Automatic Features Recognition for Symmetrical Shapes

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ABSTRACT

The future of computer-aided design (CAD) and computer-aided manufacturing (CAM) depends on the ability of their two processes to communicate with each other and with intermediate manufacturing database. Therefore, the development of a successful approach to the integration of CAD and CAM will require solution to several fundamental problems in planning and geometric reasoning. The first problem is the interface between CAD and CAM, that automatic feature recognition is an indispensable technique to solve this problem. We address this problem by developing an algorithm, which is considered an effective approach to extraction and of hybrid manufacturing features of symmetrical parts. The developed algorithm is based on the syntactic pattern primitive concept supported by production rule technique. This approach is considered a powerful tool applied to feature recognition field for symmetrical parts.

Keywords: Feature Extraction; Automatic Feature Recognition; Process Planning; Syntactic pattern Primitive; CAD/CAM.

أتمتة تميز السمات للأشكال المتماثلة

الخلاصة

ان تحقيق التكامل بين أنظمة التصميم والتصنيع المعانان بالحاسوب واحدة من أهم تلك التقنيات التي عززت من عملية تطوير تلك الأنظمة وذلك عن طريق زيادة الإنتاجية، وما توفره تلك التقنية من مرونة عمل واتصال بين كافة المراحل الإنتاجية، والذي يعتبر كمرحلة من اجل تحقيق التصنيع المتكامل بالحاسوب. ان الهدف الرئيسي من البحث هو بناء وتطوير بيئة عمل متكاملة مؤتمتة لتخطيط العملية لربط فعاليتي التصميم والتصنيع المعانان بالحاسوب لتحقيق التكامل الفعلي بينهما،وذلك عن طريق تطوير نظام يمتلك القدرة على استقراء وتحليل الشكل الهندسي من اجل تميز السمات التصنيعية للمنتج الممثلة في قاعدة بيانات نظام التصميم المعان بالحاسوب وتمويل تلك البيانات التصميمية إلى أوامر تصنيعية مناسبة ممثلة بوثيقة تخطيط العملية من اجل التشغيل النهائي للمنتج.تم تطوير وبناء مدخل وطريقة ذات فاعلية لمواجهة مشكلة الاستدلال الهندسي وتميز السمات التصنيعية لتحقيق التكامل الأمثل بين فعاليتي التصميم المعان بالحاسوب وتخطيط العملية المعان بالحاسوب بالاعتماد على مبدأ نماذج القواعد المنطقية المسندة بأسلوب قواعد الإنتاج لتميز السمات التصنيعية للأشكال الهندسية ذات المقاطع المتماثلة حول المحور المركزي، تعتبر طريقة التميز بواسطة النماذج القواعد المنطقية إحدى الطرق الرئيسية المعتمدة في تميز الأشكال ذات المقاطع المتماثلة لما تمتلكه هذه الطريقة من فاعلية ومرونة عالية في تميز الأشكال الهندسية.

INTRODUCTION

It is known that the language of CAD is geometry-based, with final product generated by the designer being stored in the database of computer. This method makes it possible to combine and display geometric entities such as Vertex, Line, Arc, and Circle, and so on to present a finished part, down stream in CAM. However, features that are the common language words, such as, cylinder, taper, chamfer, groove, ring, hole, flat surface, etc have manufacturing meaning. Attributes of these features are used in process planning to interpret the geometrical drawing of part created by the design engineer, and then this interpretation is used in making manufacturing decision. A machining feature can be used to link CAD and CAPP of machining parts. Since the CAD database is typically in a low level format, e.g. boundary representation, the CAD data need to be transformed into high level features suitable for CAPP application [1]. Syntactic pattern recognition is considered one of the important ways uses to recognize manufacturing features from symmetrical parts, which is represented as a picture, by some semantic primitives. They are written in a picture language. A set of grammars consisting of some re-writes rules define a particular pattern. A parser is then used to apply the grammar to the picture. If the syntax of the picture language agrees with the grammar, then the picture can be classified as belonging to the particular pattern class. This is very similar to nature and formal language processing in which a sentence can be analyzed to see whether it is grammatically correct. Similarly, a statement written in a computer language is parsed to see whether it possesses correct syntax. In any of the compilers, a parser is always used first to check the syntax of the user written program [2].

MANUFACTURING FEATURES

Feature technology can, in general, be classified into feature extraction, feature-based design, and feature conversion. Feature extraction (or feature recognition) is mainly concerned with identifying certain features from the various types of product representations such as boundary representations or solid models. Feature-based design, by contrast, aims at building a product model with a predefined set of design features. Feature conversion is the methodology that converts features defined in one domain to those of other domains (e.g., the conversion from design features to manufacturing features) [3]. The advantage of using features in engineering comes from the abstraction of information that the features provide. The features retain not only the geometric information but also much of the useful non-geometric information that is of interest in engineering applications. Since there are many different application areas, the definitions of features vary widely.

