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Review of Automatic Feature Recognition of Cylindrical Parts

Abdullah D. Ibrahim[1], Sabreen A. Abdelwahab[2], H. M. A.Hussein[3], Ibrahim Ahmed[4]

[1]Sustainable Design Engineering Department, Faculty of Engineering, Universities of Canada, Egypt.
[2]Assistant Professor, Department of Production Technology, Helwan University, Cairo, Egypt
[3]Assistant Professor, Department of Mechanical Engineering, Helwan University, Cairo, Egypt
[4]Professor, Department of Automotive Technology, Helwan University, Cairo, Egypt

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Abstract - *Automatic feature recognition (AFR) of computer aided design (CAD) part for the process of computer aided process planning (CAPP) is an important element to be determined for automating the planning process. Extracting of feature from standard files like (IGES and STEP) helps in solving several problems in the field of industry. In this paper, automatic feature recognition techniques of individual features of symmetrical and non-symmetrical cylindrical parts were reviewed. a literature review of feature recognition of cylindrical parts over the past decade is proposed, to distinguish features that are appropriate for turning operations, symmetrical parts with axisymmetric features which contain an internal and external feature were recognized.*

Key Words: Feature extraction, feature recognition, cylindrical parts, CAD/CAPP/CAM integration.

1. INTRODUCTION

For manufacturing processes, a part process planning is necessary which includes detailed description of the part for process planning with selection of processes, processes sequencing, selecting the machine and tools of cutting, identifying the parameters of cutting, designing of jigs and fixtures and calculating time and cost of machining process. Computer aided process planning (CAPP) is important for integrating computer aided design (CAD) and computer aided manufacturing (CAM) and making a purpose complete relation linking CAD and CAM. description of the CAD part model in basic geometrical and topological form cannot be used for process planning directly because it requires information extracted from the CAD part model in the form of features, then this information is used in process planning [1]. So, the problem of planning process is how to recognize and manufacture these features.

STEP is a standard which gives the obvious and complete representation of the par data during the life cycle, independent of any system [2].

Research [3] shows that the turning feature is a term which specifies characteristics of certain non-unique form of the chosen part, realized because some manufacturing processes will be applied to the workpiece. In solid modeling, revolved faces represent the cylindrical part faces which machined by turning machine. Revolving of a planar curve about an axis creates an original face of revolved surface. Figure (1) shows examples of revolved surfaces.

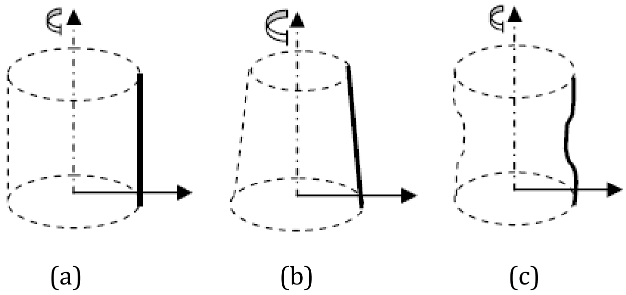

Figure (1) Revolved surfaces, (a) cylinder, (b) cone, (c) surface of revolution [3].

Features are classified according to their applications as shown in figure (2). For instance, in the feature-based design, holes, pockets, slots, steps, and so on, represent manufacturing features when compared with traditional CAD where design includes (2D) entities such as (lines, circles, arcs) and (3D) entities such as (wireframe, surfaces, solids). The information of feature has a great significance because it helps the planner of the process to select the machining tools and to determine the manufacturing processes required for machining the designed objects [4]. Generally, feature technology comprises feature recognition, feature-based design, and conversion of feature. Feature recognition (or feature extraction) is primarily concerned with categorizing specific features from the different kinds of product representations like boundary representation (B-Rep) and solid model [5].

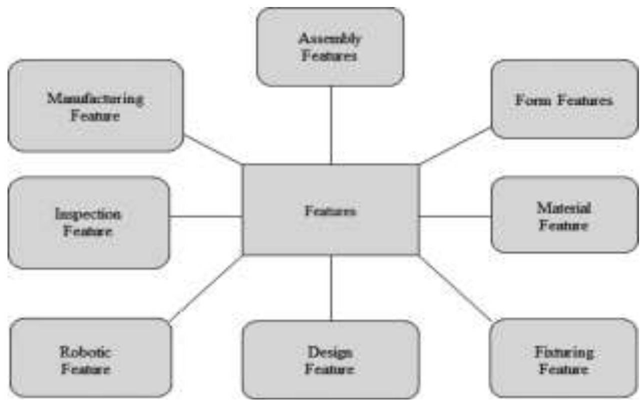

Figure (2) types of features [4]

Feature recognition is defined as the specification of feature entities and grouping them from a geometric part model. In fact, it extracts features and their parameters from the solid models [6].

There are many factors that make the process of feature recognition an important part of the CAD/CAM systems [7]. We can do the feature recognition process manually by selection of an appropriate features for the application of downstream by using an interacting system and it can be done automatically by development an algorithm for picking the appropriate features for the application of downstream from a feature's library which contains pre-defined basic features [8].

