Automatic Recognition of Machining Features using STEP Files

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Abstract

Creating link between CAD and CAPP is one of the most difficult tasks in concurrent design and manufacturing. Without proper interface between CAD and CAPP it is impossible to generate a process plan efficiently. Feature recognition is the key to achieve this objective.

In the present work software is developed in JAVA for feature recognition purpose. The input for the software is a STEP file. The software recognizes various strings in the STEP file, interprets them in terms of manufacturing and recognizes features for turned components. Rule based technique is used during recognizing process. The proposed feature recognizer is capable of recognizing cylinder and cross hole features.

Keywords- CAD, CAPP, Feature recognition, STEP

1. Introduction

Computer Aided Process Planning (CAPP) plays an important role in the development of Computer Integrated Manufacturing (CIM) systems and provides a vital link between computer Aided Design (CAD) and Computer Aided Manufacturing (CAM). Automatic extraction and recognition of part features directly from a CAD database also strengthen the link between CAD and CAPP. When manual process is used in translation of geometry language of the CAD to the higher level language of CAPP, it is often error prone, inconsistent and time consuming.

Direct information transfer using feature technology from CAD to CAPP will reduce many problems. But, most of existing CAD system does not provide part feature information. In other word, CAPP systems do not understand the three dimensional geometry of the designed parts from CAD systems in term of their engineering meaning related to manufacturing or/and assembly. To solve the CAD and CAPP interface problem, the feature recognition is one the most efficient approach.

Feature extraction can be platform independent and platform dependent. In the platform independent approach, the part's geometrical data are extracted from a neutral file such as DXF, IGES, and STEP etc. In contrast, the platform dependent approach extracts the information of the design features directly from a design by feature solid model through the object oriented model of the part.

There are different neutral files available. Some of the neutral files are IGES, STEP, DXF, STL files etc. STEP and IGES are most popular. STEP is intended for product data exchange, whereas IGES is for geometry data exchange. STEP is worldwide recognized neutral file format where it is available for almost all commercial CAD software.

ISO 10303 is an ISO standard for the computer interpretable representation and exchange of product manufacturing information. Its official title is: Automation systems and integration - Product data representation and exchange. It is known informally as "STEP", which stands for "Standard for the Exchange of Product model data". For mechanical parts, the description of product data has been standardized by ISO10303 and different protocols are available in STEP. Some of the Application Protocols are AP203, AP214, AP224 etc used for different applications. AP203 is Configuration controlled 3D designs of mechanical parts and assemblies. ISO-10303-21 is the beginning keyword of STEP file and END-ISO-10303-21 is the ending key word of the STEP file. It is based on the B-Rep.

2. Literature Review

Recognizing machining features from a CAD model is the first and foremost task in a CAPP system to plan further activities. There have been many previous attempts to recognize form features for manufacturing purposes, which can be broadly categorized into four areas: Syntactic pattern recognition, Rule based, Hint based, Graph based and Artificial neural network based systems. Syntactic pattern recognition uses a sequence of coded characters. The authors [1] extracted features from engineering drawings created in CADD format. The authors [2] developed a system for recognition of tapered and curved base features later used same technique for identifying the finish cut machinable volume from rough machined parts. Rule based technique used by authors [3-5]. The authors [3] used (Data Interchange Format) DXF file for the recognition of features. The author [4] used the STEP design file as a information source for recognition of features. This work is limited to only prismatic parts. The author [5] used STEP 214 file for extraction of basic features. The authors [6] used 3D model data in STEP AP-203 format as input and recognized various features. This work was mainly focused for sheet metal components. The authors [7] developed a system for 2.5 D parts and used hint based technique. The graph based technique was introduced by authors [8], presented attributed adjacency graph for recognizing polyhedral features for process planning. In graph based technique the features are recognized using arcs or nodes. Nodes represent attributes such as surface finish of a face, type of face such as planar, cylindrical etc. whereas arcs represents concavity and convexity of the corresponding edges. The main limitation of this approach is its inability to detect features with non planar surfaces. The use of the modified attributes adjacency scheme was another effort by authors [9] in identifying features. The authors [10] used both graph and hint based feature recognition. The authors [11] presented a model for 2.5 D parts for this purpose used artificial neural network. The authors [12] used ray firing technique, rays are passed from a virtual plane parallel to machining surface. Because of length change from plane to various parts of the CAD models, different patterns are produced. From these patterns, features are recognized.