Feature is defined: as special information about the semantics of part of the geometry and topology [4]. For process planning a feature is defined as a geometric form and a set of specification for which a process planning exists and this process is almost independent of the feature of the parts [3]. As another viewpoint in process planning area, Kusiak [5] suggested that feature denotes shape and attributes associated with machining or assembly operation for many relationships of a feature class articulated in terms of the components of the candidate and their relationships.

AUTOMATIC FEATURES RECOGNITION (AFR) TECHNIQUES

Automatic feature recognition techniques provides the capabilities for translating the part definition data between CAD & the feature needed to drive, for example, a process planning system. Applied to process planning a part, feature recognition system would distinguish features of a part based on the geometric and topological information stored in the CAD database. Once a feature and associated manufacturing information are identified, the information then can be passed to process planning to generate process plans [6]. The AFR technique is to take a general CAD model, which is available commercially to provide an automated interface to recognize and extract the manufacturing features from the model. Feature extractor will derive all the features of a part based on the geometric and topological information stored in CAD database. Feature recognition from solid model has been considered as one of the solutions for bridging CAD & CAM [7]. The AFR technique is developed by geometric operation on B-rep solid models. It automatically identifies and groups topological entities, such as faces of a B-rep model, into functionally significant features such as holes, slots, pockets, ribs, fillets, etc. It also extracts their size and positional parameters for use later on [8]. Process planning activities such as setup generation, process selection, tool selection, machining sequence, etc. are largely dependent on the types of features and their inter-relationships in the model. AFR outputs feature information that is useful to various processes planning activities [8, 9].

SYNTACTIC PATTERN PRIMITIVE (SPP) APPROACH

Syntactic pattern recognition approach is considered powerful tool for recognition of manufacturing features from symmetrical geometric parts including manufacturing features which have rotational and prismatic surfaces [10]. Let us use a simple design as an example, in two-dimensional drawing. A groove is represented by its projection as well as by eight pattern perimeters defined as shown in figure (1). They are A, B, C, D, E, F, G, and H and represent pattern primitives, each one of them has a unit length. We can substitute a line drawn with the pattern perimeters. The previous drawing can be represented to start by a string "AGACA" notice that we have arbitrarily selected to start the drawing from the left.

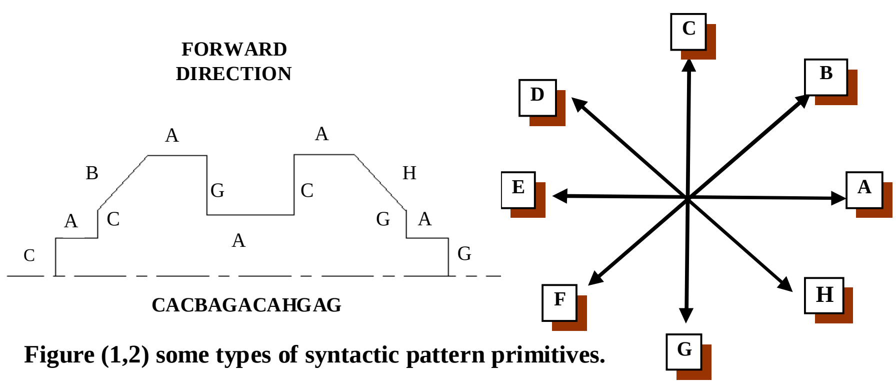


Figure (1,2) some types of syntactic pattern primitives.

There are three components in the syntactic pattern recognition method: -Input string, a pattern grammar, and a parser. The input string represents a semantically unknown pattern, the semantics of a pattern will be known if it can be classified as belonging to a known group of pattern. Both the left-hand side and the right hand side consist of symbols, connectivity's, and operators. Depending on the type of grammar used, different types of connectivity's are allowed. A pattern grammar can then be written for the simple grooves.

ROTATIONAL FEATURES TREE

The research is focused on making the proposed algorithm capable of recognition of the rotational features from symmetrical parts. There are different types of rotational features depending on the type of geometric entity (axial, radial), location (external, internal), and number of surfaces (cylinder, U-groove), therefore the proposed algorithm must consider all these parameters after it begins to recognize the process. To demonstrate the capability of the proposed algorithm for extraction and recognition of manufacturing rotational features, Figure (3) shows the types of features which can be recognized by the proposed algorithm.