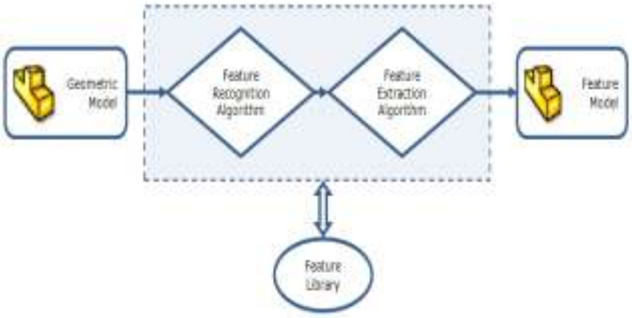

Figure (3) Automatic feature recognition [8].

Systems of automatic feature recognition (AFR) comprise a group of automatic steps despite the number of features included the model. And the steps are: extracting of features, generating of a process plan and path of tool. Figure (4) shows automatic feature recognition's flow diagram [8].

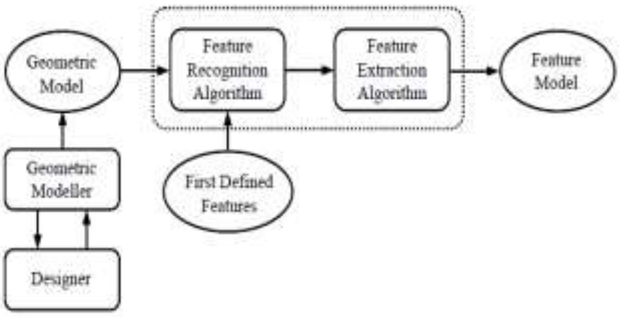

Figure (4) Flow diagram for automatic feature recognition [8].

Generally, the representation of the geometry model in the CAD systems is about low-level geometric entities like edges, surfaces and vertices. The process of feature extraction from low-level geometric entities, allows the information sharing between both design and planning of manufacturing process. Also, many factories could share information and data about regarding their products in a standard of exchange form [9, 10].

2. MANUFACTURING FEATURES

manufacturing features (Figure 5) are a group of related geometric elements which are corresponding to a particular manufacturing processes or method which can be used for reasoning the suitable manufacturing processes or method for production of the geometry. Examples of manufacturing features are holes, slots, pockets, fillets, chamfers, keyways etc. they are generally used in different kinds of manufacturing processes like machining, casting, forging, etc. [11].

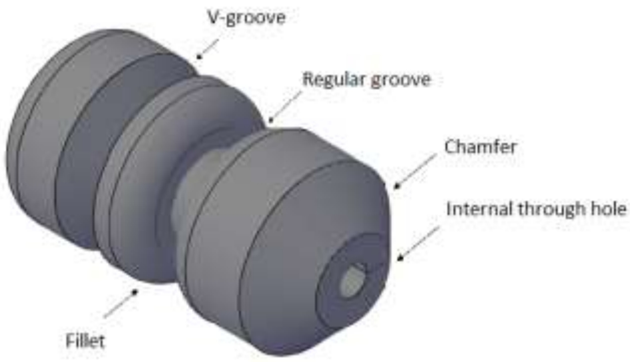

Figure (5) Example of manufacturing feature of cylindrical part, recreated from [11].

Manufacturing feature technology is the focus of ongoing research, especially with those who deal with the feature recognition algorithm. For example, the research [12] discussed many automatic feature recognition systems and presented the thorough a survey of the recognition of manufacturing feature using rule-based pattern regardless of how important the manufacturing features in the integration of CAD/CAPP systems. Research [13] shows that it is impossible to manufacture feature technology without organizing of the manufacturing feature databases. And it presented the object database logic level which is concerned with manufacturing features. This logic level comprised of some layers typically topics, attributes, structures, and methods. The layers are illustrated and described with some examples.

Research [14] explored that how to apply the feature-based representation and designing in design-for-manufacture by using manufacturing feature libraries (Figure 6,7) which underline the consideration of aims of design process and relevant limitations in the initial stage of design process. Factories can produce good products by the earlier considering of aims and limitations. Also, the product will get the chance to reach marketplace early because it is correctly designed without any interruptions, delays, problems, or order changes.

Research [15] mentioned that manufacturing features always related to processes of manufacture. So, to plan manufacturing features into manufacturing processes, many techniques can be used. rules or decision tables can be used for this process.

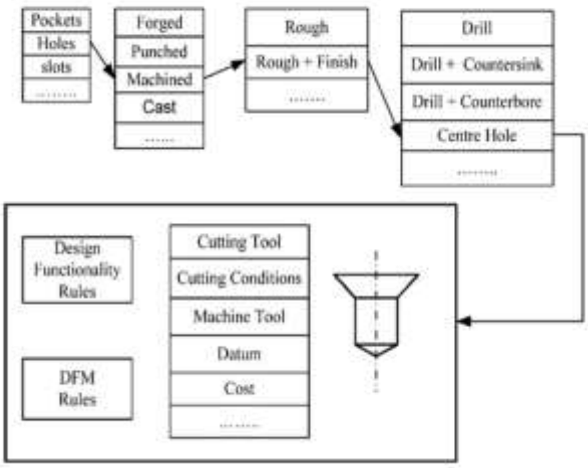

Figure (6) manufacturing feature library [14]