Most of the feature recognition systems developed so far deal with a variety of straight features of slot class, hole class and their interactions with each other on the planes for prismatic parts. These systems are found lacking in the identification of complicated features, such as cross hole features and inclined holes in rotational parts. This research work concentrates on developing a feature recognizer for this purpose.

3. Methodology

In this research, the STEP file is suggested to be the standard for the design file due to the fact that it is an emerging international standard protocol for the exchange of technical product data and the standard protocol is one of the key tools in the field of electronic commerce. It is part of the thrust toward global manufacturing and worldwide competitiveness. Many major multinational companies are investing significant resources for its development and implementation. The first requirement for the present developed system is extracted geometrical data from STEP file.

3.1. Geometric data Extraction from STEP file

The STEP file is a text file that contains geometrical data of a component including boundary representation data such as shells, faces, edge loops, vertices; surface geometric data such as planes, cylinders, cones, toroidal, spherical; curve geometry such as lines, circles, B-splines, ellipses.

Searching STEP file starts with a string CLOSED_SHELL and ends with the coordinates of geometry. Extraction of various strings and entities (# number) from STEP file is done according to the hierarchy shown in (Figure 1). In this research JAVA language is used to search various strings and entities in the STEP file. JAVA is based on object oriented program, so representation and extraction of data is simple and easy. The command strLine.indexOf("CLOSED_SHELL") is one of the functions that can be used to locate a specified text string, e.g., CLOSED_SHELL of a file. Like that all the strings are located and placed in arrays. All these arrays are placed in tabular form and then these tables are displayed in windows.

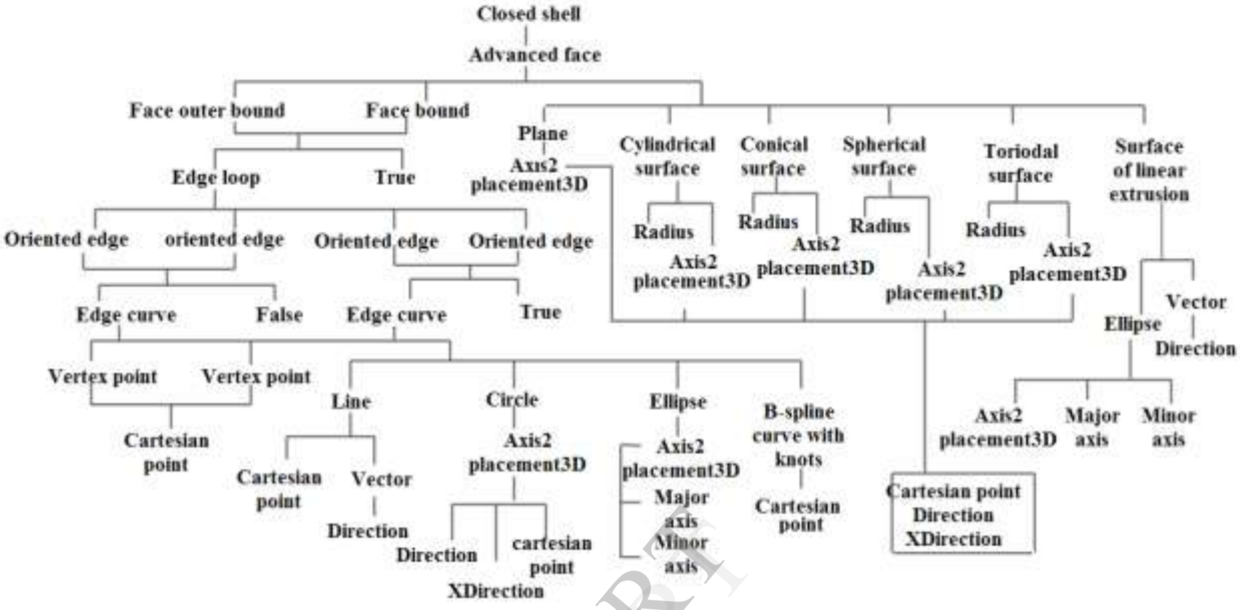


Figure 1. Hierarchy of geometrical strings

For the purpose of recognition of feature, evaluation of EDGE_CURVE construction, circle centers, radius of the circles, various surfaces, surface radius and axis coordinates of surface is required. For explanation of above aspects recognition of a cylindrical feature is described in detail in the following sections.

