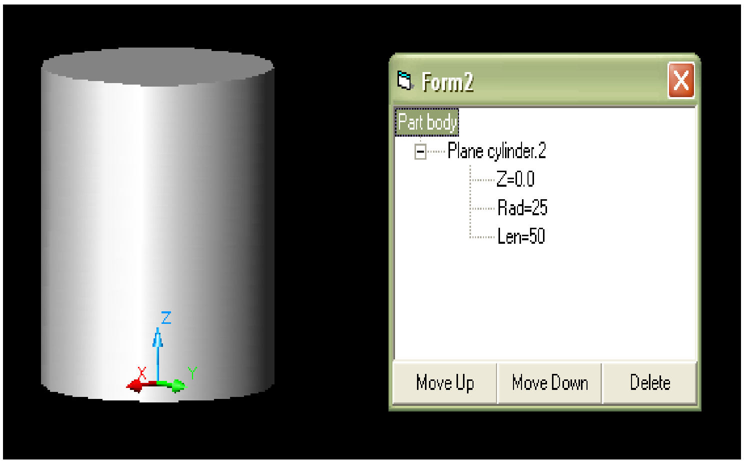


Figure 1: Plane Cylinder with its feature list.

### 3.2 Algorithm for taper cylinder

- The algorithm for modeling and storing a taper cylinder feature is given below. The model created and feature list stored is presented in Figure 2.
- Axes variables xv, yv, zv are declared in AutoCAD user co-ordinate system, arc and reference point are specified.
- Lower radius, higher radius, length and angle of taper are declared.
- From the previous feature history starting point is considered and taper angle is calculated if radius and length are specified. If this is the first machining feature then starting point is reference point itself.
- Nodes of the features like lower radius, higher radius, starting point and length are defined from in built function.
- Taper cylinder is created in AutoCAD window and dimensions of the machining feature are stored in information storage module.

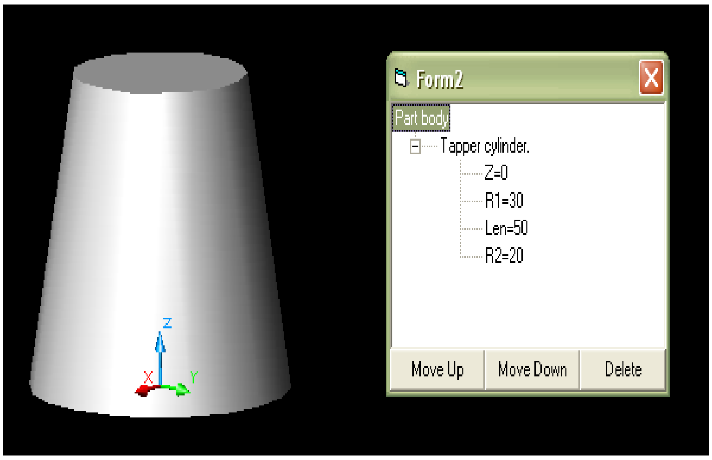


Figure 2: Taper Cylinder with its feature list.

### 3.3 Algorithm for groove

The algorithm for modeling and storing a groove feature is explained in this section. Figure 3 shows the model created and feature list stored.

- The variables width, height, starting point and ending point are specified as machining features.
- Machining feature is considered along the reference axis from the previous machining feature.
- Always this should not be the first machining feature on the component.
- Groove is created in existing component in AutoCAD window.
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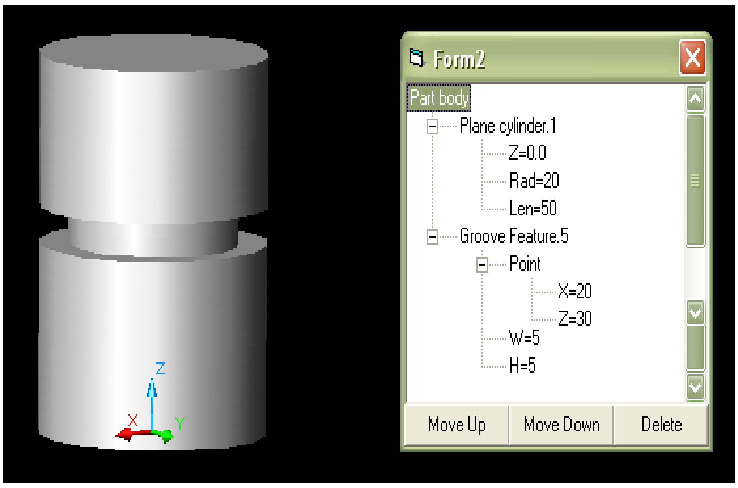


Figure 3: Groove with its feature list.