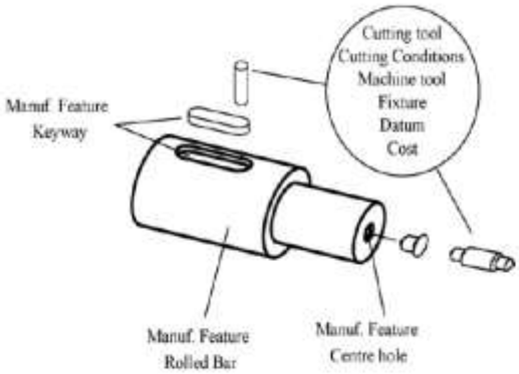

Figure (7) designing using manufacturing features [14]

An entirely opposite method to design using manufacturing features is to totally depend on recognition of feature where some information given by the stage of design is moved to manufacture process planning. The main disadvantage of this method is that the dimensions and tolerances are wholly lost while moving information from the design stage to the manufacture process planning. The advantage, however, is that the achieving of a complete parting of concern between design and manufacturing [11].

3. TECHNIQUES OF AUTOMATIC FEATURE RECOGNITION (AFR)

The automatic feature recognition (AFR) process is the primary element in computer aided process planning (CAPP) and is the main part in several CAPP systems. And many researches in the field of feature recognition are done in current years [16]. In the feature recognition stage, the information of the workpiece is automatically extracted from the part in a geometric solid model [17]. Algorithms of automatic feature recognition comprise two main parts: features definition and mechanism of features recognition. Researches [18,19] analyzed the developed AFR approaches which can be found in many researches.

Several methods are developed for mechanisms of automatic feature recognition that can be classified into the following techniques [12,20]:

A- Syntactic pattern recognition,
B- Graph-based methods,
C- Rule-based methods,
D- Volumetric methods,
E- Hint-based methods,
F- Hybrid method and
G- State transition diagrams and automata.

3.1. Syntactic pattern recognition

In this technique, the part model is created using semantic simpler sub patterns called primitives [12,20]. A group of grammar, which contains some of rules and pattern definition. In this method, the parser was used to apply a grammar to the discretion of the part for the analysis of the sentence as an input. If the sentence structure agreed with the grammar, the description is then classified into a consistent group of forms called (pattern). components of pattern recognition included in this method are shown in Figure (8) as following [12]:

 String of input which represents unknown grammar.
 recognized form of semantics after classifying it into a set of predefined patterns through form of lookup syntax.
 Definition of the pattern of syntax is done using the grammar.

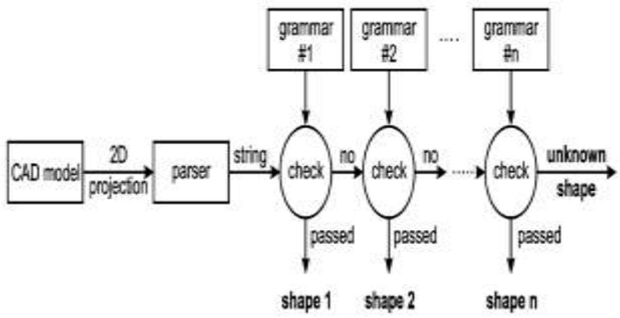

Figure (8) architecture of syntactic pattern recognition [12].

This method needs the definition of the form primitives and providing the design model which is automatically translated into a suitable description of the part for (string) [5]. It is the earliest approach of automatic feature recognition that identifies simple features. Research [20] shows the application of this method to recognize the 2D parts in the vision of computer. It is a good method that can represent complex patterns through simple sub patterns and relations between primitives. Complex patterns of features are represented by combining an arrangement of geometric primitives to form an expression.

Research [21] has developed a syntactic pattern recognition method to extract the details of manufacturing from the geometric part models. In this method, a part is represented in form of a syntactic pattern using the geometric primitives in 2D and 16 pattern primitives have been defined. Also, the elements of turning surfaces like diameter, radius, taper, face, arc, fillet, chamfer, and groove can be defined with the aim of pattern primitives.

The application of syntactic pattern method has done successfully to both prismatic parts and turning features of cylindrical parts. Though, its application to nonaxis-symmetric 3D parts or nonturning features of cylindrical parts with was limited. This might be incompletely because of the absence of an appropriate language for 3D parts. The uncertainty was another limitation of the syntactic patterns. The primitives included in the syntactic pattern method usually cannot represent some geometrical properties like the primitive's size, relative orientation and edge concavity, which are important for recognizing features.

To summarize this technique, it uses primitives for creating part models, the system input is prepared by the parser as a set of consistent forms called pattern. This system is consisting of input string, semantic form and sentence pattern definition. This method has been developed by many researches and it successfully applied on prismatic and cylindrical parts, but its application on 3D nonaxis-symmetrical and cylindrical parts with nonturn features still limited.