3.1.1. EDGE_CURVE construction

As shown in (Figure 2) CLOSED_SHELL (#35) consists of various ADVANCED_FACEs (#75). Each ADVANCED_FACE is bounded by number of edges which is termed as FACE_OUTER_BOUND (#74). Each FACE_OUTER_BOUND is formed with edges as a loop which is termed as EDGE_LOOP (#69). Further each EDGE_LOOP is formed by ORIENTED_EDGEs (#70, #71, #72, #73) termed as EDGE_CURVE (#49, #56, #63, #68). Each EDGE_CURVE last entity connects geometric shapes like CIRCLE (#44), LINE (#53), CIRCLE(#60), LINE(#67). So, for a cylinder EDGE_CURVE construction is circle, line, circle, line.

3.1.2. Finding the centers of circles of a cylinder

As shown in (Figure 2) and in continuation from EDGE_CURVE construction (eg. circle, line, circle, line) each circle (#44 and #60) consists of AXIS2_PLACEMENT_3D (#43). In turn, AXIS2_PLACEMENT_3D consists of a circle center as CARTESIAN_POINT (#41). The Last three numbers without hashes of CARTESIAN_POINT indicates coordinates of the circle center (x=0, y=0, z=0).

3.1.3. Finding the radius of circle of a cylinder

As shown in (Figure 2) and in continuation from EDGE_CURVE construction (eg. circle, line, circle, line,) the last number without hash (#) in the CIRCLE (#44) denotes the radius of the circle (50).

3.1.4. Finding the surface and radius

As shown in (Figure 2) CLOSED_SHELL (#35) consists of various ADVANCED_FACEs (#75). Each ADVANCED_FACE consists of surfaces like CYLINDRICAL_SURFACE (#40), CONICAL_SURFACE,TOROIDAL_SURFACE,SPHERICAL_SURFACE etc. The last number without hash (#) in the CYLINDRICAL_SURFACE denotes the radius of the cylinder (50).

3.1.5. Recognition of axis coordinates of a cylinder

As shown in (Figure 2) CYLINDRICAL_SURFACE string line contains axis information (#39). This entity (#39) is in turn connected to AXIS2_PLACEMENT_3D. In this line, entity #93 connects to CARTESIAN_POINT ('Axis2P3D Location' ….) string. Last three numbers (0, 30, 0) indicates axis coordinates of the cylinder.

3.1.6 Recognition of a cylindrical feature

After extracting data from STEP file, following rules are applied for recognition of cylindrical feature. The geometry is shown in Figure 3.

Rule 1: EDGE_CURVE construction must be circle, line, circle, line (or) line, circle, line, circle

Rule 2: Radius of circles in EDGE_CURVE is equal to cylinder radius.

Rule 3: X and Z coordinates of circle centers are same and Y coordinate is different.

Rule 4: Surface must be CYLINDRICAL_SURFACE.

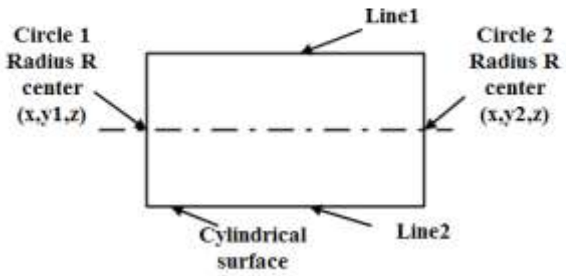


Figure 3 Cylindrical feature geometry

3.1.7 Recognition of a cylindrical cross hole feature

Existence of bspline string in EDGE_CURVE construction indicates cross hole feature presence. The procedure for finding the cylindrical cross hole feature, position with respect to axis, inclination of hole is shown in Figure 4.

```
#35=CLOSED_SHELL('Closed shell',(#75,#92,#132,#149,#177,………………..#586)); …
#75=ADVANCED_FACE('PartBody',(#74),#40,.T.);
#40=CYLINDRICAL_SURFACE('generated cylinder',#39,50.); #74=FACE_OUTER_BOUND('',#69,.T.) ;
#69=EDGE_LOOP('',(#70,#71,#72,#73)) ;
#70=ORIENTED_EDGE('',*,*,#49,.F.) ;
#71=ORIENTED_EDGE('',*,*,#56,.T.) ;
#72=ORIENTED_EDGE('',*,*,#63,.T.) ;
#73=ORIENTED_EDGE('',*,*,#68,.F.) ;
#49=EDGE_CURVE('',#46,#48,#44,.T.) ;
#56=EDGE_CURVE('',#46,#55,#53,.F.) ;
#63=EDGE_CURVE('',#55,#62,#60,.T.) ;
#68=EDGE_CURVE('',#48,#62,#67,.F.) ;
#44=CIRCLE('generated circl',#43,50.) ;
#53=LINE('Line',#50,#52) ;
#60=CIRCLE('generated circle',#59,50.) ;
#67=LINE('Line',#64,#66) ;
#43=AXIS2_PLACEMENT_3D('Circle Axis2P3D',#41,#42,$) ;
#59=AXIS2_PLACEMENT_3D('Circle Axis2P3D',#57,#58,$) ;
#41=CARTESIAN_POINT('Axis2P3D Location',(0.,0.,0.)) ;
#57=CARTESIAN_POINT('Axis2P3D Location',(0.,20.,0.)) ;
#39=AXIS2_PLACEMENT_3D('Cylinder Axis2P3D',#93,#94,#95) ;
#93=CARTESIAN_POINT('Axis2P3D Location',(0.,30.,0.)) ;
```