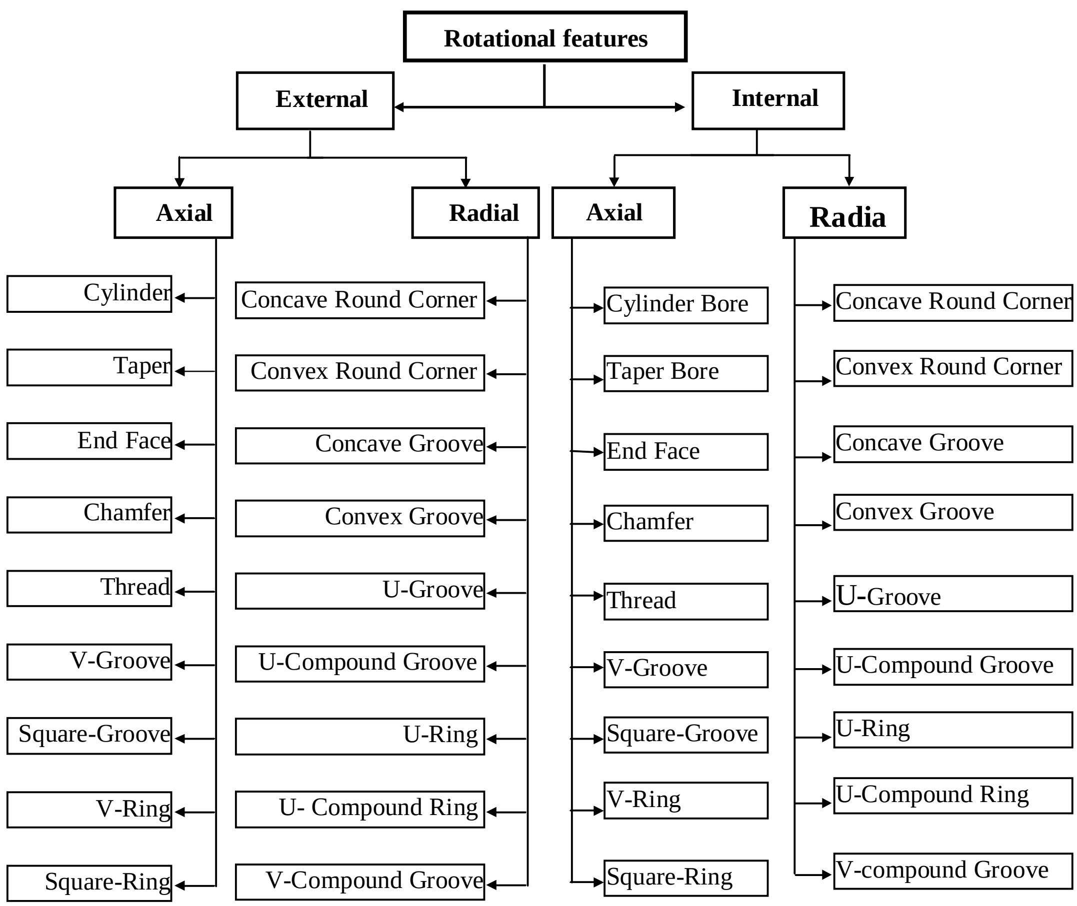


Figure (3) manufacturing features tree.

THE PROPOSED ALGORITHM STRUCTURE

The first task toward automatic process planning is the development of features recognition system, which provides the capability for translating the part definition data between CAD and applied process planning. Features recognition system will distinguish features of part based on the geometrical and topological information stored in the CAD database. Although the part feature recognition technique is a goal pursued by many researchers, successes have been limited to simple part geometry. Therefore, in this work an algorithm has developed which considers more comprehensive and realistic procedure for providing the automatic conversion of CAD language to CAM language through recognition of manufacturing feature system.

The proposed algorithm is based on syntactic pattern primitive techniques supported by rules-condition facility, which is specific for processing the symmetrical parts only. This algorithm has the capability of recognizing the most rotational features and some prismatic features. All these features can be manufactured by turning, milling, and drilling operation. Generally, the algorithm is divided into two main stages (preprocessor and postprocessor stages) for recognition features to both rotational and prismatic parts. The framework of proposed algorithm structure represented in figure (4) includes two stages addressing the main required procedures. First stage (preprocessor) includes many tasks and starts from extraction of 3D data required stored in CAD database, processing, converting, and preparing these entities data for next stage. The second stage (postprocessor) includes also many tasks which begin from representing and defining of the geometric entities parts by pattern primitives, classifying predefined features and extraction and recognition of the manufacturing features and determining all parameters associated with all developed features. To remove ambiguity will be presented in detail in the next section.

The central task of the first step in algorithm module is to provide the 2D part profile data required. To do that, the algorithm begins to determine the entity's data required, which represent the upper-half section (2D profile) of part geometry through manipulating the retrieval of entity's data from database of CAD system, which represents the 3D geometric parts.