3.2. Graph-based methods

Graph-based method is now one of the most useful techniques of feature recognition that recognizes the features by linking the graph of feature to the suitable subgraph [22]. The main reason of the graph-based method is that it can use several advanced algorithms and concepts directly from applied mathematics, particularly in theory and topology of graph. In the graph-based methods, a group of features is modeled using the structure of graph, that presents topology and geometry required for specifying a certain feature. These graph structures can then be arranged in different computational forms [23]. The graph-based method was proposed by Joshi in 1987 [24] to develop the representation process of the part which include topological and geometric information of the part. In these methods, the part model boundary representation (B-Rep) is transformed into a graph which represents its topology. Representation of primitive features is done using graph templates. Representation of the graph contains nodes and links, respectively, identical to edges and faces of the part model. more data might be related to the graph for representing the geometric entities characteristics like concavity and face orientation. Research [12] shows that the B-rep part model is translated into the Attributed Adjacency Graph (AAG). The (AAG) is defined as a triple G = (N, A, T), where N is the group of nodes, A is the group of arcs (links), and T is a group of attributes of arcs in A, in which every arc takes number (zero), if its nodes make a concave adjacency relation, and it takes number (one) if they make a convex adjacency relation. Research [25] has mentioned the steps included in the graph-based feature recognition as following:

- Generation of the graph-based representation of the part
- Part features definition
- Part features matching in the graph representation

Figure (9) shows a simple example of (AAG) graph section. It is representing a slot with three faces of the part model (F1, F2, F3). The graph section of the slot shows that F1 is linked to F2 and F2 is linked to F3, and the graph arcs shows that there is a concave adjacency relation between F1 and F2, and between F2 and F3.

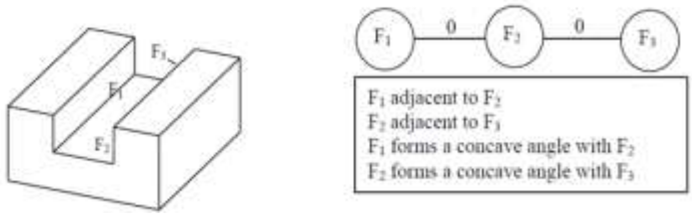

Figure (9) Using attributed adjacency graph (AAG) in feature recognition [24].

Research [26] has developed the (AAG). It suggested the Improved Attribute Adjacency Graph (IAAG) algorithm which can provide the topological information in addition to the geometric relationships of faces that contain the feature to overcome some inadequacies of (AAG) algorithm. It used values (+0, -0,0,1, +1, -1) with the values (0,1) of the AAG. The characteristic of the graph-based methods is the ability to recognize the isolated features although they have inadequacies in the recognition of interacting features and multiple explanations [24-27]. Research [28] approved that the graph-based method is an effective approach for recognizing simple and complex features.

To summarize this technique, it links the graph to suitable subgraph which can represents the needed geometry and topology for identifying the required features, in which the graph contains nodes and links, respectively, identical to edges and faces of the part model.

In this method, for part modelling, the boundary representation of the B-rep part model is translated into the Attributed Adjacency Graph (AAG), which includes a group of nodes (N), a group of links (A) and the form of arcs (T), this form takes the number (0) in case of concave relationship between the nodes and takes the number (1) in case of the convex relationship. The developed (AAG) helps in representation of interacting and complex features.

3.3. Rule-based methods

Rule-based method is a simplification of syntactic pattern method, it is verified to be stronger and it can handle types of part models more than the syntactic pattern method. Unclear predefined rules and representation needed for each imaginable feature, affect the rule-based approach and make it hard and complex [12]. This method used rules for representation of knowledge and used rules of deduction in feature recognition process for getting knowledge about the feature's geometrical and topological characteristics like the other expert systems [20].

This method used a group of heuristic rules for describing the functioning definition of a group of features. For instance, Figure (9) proposed a group of heuristic rules for describing a slot feature, they are bit different from which presented using a graph-based method. The slot is consisting of faces F1, F2 and F3, the face F1, is adjacent to F2. Also, F2 is adjacent to F3. The faces F1, and F3 are making parallel relation. F1 forms right angle (90°) with F2. Likewise, F3 forms right angle (90°) with F2. These rules are generally coded for describing features in languages which called building tools and they are used for developing the expert systems. Research [29] is considered rule-based method as an expert system method.

This rule always helps to identify features like a hole, pocket or slot. A form of generic rule like the following [20]:

(rule < rule# > (if (< condition -1 >)
(< condition -2 >) . . . (< condition -N >))
(then (< action -1>) (< action -2 >) . . . (< action -N >)))

Research [12] shows that this system provides an accurate description and specification of full form feature. The system's main disadvantage is the absence of the mechanism of knowledge achievement, that is a form feature extraction problem and cannot be corresponded with patterns in the base of knowledge.

Research [29] used logic programming rules for extracting subtractive swept features like cylindrical holes, slots and pockets. This technique converts 3D part model in (B-Reb) into (PROLOG) facts. Those facts were used by rules of production which code the conditions that are necessary and enough for a feature. An illustrated example of rule for describing a feature of cylindrical hole is shown in Figure (10).

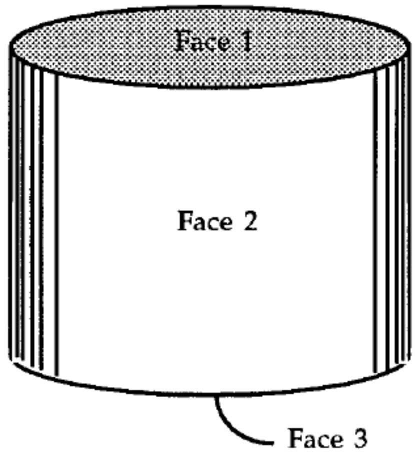

Figure (10) Example feature (cylindrical hole) and its associated rule [29].

to summarize this technique, it considered as a simplification method of syntactic pattern feature recognition and its valid for more kinds of features. It uses rules for representation of knowledge of geometrical and topological characteristics of features by using a group of heuristic rules after coding them in a language known as a developed expert system.