Figure 2 Partial STEP file for cylinder recognition

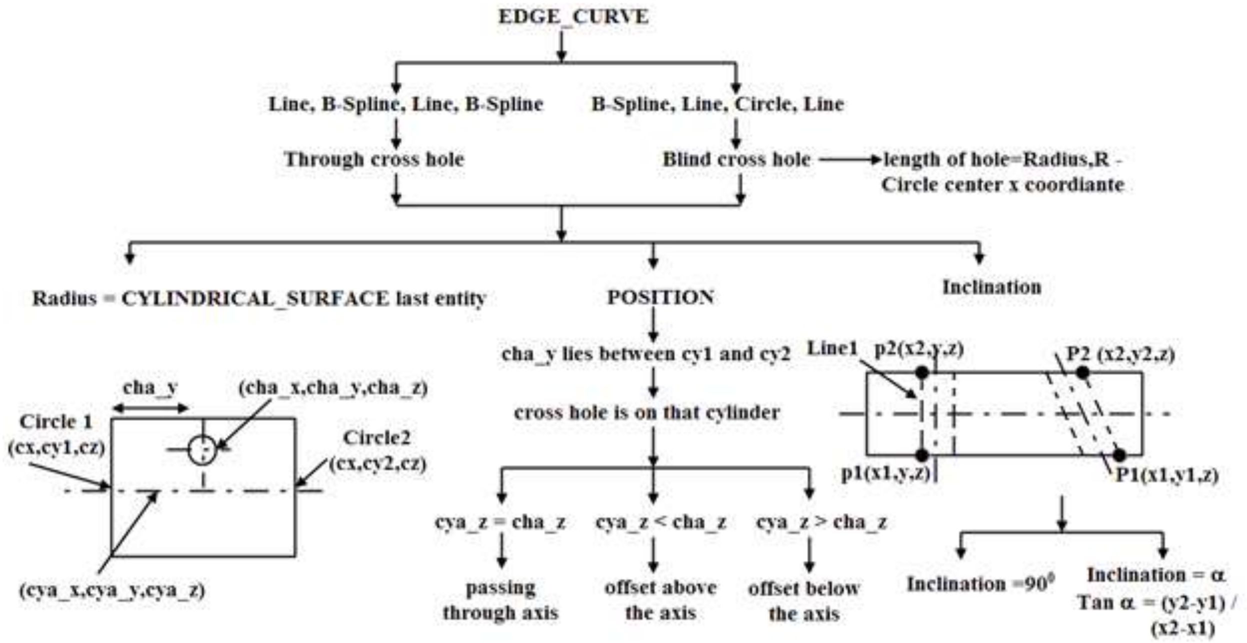
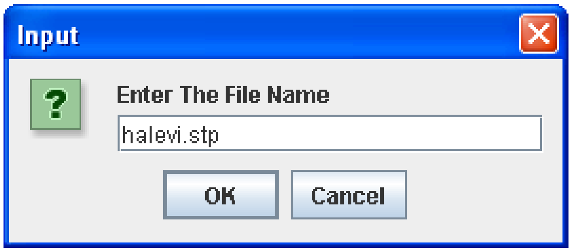


Figure 4. Feature recognition procedure

3.1.8 Development of a JAVA program

Developed JAVA program is user friendly and extracted geometrical data can be seen in tabular form. When a JAVA program is executed, a window is opened and asks filename as shown in (Figure 5).