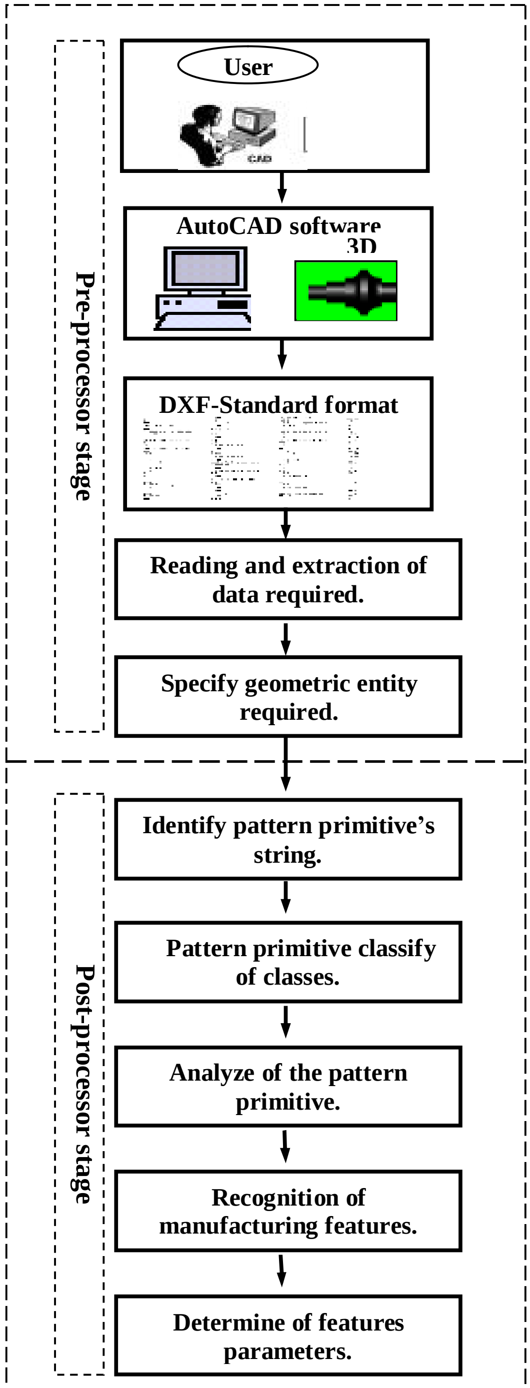
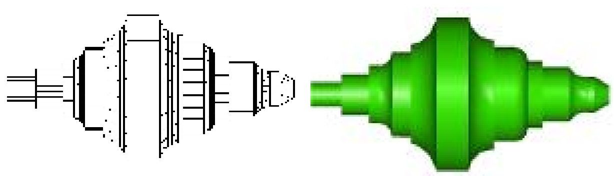


Figure (4) manufacturing features extraction and recognition algorithm.

Figure (5) shows how data structures of 3D geometric parts and the entities data type are represented in database CAD system.

Therefore, when the entity data are received, the process of applying some appropriate logic concept to check and examine the type of data for extracting the entity data will take place, which represents the upper-half section (2D profile) of geometric shape. The entity data of upper-half section consist of lists of vertices. These data are very ambiguous and very difficult to understand by computer logic, when they are used for identification and recognition of manufacturing features. We need to consider lines and arcs entities rather than vertices, because they are considered more useful and feasible when used in features recognition field. The process to convert entities data from low level (Vertices) into high level (Lines and Arcs) directly is difficult. Therefore the algorithm procedure in this step starts to convert the entities data of upper-half sections (List of Vertices) into entities of more comprehensive and common use in recognition manufacturing features (Series of Edges). This is considered closer than line and arc entities. The edges are considered as extending between each pair of adjacent vertices. Where any edge represents straight surface or segment from curved surface, the curved surfaces when present in 3D-wireframe is converted into collection of vertices.



Vertices	X	Y	Z
Vertex 1	10	10	20
Vertex 2	10	20	20
Vertex 3	20	20	30
Vertex 4	20	30	30
Vertex 5	30	30	40
Vertex 6	30	40	40
Vertex 7	40	40	50
Vertex 8	40	50	50
.	.	.	.
.	.	.	.
Vertex N	N	N	N

Figure (5) structure of entities data.

The ambiguities still overlays the 2D profile data; therefore the developed algorithm converts these entities edges data into entities more important in recognition field and nearest to computer logic. In this research the developed algorithm solved this problem by applying mathematical concepts by determining the geometric relationship between adjacent edges. The edges of upper-half section represent either lines or arcs. Therefore we can determine a relationship between all pairs of adjacent edges. The algorithm starts executing the matching procedures on each edge selected and checks it with another edge depending on each result of acquisition parameter. Therefore the algorithm procedures become capable of classifying all these edges associated with geometric shape into lines and arcs. Figure (6) explains the above concept.