This technique provides an accurate and complete specification of the feature's form, but the disadvantage is the absence of swept subtraction mechanism of the information.

3.4. Volumetric methods

The volumetric methods are generally decomposing the removed volume (machined volume) into convex cells, these cells are combined to create machining features using a group of rules. These methods are suitable for dealing with interacting features and providing several feature's interpretations. Though, they have some disadvantages like computational complexity and, sometimes, cannot generate the features of nonconvex delta machining [30-34].

Volumetric decomposition method is primarily classified into: convex-hull decomposition subgroup [33,35] and cell-based decomposition subgroup [36].

Research [37] has mentioned some negatives of volumetric decomposition method as follows:

- It is not possible to use this method for generating machining features.
- It generates form features that should be transformed into machining features.
- It is an expensive method and does not guarantee the accuracy of generated machining features.

A cell-based decomposition method was proposed to create machining models. In which the decomposition of volume into cells is done by making all surfaces and half spaces extend and intersect. Then mixing a set of these cells for obtaining the machining feature form. Then repeating of cell composition process till all cells of delta volume expand. Finally, the cell composition lead to the total decomposition of delta volume into machining features group. Altering the sequence of the cell's composition generates new machining features [38].

The primary steps of the cell-based decomposition method include [9,12]:

- Determination of the overall removable volume,
- Cells decomposition of delta volume,
- Obtaining the machining feature form by composition of cell, and
- Machining features classification.

Researches [18,22] show that this method is computationally complex and the accuracy of generated group of machining features is not guaranteed. This approach cannot be used directly of machining features for generation the machining features. But the form features are generated, which are then transformed into the machining features.

To summarize this technique, in these methods, the volume of removal (machined volume) is first decomposing into convex cells, then these cells are combined to form the machining features based on rules group.

These methods are classified into: convex hull volume decomposition and cell-based decomposition. Many researchers agreed that these methods are good in dealing with intersecting features and can give good interpretations of features, but they are not reliable for generation of machining features directly because they are not accurate methods, so, they generate the form of features which need to convert to machining features, also they are considered complex and expensive methods.

3.5. Hint-based methods

Researches [39,40] presented hint-based reasoning method which can be used with intersecting features to overcome fail because the of faces/edges/vertices are altered when features intersect by using a system named object-oriented feature finder (OOFF). These researches have defined the ''rule of presence'' which specified that some features produced by machining process have a trace at the boundary of the part even in the case of features intersection.

Research [41] mentioned that hint-based feature recognition method steps as follows:

1- Hints of feature are created by identifying the faces properties on the part solid modeling.
2- Dividing of the hints of feature into (promising, unpromising and rejected) hints.
3- Handling of the promising hints to create the real features by using a "feature completer".
4- Performing of the verification step for ensuring the validity of the recognized features.
Hints might include geometry, features of design, tolerances, and more attributes related to the CAD part model.
This method is good for interacting features recognition, but still limited to 2.5-D swept features, and most of prismatic parts.

Other researches have done to improve the method to recognize class of features, to raise the algorithm's effectiveness, to use the hints as an additional information, and to be independent from the application of a modeler in the part design [42 - 44]. According to these researches, this method is suffering from many limitations: several duplicates which included in a big number of hints, hint generation process might miss some tiny features if an insufficient group of viewpoints were chosen and finding the process of bounding faces may give a not suitable result.
To summarize this technique, it is used to recognize the intersecting features by using object-oriented feature finder (OOFF) system. The steps of feature recognition using this method are as following: creating of feature hints, classification of feature hints, achieving of promising hints and verifying of the validity of feature recognition process. Although it is a good method for recognizing of intersecting features, it has some disadvantages like existence of several duplicates in a big number of hints and missing of some tiny features which produce inaccurate result.

3.6. Hybrid method

The hybrid technique is an effective method of feature recognition. This can be attributed to the fact that it can represent both the high-level features as well as low-level basic geometric entities. Also, it can support both the traditional tolerances and the geometric tolerances [45].
Research [22] proposed a hybrid method for recognizing of machining features automatically from the boundary representation (B-rep) part solid models. This method is a combination of aspects of hint-based and graph-based feature recognition methods with volume decomposition feature recognition method, therefore, it is useful for many kinds of feature interactions. The proposed system is an improved method of the part graph in which classifying all face nodes into stock faces and part faces. Then the input graph is frequently decomposed into a group of subgraphs, named minimal condition subgraphs (MCSGs). Then, all MCSGs are done for producing the feature.

Research [46] proposed the system of automatic feature recognition based on face-edge (EAAG) which used planar of molded parts and free-form surfaces for recognizing isolated and interacting undercut features. It used the characteristics of face and parting lines as signs to recognize the undercut features and it developed an algorithm of convex-hull for dealing with the characteristics of free-form surfaces face. This system contains a big group of heuristic rules for generating the hints and has been verified as a successful system.