After entering filename with .stp extension press OK button a window opens as shown in (Figure 6).In this window if 'window' button is pressed then FOB (face outer bound), FB (face bound), PLANE, CIRCLE, MAIN and FEATURE buttons appears. When these buttons are pressed various windows opens as shown in Figure 7. When FEATURE button pressed then it displays the various features and parameters of each feature. When other buttons are pressed various windows are opened which displays extracted data tabular form. Face bound table information will be displayed when there is an internal feature exists.


Input

Enter The File Name

halevi.stp

Figure 5. Window asking filename

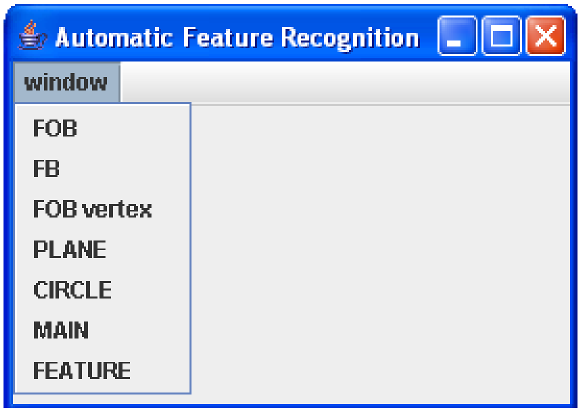
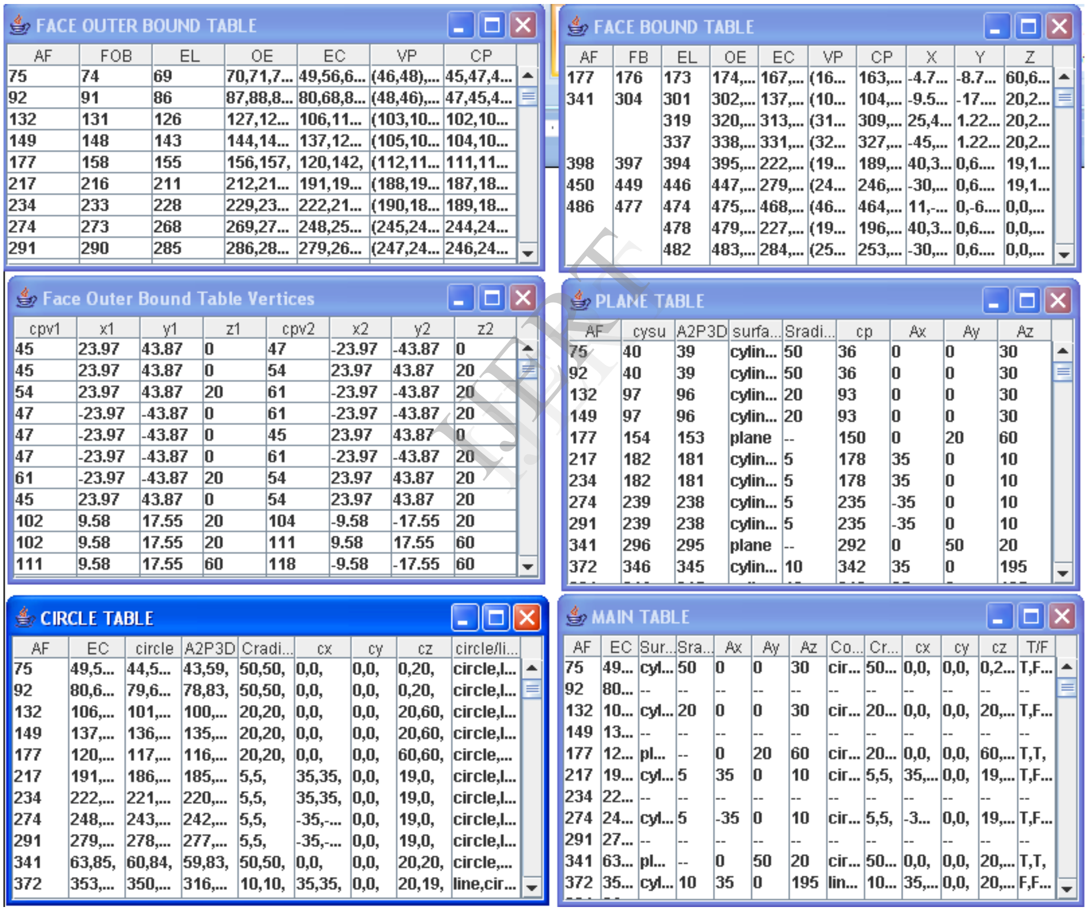