### 3.4 Algorithm for through hole

The following algorithm gives information about modeling and storing the feature data of a through hole. The model created and feature list stored is shown in the Figure 4.

- Starting point and ending point of the hole is specified and distance between these two points should be always greater than the total length of the component.
- Radius of the hole is specified.

- Hole is Created with specified dimensions and the feature information radius and length of the hole are stored and displayed in the feature list window using nodes.

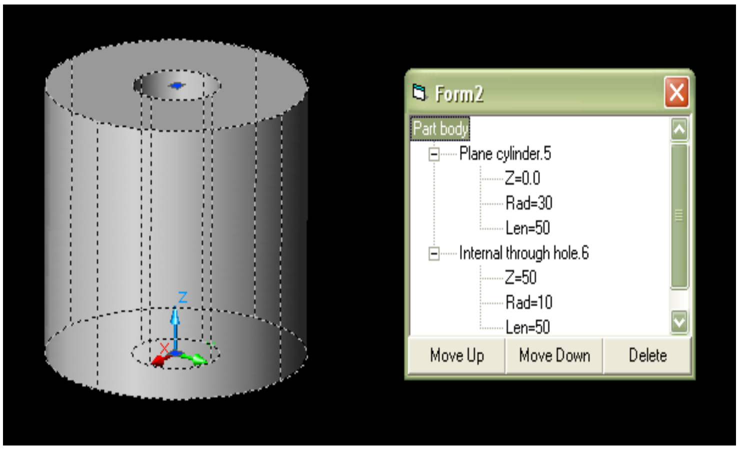


Figure 4: Through hole with its feature list.

### 3.5 Algorithm for blind hole

The algorithm for a blind hole is explained with the help of Figure 5.

- Starting point and ending point of the hole is specified and distance between these two points should be always less than the total length of the component.
- Radius of the hole is specified.
- Blind hole is Created with specified dimensions and the feature information radius and length of the hole are stored and displayed in the feature list window using nodes.

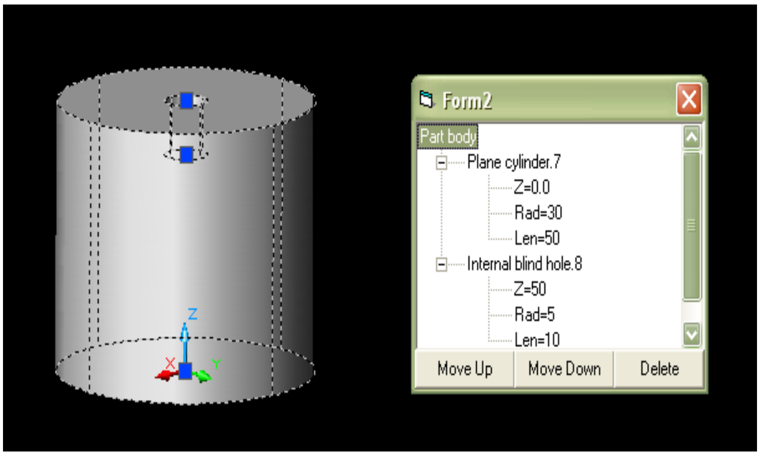


Figure 5: Blind hole with its feature list.

## 4. PROCESS PLAN GENERATION

Existing CAD systems commonly represent geometric models in terms of elementary geometric entities such as lines, arcs, surfaces, cubes and cylinders. While generating process plan it is necessary to convert the CAD data into design oriented geometric entities, into manufacturing related features such as plane cylinders, taper cylinders, holes, slots, pockets. This process is tedious and time taking. Ideal CAD/CAM integration requires machining processes and sequence of operations should be generated automatically. In the present work, automatic process plan module convert the design data from the modeling module into manufacturing information using the knowledge based database. The CAPP system developed is composed of different activities.