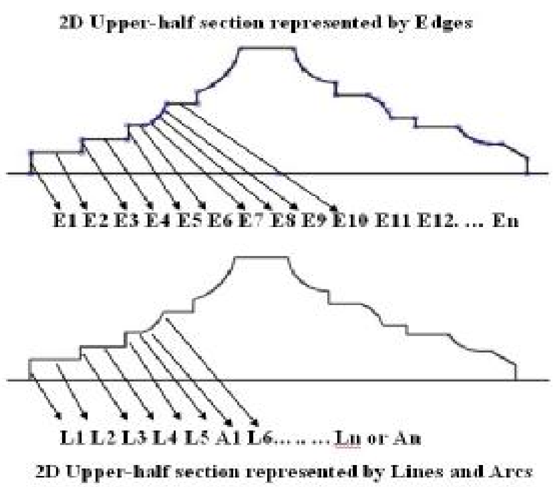


Figure (6) 2D Upper-half section.

This stage is considered very important, because it includes the function of extraction and recognition of manufacturing features. This task is performed by applying SPR technique, which includes transforming the entities of upper-half section into a series of string characters depending on the type of entities and manipulation of these through recognizer model for identification and recognition of manufacturing features. To help the computer to understand and interpret the manufacturing features in geometric shape, the research depends on the concept of syntactic pattern primitive techniques for recognition of the manufacturing features. In syntactic pattern recognition, a complex part profile is one that we wish to identified and represent in terms of simple basic pattern primitives. To formalize the pattern-recognition process, there is 24-pattern primitives, developed in this research and have been defined as shown in figure (7).

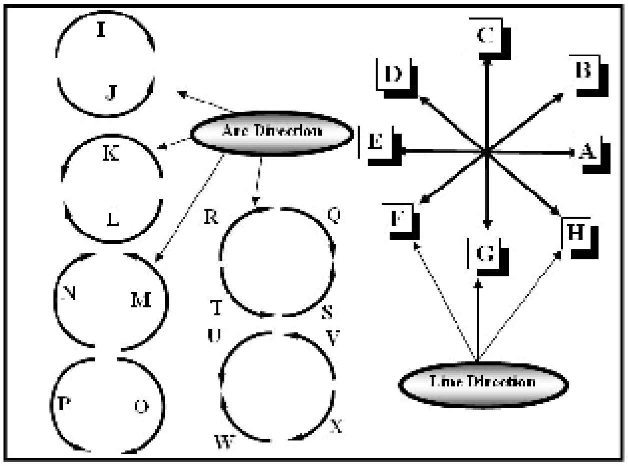


Figure (7) The Pattern Primitives.

The geometry of rotational part is defined by a series of lines and arcs segments. By using of basic pattern primitives the 2D profile data is then represented and expressed as a pattern string of "ASDFGHHJ…" associated with the part geometry data. The algorithm begins to analyze entities of geometric shape and attempts to diagnose the type of entities and proposes the pattern primitive suitable through geometry factors, Figure (8) shows the upper-half section represented by pattern primitive string.

The transformation process of geometric entities of series of lines and arcs into pattern primitive string statements is achieved through applying certain rules to perform the matching procedures between the geometric entities and the library of pattern primitives stored in database of computer. There are basically different shapes of line and Arc segment with a start point, terminal point, center point, direction, and location. An English character is assigned to each pattern primitive. With the reference of the Cartesian coordinate system rules associated with each one in order to identify them. With the aid of pattern primitives, symmetrical surfaces such as turning surfaces can be defined by pattern primitives depending on the type of entities (line or arc), direction of entity (forward or backward direction), and location of entity (external or internal). Since the pattern string is a series of characters, the computer can be applied to parse the string and identify the manufacturing features. The manufacturing features such as grooves and rings can be described by specific combination of the rotational surfaces (pattern string).

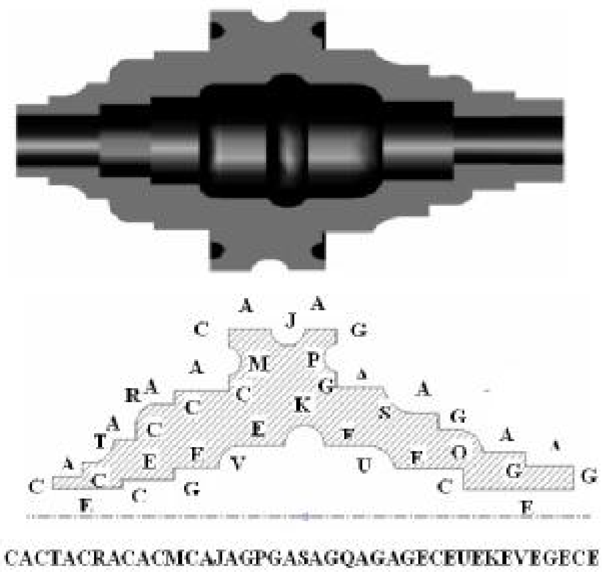


Figure (8) pattern primitive's string.