Research [47] proposed hybrids include the method which used a combination method comprises the concepts of graph-based method and expert systems.

Research [48] presented a system for feature recognition which can recognize user defined features (UDF). It used a graph-based method for representing and recognizing the features. The (UDF) was represented by using an (AAG) that contains topological and geometrical attributes.

Research [49] presented a hybrid method which include (graph-based method + rule-based method) to recognize the interacting features from boundary representation (B-Rep) of prismatic parts CAD models. The author has developed the system for recognizing all simple orthogonal features of the prismatic parts.

To summarize this technique, they are efficient methods that deal with both low-level and high-level features, also can deal with traditional and geometrical tolerances. Many researches developed hybrid methods for representing and recognizing several kinds of features of cylindrical and prismatic parts, these hybrid systems proved their effectiveness in automatic feature recognition field. These researches have combined different methods such as rule-based, graph-based, and expert systems.

3.7. State transition diagrams and automata

These methods were developed in 1979 and they were the first application of for automatic feature recognition in (CIMS/PRO CAPP) system, [50,51]. This method is like context free grammar. In state transition diagrams and automata, a grammar is written by replacing the states with nonterminate and replacing the inputs with terminate symbols. ‘‘space sweeping’’ process is used for forming of the part model as a volumes combination which have gotten in this process. In cylindrical parts, sweeping operation is representing the rotation of the contour of the part around its axis, while, in prismatic parts, sweeping operation is a facial translation in a specific direction. The part representation (CIMS/PRO) for automatic feature recognition of prismatic parts is shown in Figure (11a). An example of the implementation of this method of families' classification in cylindrical parts is shown in Figure (11b) [52].

To summarize this technique, this is the first automatic feature recognition application.in this process, the state replaced with nonterminated symbols and the input replaced with terminate symbols to write the grammar.
In this method, part modelling depends on combining of volumes which called space sweeping process for both cylindrical and prismatic parts.

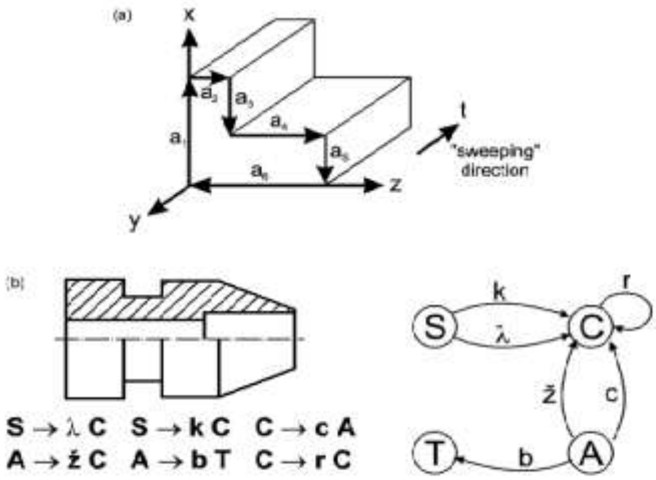

Figure (11) (a) part representation (CIMS/PRO) of prismatic part; (b) automata implementation in group technology for cylindrical parts [52].

4. LITERATURE REVIEW

This paper describes a comprehensive review on feature recognition of cylindrical parts. According to the literature survey, the major research work in automatic feature recognition of cylindrical parts is summarized in Table (1).

Table (1) Summary of major research work in feature recognition of cylindrical parts

Ref. No.	Authors	System Details	Remarks
1	J. Kumar and N. Roy, (2007)	Used biquadratic Bezier Batches.	Implemented coordinates in biquadratic Bezier patch equation for feature recognition of the rotational parts by matching from predefined features.
3	Li S. and Shah J.J. (2008)	Used a method for recognizing interacting and noninteracting rotational features.	Presented a method to support user-defined turning features that can be represented by using neural representation of features (N-REP).
5	Mithal Ahmed Al-Bassam, (2012)	Used algorithm based on the syntactic pattern primitive concept supported by production rule technique for the cylindrical parts.	Developed an effective method for extraction and of hybrid manufacturing features of symmetrical parts.
8	KADİR AKKUŞ (2011)	Used NC-Code generated from (STEP AP224) file and verified via C.N.C. simulator	Investigated the efficiency of NC-Code CAD data of the cylindrical parts and produced some test parts.
53	Oussama J., Abdelilah E., Ahmed R. (2014)	Used STEP AP203 Ed2 and built new manufacturing features by extending the surfaces of material of interacting features until the blank or material surfaces of the part.	Explained a new approach to link between CAD and CAPP and recognize both isolated and interacting features for cylindrical parts.
54	S. Sivakumar, V. Dhanalakshmi, (2012)	Used logic rules for identifying turning features.	Proposed simplified and generalized approach to extract manufacturing features from STEP files of cylindrical parts.
55	Deb S, Parra-castillo JR, (2011)	Used a novel back-propagation ANN method by restructuring it with prior domain knowledge.	developed an approach for an automatic feature recognition and extraction of data from the CAD file of the cylindrical parts modeled by the commercial CAD software, CATIA.
56	Ersan Aslan, Ulvi Seker, Nedim Alpdemir, (1999)	Used the defecto industry standard (DXF) files for determining the existing features on cylindrical parts for machining them on turning centers.	presented a module for feature extraction of the cylindrical parts, and this module forms part of expert system.
57	E. Aslan (2005)	Used the defecto industry standard (DXF) files for determining the existing features on cylindrical parts for machining them on horizontal machining centers.	Presented a method to extract and define the machining parameters, also, this method can help for unifying the process and preparing the frame of the machining process parameters of the cylindrical parts.
Ref. No.	Authors	System Details	Remarks
58	D. Sreeramulu, C.S.P.Rao, (2011)	Used a general Java code for the data extraction from STEP file and for the feature's recognition on the cylindrical parts.	Presented a practical method for integrating CAD and CAPP systems using STEP file for the automatic feature recognition process of the cylindrical parts.