1. Machining features generated in the design stage are recognized and stored under the Visual basic control of AutoCAD activex interface. This functions simultaneously when the project runs in the AutoCAD interface.
2. The feature list recognized and stored is utilized to develop the process plan by linking with main source file. Based on the part body recognized from the feature list, respective knowledge base is used for the respective features such as plane cylinder, taper cylinder, groove, through hole and blind hole.
3. Determination of the machining operations for the identified features and considers the constraints associated with the dimensions.
4. Determination of the machining sequence for fixturing the part.
5. Determination of the cutting tools considering the machine-tool, dimensions and tool geometry.
6. Determination of the cutting conditions considering the tool parameters, machining features material, machine capacity.
7. Generation of the process plan.

Figure 6 shows an example of process plan generated for the part modeled. The model is built using constructive solid geometrical method, with the components and features shown in Figures 1, 2 & 5. The design data of the entities and features is stored at the back end and is used to generate the process plan as shown in Figure 6. Figures 7-9 show in detail, the different pop-up windows that generate during the process. Figure 7 show the model built using the existing entities, while Figure 8 represents the parametrical data of the built component. The process plan generated using the generated design data and machining entities, is shown in Figure 9.

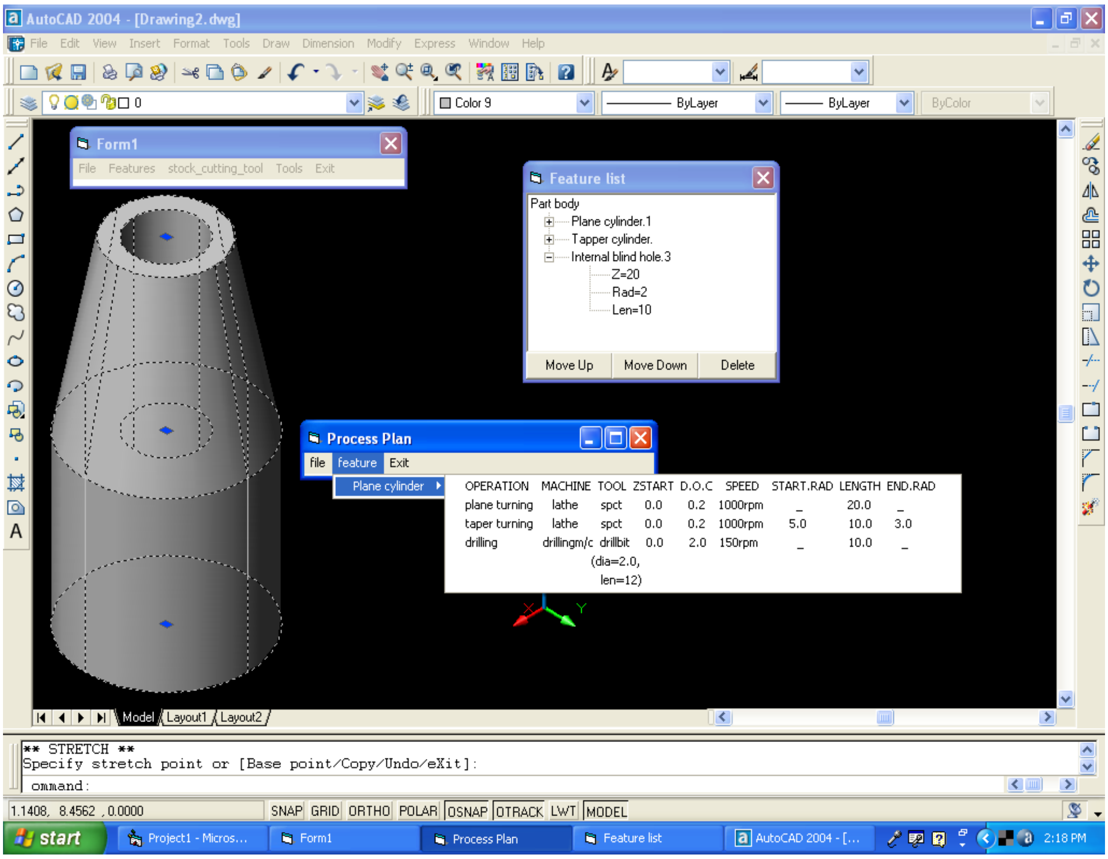


Figure 6: Proposed CAPP system for the illustrative turning component.