7. Classification and Identification of Feature Classes: -

The basic predefined turning features are the boundary surfaces of these features. Each predefined feature has a unique pattern string and may consist of one, two, three, four or five surfaces. There are four different groups of predefined turning features specified in this research. They are classified by the direction of their parent surfaces into groups.

The sophistication of the recognition system is dependent on the number of predefined features included. The power of the system is fully appreciated when it is used for large numbers of predefined features. Therefore the input string statement of pattern primitives, which represent the upper-half section, is classified into classes and sub classes like the classification used in predefined features. Figure (9) shows how the classes are classified.

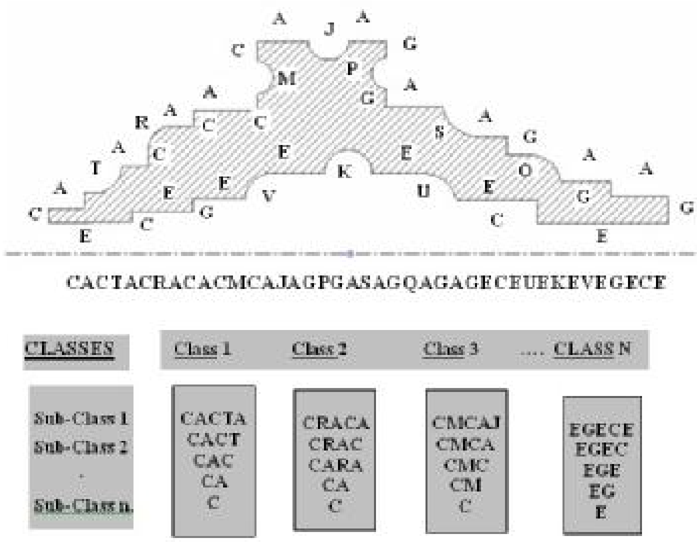


Figure (9) string statements classes.

With the syntactic approach, a complex part can be described by using a string of pattern primitives such as 'ABCDE…', Since each predefined feature has a unique string (pattern), the computer can easily perform features recognition based on string matching. Part geometry data and the pattern string defined for the 2D profile of upper-half section profile for rotational shapes are input to this module. Based on the input and predefined features, a part feature recognition algorithm developed is applied to identify the surfaces and features as well as the hierarchical relationship among them. The basic concept of the part features recognition algorithm is based on pattern string matching. The pattern matching consists of certain grammar developed by research for processing and analyzing of the pattern string based on the production rule and the type feature from feature library, which is present in the knowledge base. The pattern string matching (parsing) performs recognition features by inspecting and comparing sets of five characters of the pattern string each time with the predefined turning features. The pattern string matching starts with five most left characters of the pattern string and continues to the right. If no predefined feature is found then the first characters of the set is dropped and the next right most character of the unevaluated pattern string is picked to form a new set of characters. Some types of rotational feature and grammar are represented in figure (10).

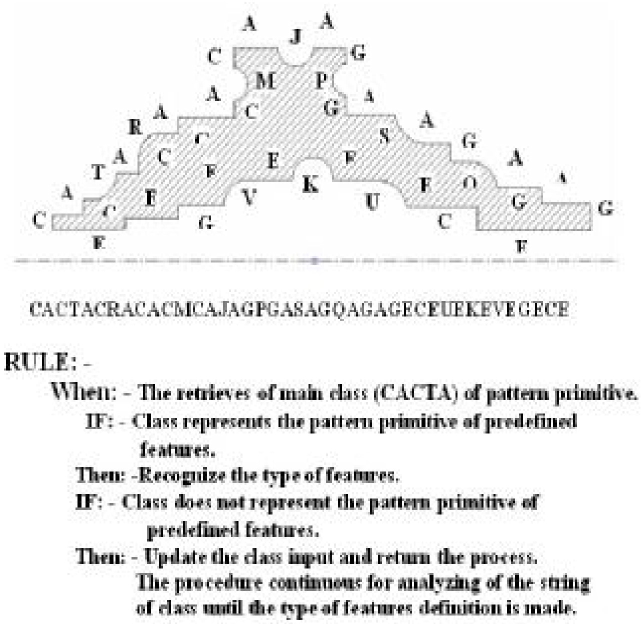


Figure (10) classes identification.

MANUFACTURING FEATURES RECOGNITION SYSTEM

The description of the part is the input to intelligent process planning system. Generally, the representation must be complete and unambiguous, in order to make the system efficient, the representation should also carry only the minimum amount of information necessary. The automated conversion process converts entity data from database of a CAD system into inputs for process planning system that is called CAD interface, geometric reasoning, and automatic features recognition. The part information necessary for process planning includes geometry, geometric relationships, dimension and tolerances, and additional manufacturing specifications. Depending on the sophistication of the planner, all or part of the information is included in the representation. The manufacturing features system consists of two modules as shown in Figure (11) as follows: -

1- Part features recognition module.