59	Tahir fidan, (2004)	Used STEP AP224 features generated as the basic entities for cylindrical part design and used an object-oriented design method in developing the feature modeler.	Proposed a system consisted of three phases: (library of feature, modeler of feature and preprocessor) for automatic feature recognition of cylindrical parts.
60	Fidan T., Amaitik S. M , Kili�. S, (2003)	Used the concept of (STEP AP224) and features- based modeling for the cylindrical parts.	Investigated the extraction of features from STEP AP224 on cylindrical parts and Investigated the techniques of definitions, classifications, attributes, generation and attachments of these features.
61	M. Gizaw, Ahmad Majdi B A Rani and Y. Yusof, (2011)	Converted (EXPRESS defined classes of AP224) domain into (an object-oriented classes). Then they are serialized and de-serialized for implementing them.	Developed a system of turning and milling operations, mainly for data model development by using (STEP-NC) file structure, which attended by using a general architecture and functionality.
62	Y. Yusof, R. S. U. Rosso-Jr, K. Case and S. T. Newman (2006)	Used models of information that defined in the standard of (ISO14649) for creating the NC programs for turn/mill workstation.	Presented CAPP/CAM systems related to the file structure (STEP-NC) which is forming possible basis for satisfying the newest requirements and demands regarding the process chain of (bi-directional CAx) for machining.
63	Y. Yusof, S. T. Newman, K. Case and R. S. U. Rosso-Jr, (2005)	Used the STEP-NC standard structure to generate (ISO 14646 code) which deal with manufacturing of turn/mill component.	Proposed a STEP Compliant NC for developing a new structure which can help in manufacturing by using feature-based process planning from the CAD data directly.
64	Yusri Yusof and Keith Case,(2008)	Used the standard of (ISO14649) for creating the NC programs.	Proposed a system with (STEP compliant CAD/CAPP/CAM) for manufacturing of the cylindrical parts by using CNC turning centers.
65	N. L. Maziero, J. C. E. Ferreira and F. S. Pacheco, (2004)	Used the (connections class) for generating a list which describes the relations between the assembly parts, the kind of relation (axial or diametrical) and the assembly features included.	Presented an approach for identifying the assembled parts automatically in an environment of feature-based design of the cylindrical parts.
Ref. No.	**Authors**	**System Details**	**Remarks**
66	Carlos Rico, Carlos Suirez, Sabino Mateos, Eduardo Cuesta and Angel Duarte, (1997)	Described and reported general aspects for developing an automatic planning system, which able to generate the NC program by identifying the geometry of the part.	presented a method for recognizing the part geometry which combine the 2D profile's automatic identification and the feature-based method of the cylindrical parts.
67	Sankha Dep and Kalyan Ghosh, (2007)	Used CLIPS rule-based expert system shell and developed a set of knowledge-based rules to carry out to setup information.	Proposed an approach to solve the problems of setup planning in generative CAPP systems for the rotationally symmetrical parts.

68	Mark R. Henderson and David C. Anderson, (1984)	Used a feature graph as an input data which includes adequate information for planning of the machining process of the simple objects.	Presented a developed method for extracting the information of manufacturing process automatically in a part feature form.
69	Srinivasakumar S. Madurai and Li Lin, (1992)	Used a data- compactor of feature extraction (a system's preprocessor) for reading the part model data (geometrical and topological information) in the (IGES) format.	Proposed a feature extraction and recognition system which take the input as a CAD drawing file from the supplier and then it generates the standard feature file as an output which can interface with all (CAPP) software.
70	Stanislav Moskalenko, (2014)	Used STEP format for providing the geometrical and topological information of the parts to be machined.	Proposed a new system for automatic feature extraction and classification which can process mechanical cylindrical and prismatic parts according to (Opitz Code) System.
71	P.N.E.Naveen, M.Yasaswi, (2012)	Used an approach of feature-based modelling for eliminating the extraction of features from the drawn component's programs.	Presented a method to extract machining features from the solid modelling, by using a system of an integrated geometric modelling of the cylindrical parts.
72	Roberto Silvio Ubertino Rosso Junior, (2005)	Used an ISO 14649 (STEP-NC) to be integrated with ISO10303 (STEP). And used a case study of a cylindrical asymmetric component for demonstration of the applicability and manufacturing model of product.	Proposed a methodology for designing, specifying and modelling of a system of STEP compliant CAPP/CAM and used it as a strong industrial tool for the cylindrical parts.
73	Ahmad Faiz Zubair and Mohd Salman Abu Mansor, (2018)	Decomposed the volume of external features regarding the roughing and finishing operations. Then calculated the generated volumes of bodies and made a comparison between generated volumes and the (ODV_{manual}).	Presented an approach for the individual feature's recognition of symmetrical and non-symmetrical cylindrical parts. internal and external axisymmetric features have been recognized for distinguishing features which are appropriate for turning process or for milling process.
Ref. No.	**Authors**	**System Details**	**Remarks**
74	Oussama Jaider, Abdelilah Elmesbahi and Rechia Ahmed, (2015)	The system classified features into two categories, simple features and special features.	Proposed a new approach for recognizing the isolated and interacting features of cylindrical parts by analyzing both geometrical and topological data which are extracted from STEP AP203 data file.
75	Mohamed Abdelgawad Mostafa, (2004)	Used case-based reasoning methodology (CBR) as an intelligent solving problem technique to develop the process planning.	Presented a method for the automatic generation of CAPP and C.N.C. code of cylindrical parts using the similarity of geometrical and topological information.