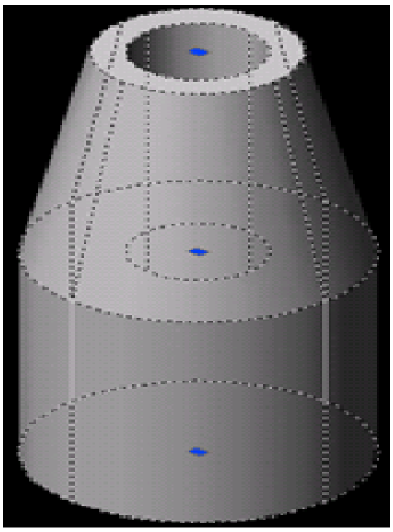

Fig. 7 Component generated in modeling stage

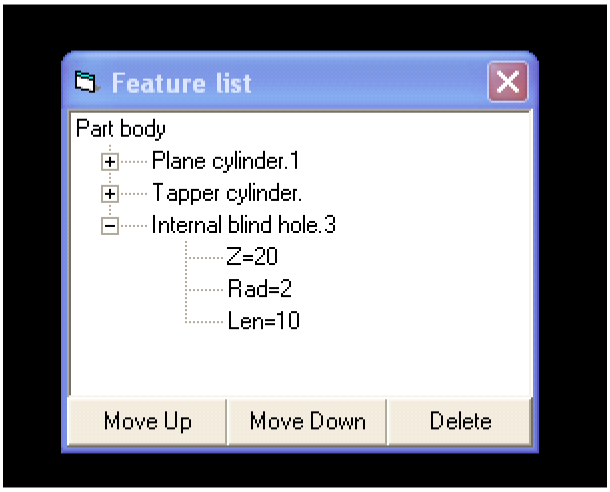


Fig. 8 Feature list obtained for the illustrative example

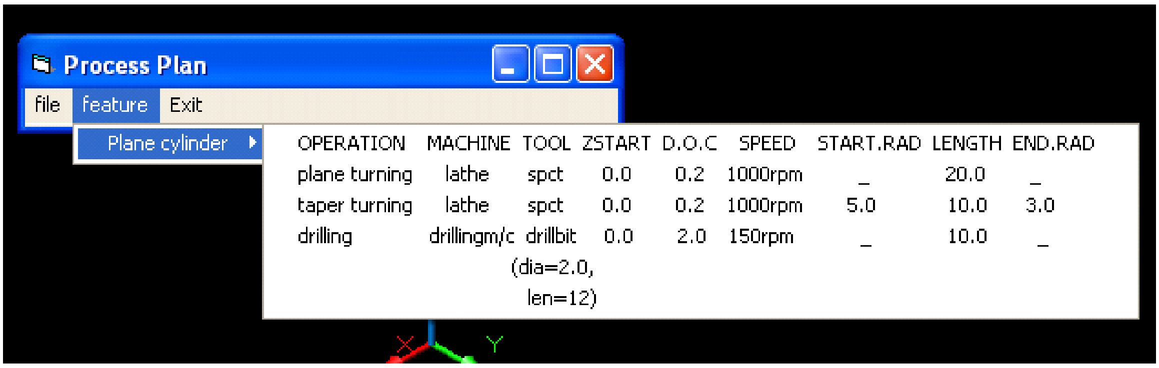


Fig. 9 Process plan obtained for the illustrative example

## 5. CONCLUSION

This work attempts to develop algorithms for modeling the components through the input of machining features. This feature based modeling approach eliminates extraction of features from the programs of the already drawn components. As a result, feature information is directly available to downstream activities, and feature extraction is no longer needed. Hence, it is economical in terms of time and cost compared to available feature based techniques. The feature based approach described is capable to perform process plan generation for the turning components based on the input features given in modeling. The system is user friendly, flexible and expandable. The system enables a reduction of over all lead time and improves the efficiency of the machined components. However, in the present study takes up only few machining features, and can be extended for more features to arrive at a complete process plan for any real time component.

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