2- Feature knowledge representation module.

Extraction of surface features in a CAD database is an essential part of a fully automated process planning system.

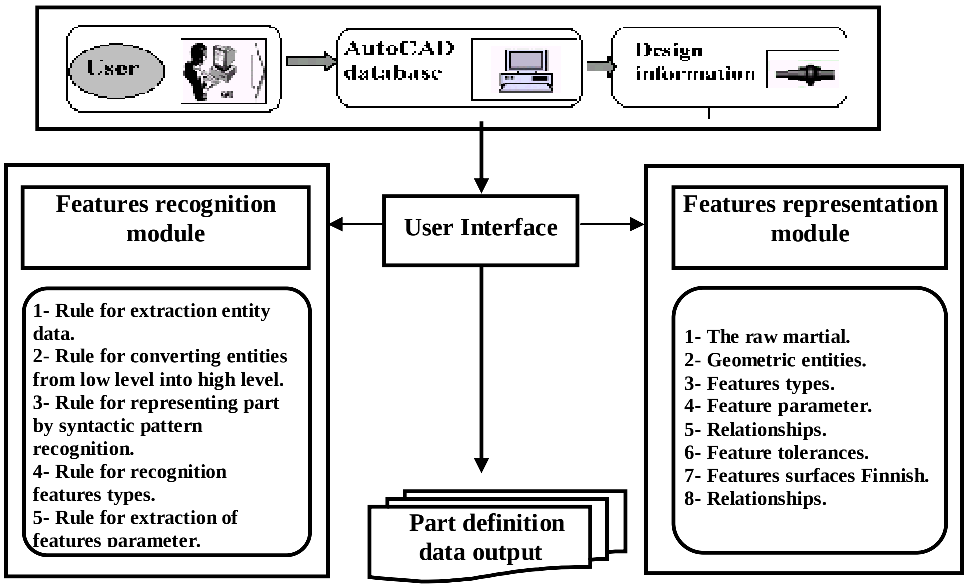


Figure (11) Manufacturing Feature Knowledge Base System

A features recognition mechanism is composed of five types of rules as follows: -

- *Rules to geometric entity extraction in a CAD database. This type of rule is tasked to read entities from a workpiece using a CAD data file.*
- *Rules for basic geometry determination. These types of rules are used for deciding the basic geometry of the workpiece.*
- *Rules for converting the entities of Upper-half section from low level into high level to be understood by computer logic.*
- *Rules for defining and representing the geometric entities by pattern primitives are based on the syntactic pattern approach.*
- *Rules for object reconstruction and surface identification.*

One of the most important pieces of information in a process planning system is the geometry of the planned work piece. The general shape, the length, the diameter, the number of surfaces to be machined, etc are categorized as geometric knowledge. A work piece is represented in the form of a frame in knowledge base. In fully automated IFBPP system these features are extracted from a CAD database system. A frame for describing a shaft is illustrated in Figure (12) as follows: -

A frame for defining a shaft: -
Part name: - Shaft
Material = Cast- Carbon – Steel
Length = 30
Major-diameter =15
No–of–features = 10
Type–features = Cylinder surfaces.
Location–features = External
Length features = 4
Diameter features =5

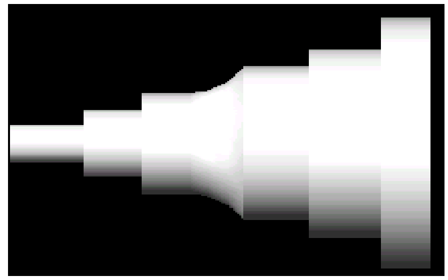


Figure (12) a frame for Defining Shafts.

SYSTEM IMPLEMENTATION

The system through interaction with the user performs extraction and recognition tasks of the manufacturing features from processing the geometric entities data and converts it from low level into high level. This system represents a link between CAD and system through automated information design by extraction and recognition of the manufacturing features. The output results from this system are considered the input to manufacturing domain. The extraction geometric entity stage works through many steps. First step requires the user to enter the file name the system directs manipulating the entered file and extracts the raw data of geometric entities required. The system in this stage tries to identify the output results represented in the previous stage. Part geometry data and the pattern string primitives to 2D-profile of upper-half section are input to the module. Based on this input and predefined features stored in feature library of computer database, the features recognition algorithm described previously is applied to identify the features by recognizing the type of features, compute the dimension parameters, and to build the hierarchical relationship among them as well.

SYSTEM TESTING

Examining and testing the capabilities of the proposed system are carried out through selecting mechanical part which is considered as an example for testing the system. The parts design models selected are taken from the real world problem chosen from the manufacturing environments, which are shown in figure (13).