76	Zaid Hikmat Yaqoub, (2010)	Used STEP file (ISO 10303, part 21) to extract coordinate from the profile of the part and used three methods (syntactic pattern recognition, sweeping process and rule of logic) of feature recognition to identify types of cylindrical, step and slot features.	Proposed a methodology to integrate CAD system into CAPP/CAI system by specifying types, coordinate and dimensions of machining/inspection features for planner cylindrical parts.
77	Yakup Yildiz, Ihsan Korkut and Ulvi Seker, (2006)	Used Delphi 7 programming language to establish the system. In this system, the data is prepared in any CAD program and saved as DXF format then send to the system as an input. The CNC part program is then automatically generated as machining features for producing the workpiece.	Developed an approach for recognizing the features automatically and generating the (AFR/ACCG) CNC code for cylindrical parts.
78	Rafik Elaakil, Rechia Ahmed, Abdelilah El Mesbahi and Oussama Jaider, (2017)	Described data integration module contains the GD&T extraction method from a step ap238 data file. this method locates the surface roughness, its value and the advanced face to which the surface roughness is applied using custom defined functions.	Developed a new approach to extract tolerances from a step ap238 files, and then associate them with their linked machining features, this new method for starting and implementation of object oriented which improves the reusability, flexibility and the relations between the machining features and their tolerance properties. the module represented an input data for ICAPP-TURN system.
79	N. Ismail, M.R. Osman,C.F. Tan, S.V. Wong and S. Sulaiman, (2004)	Used a neutral data format, namely STEP file of any (CAD) model. Cylindrical features can be modeled using the methods of constructive solid geometry or feature-based design.	Proposed a method for extraction of cylindrical features in which any CAD system can be used to model the part.
Ref. No.	**Authors**	**System Details**	**Remarks**
80	Vangipurapu Naga Malleswari, (2013)	Used CATIA software to create the 3D rotational parts and used a generalized JAVA code for extracting the data from CAD part model.	Proposed a methodology to recognize the features of rotational components automatically from STEP (AP203) neutral file by using a developed software consisting of five main segments.

5. CONCLUSIONS

In this paper, recent trends on automatic feature recognition of cylindrical parts are reviewed with a focus on techniques of automatic feature recognition which help in development of the automated CAPP systems and in saving the design time and effort in addition to reducing of the design cost. Automatic feature recognition techniques are still facing some problems such as algorithms complexity which are used in case of an intersection of features, multiple combinations of features interaction which lead to a combinatorial explosion in the stage of recognition of feature, techniques of automatic feature recognition are still limited to orthogonal features and cannot deal with nonorthogonal features and errors made because of combining techniques of automatic feature recognition. Novel researches in automatic feature recognition still trying to find an algorithm for providing a fully automated feature recognition operation.

I recommend that further research should investigate a methodology for recognizing some turning machining features such as threading and knurling by using special geometrical hints.

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BIOGRAPHIES

Abdullah D. Ibrahim is a Ph.D. Student, Production Technology Department. Faculty of Industrial Education, Helwan University. He obtained his B.Sc. (2002) and M.Sc. (2017) in Production Technology.

Sabreen A. Abdelwahab is as assistant Professor at Production Technology Department, Helwan University. She received her B.Sc. (2000) and M.Sc. (2008) major field Automatic control and PhD (2015) in Mechanical Engineering, Faculty of Engineering at Ain Shams University, Cairo-Egypt. Her research interest include mechanical engineering, mechatronics, robotics and automatic control.

H. M. A. Hussein is an Assistant Professor, Mechanical Engineering Department, Faculty of Engineering, Helwan University, Cairo, Egypt He obtained his PhD in Mechanical Engineering (2008). His research interests include Computer-Aided sheet metal die design, AI application to sheet metal forming, CAD/CAM, AutoCAD applications and customizations.

Ibrahim Ahmed, is a Professor of Vehicle Dynamic and Control at Helwan University in Egypt. He is currently the Head of Production Technology Department. He obtained his B.Sc. (1990) and M.Sc. (1995) of Automotive Engineering from Helwan University in Cairo, Egypt followed by another M.Sc. from Eindhoven University 1997. He obtained also the PhD (2002) from Newcastle Upon Tyne, UK. He has about 50 papers in the field of Vehicle Dynamics and Tribology. He has many contributions in the field of Noise, Vibration and Harshness (NVH).