Examining the capability of the system to extract and recognize of manufacturing features (design information) through output results of features recognition module.

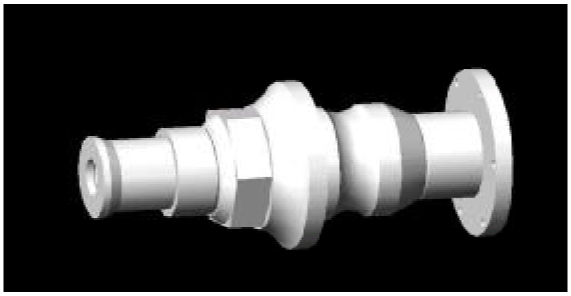


Figure (13) design model of case study.

The system is developed for providing the process planner with all information required about design and manufacturing stages. The system is developed to deal with symmetrical parts only, which are considered the parts machined in the company workshops. To test selected design module the system must be feed with required information for implementation of the system. After providing the needed information, which is considered essential data to feed the system mechanism, the system is invoked to provide the user with a solution to the process planning problem. The output results of the system in this stage include representation of all information required about design model after the system performs many manipulation processes on the raw data of the design model. The output results can be illustrated as shown in figure (14) through the system window include feature type, location, entity type, feature dimension such as (length, diameter, radius, slop, etc.), topological information (tolerance, surface finish).

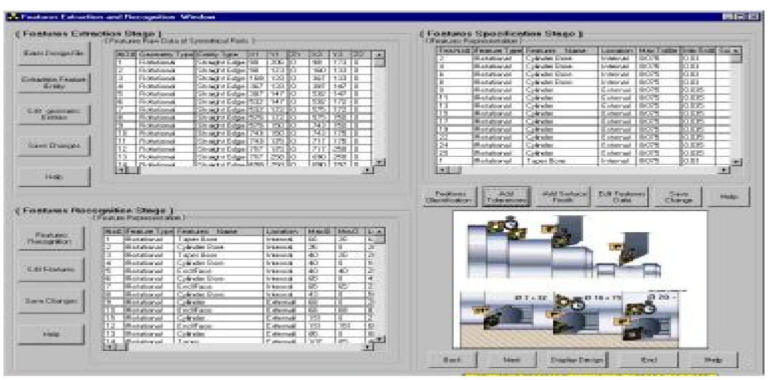


Figure (14) feature recognition system screen.

CONCLUSIONS

Feature recognition has been developed to serve as an interpreter that can translate a part from an existing commercial CAD system to CAPP. The feature recognition algorithm works on extracting part definition data from CAD system via DXF standard format and an output format is generated which can be accessed by many manufacturing functions. A part feature recognition algorithm is based on the syntactic pattern primitive's concept was developed to serve interpreting and translating a part from language definition to the CAPP language definition. The syntactic pattern primitive approach is considered an active tool for extraction and recognition of the symmetrical parts. The proposed algorithm is considered efficient in applications through covering most types of rotational and prismatic features, where procedures for feature recognition have been implemented to extract high-level manufacturing features of the part to be manufactured.

REFERENCES

[1]Tseng, Y. J. "A modular Modeling Approach by Integration Feature Recognition and Feature-Based design" Computer in industry, Vol. 30, PP. 113-125, 1999.

[2]Perng, D. Chen, Z. and Li, R. "Automatic 3-D machining Features Extraction from 3D CSG Solid Input" Computer-Aided Design, Vol. 22, No. 6, PP. 285-294, 1990.

[3]Helmy, H. A. "Feature Recognition and CAD Direction Inspection Using Solid Representation" Ph.D. Thesis, Lehigh University, 1991.

[4]Baker, R. P. and Maropoulos, P. G. "An Architecture For the Vertical Integration of Tooling Consideration From Design to Process Planning" Robotic & Computer- Integrated Manufacturing, Vol. 16, PP. 121-131, 2000.

[5]Grady, P. "Issues in Feature Based Design For Assembly" University of Lowa, 1999.

[6]Roller, D. and Brunt, P. "CAD Systems Development" Springier-Verlag Berlin Heidelberg, 1997.

[7]Modual, S. S. and Lin, L. "Rule-Based Automatic part Feature Extraction and Recognition From CAD Data" Computer and Industrial Engineering, Vol. 22, No.1, PP. 49-62, 1992.

[8]David, W. R. "Efficient Converter for Features Based Mechanical Component Representation" Advance of Design Automation Vol. 2, ASME 1993.

[9]Corney, J. and Clark, D. E. "Efficient Face-Based Feature Recognition", Heriot-Watl University, Canada, 1993.

[10]Kulkarni, V. S. and Pande, S. S. "A system for Automatic Extraction of 3D part features Using Syntactic Pattern Recognition Technique" Int. J. Prod. Res. Vol. 33, No. 6, PP. 1569-1586, 1995.