Figure 6. Starting window of JAVA program



FACE OUTER BOUND TABLE

AF	FOB	EL	OE	EC	VP	CP
75	74	69	70,71,7...	49,56,6...	(46,48),...	45,47,4...
92	91	86	87,88,8...	80,68,8...	(48,46),...	47,45,4...
132	131	126	127,12...	106,11...	(103,10...	102,10...
149	148	143	144,14...	137,12...	(105,10...	104,10...
177	158	155	156,157,	120,142,	(112,11...	111,11...
217	216	211	212,21...	191,19...	(188,19...	187,18...
234	233	228	229,23...	222,21...	(190,18...	189,18...
274	273	268	269,27...	248,25...	(245,24...	244,24...
291	290	285	286,28...	279,26...	(247,24...	246,24...

FACE BOUND TABLE

AF	FB	EL	OE	EC	VP	CP	X	Y	Z
177	176	173	174,...	167,...	(16...	163,...	-4.7...	-8.7...	60,6...
341	304	301	302,...	137,...	(10...	104,...	-9.5...	-17....	20,2...
		319	320,...	313,...	(31...	309,...	25,4...	1.22...	20,2...
		337	338,...	331,...	(32...	327,...	-45,...	1.22...	20,2...
398	397	394	395,...	222,...	(19...	189,...	40,3...	0,6....	19,1...
450	449	446	447,...	279,...	(24...	246,...	-30,...	0,6....	19,1...
486	477	474	475,...	468,...	(46...	464,...	11,-...	0,-6....	0,0,...
		478	479,...	227,...	(19...	196,...	40,3...	0,6....	0,0,...
		482	483,...	284,...	(25...	253,...	-30,...	0,6....	0,0,...

Face Outer Bound Table Vertices

cpv1	x1	y1	z1	cpv2	x2	y2	z2
45	23.97	43.87	0	47	-23.97	-43.87	0
45	23.97	43.87	0	54	23.97	43.87	20
54	23.97	43.87	20	61	-23.97	-43.87	20
47	-23.97	-43.87	0	61	-23.97	-43.87	20
47	-23.97	-43.87	0	45	23.97	43.87	0
47	-23.97	-43.87	0	61	-23.97	-43.87	20
61	-23.97	-43.87	20	54	23.97	43.87	20
45	23.97	43.87	0	54	23.97	43.87	20
102	9.58	17.55	20	104	-9.58	-17.55	20
102	9.58	17.55	20	111	9.58	17.55	60
111	9.58	17.55	60	118	-9.58	-17.55	60

PLANE TABLE

AF	cysu	A2P3D	surfa...	Sradi...	cp	Ax	Ay	Az
75	40	39	cylin...	50	36	0	0	30
92	40	39	cylin...	50	36	0	0	30
132	97	96	cylin...	20	93	0	0	30
149	97	96	cylin...	20	93	0	0	30
177	154	153	plane	--	150	0	20	60
217	182	181	cylin...	5	178	35	0	10
234	182	181	cylin...	5	178	35	0	10
274	239	238	cylin...	5	235	-35	0	10
291	239	238	cylin...	5	235	-35	0	10
341	296	295	plane	--	292	0	50	20
372	346	345	cylin...	10	342	35	0	195

CIRCLE TABLE

AF	EC	circle	A2P3D	Cradi...	cx	cy	cz	circle/li...
75	49,5...	44,5...	43,59,	50,50,	0,0,	0,0,	0,20,	circle,l...
92	80,6...	79,6...	78,83,	50,50,	0,0,	0,0,	0,20,	circle,l...
132	106,...	101,...	100,...	20,20,	0,0,	0,0,	20,60,	circle,l...
149	137,...	136,...	135,...	20,20,	0,0,	0,0,	20,60,	circle,l...
177	120,...	117,...	116,...	20,20,	0,0,	0,0,	60,60,	circle,...
217	191,...	186,...	185,...	5,5,	35,35,	0,0,	19,0,	circle,l...
234	222,...	221,...	220,...	5,5,	35,35,	0,0,	19,0,	circle,l...
274	248,...	243,...	242,...	5,5,	-35,-...	0,0,	19,0,	circle,l...
291	279,...	278,...	277,...	5,5,	-35,-...	0,0,	19,0,	circle,l...
341	63,85,	60,84,	59,83,	50,50,	0,0,	0,0,	20,20,	circle,...
372	353,...	350,...	316,...	10,10,	35,35,	0,0,	20,19,	line,cir...

MAIN TABLE

AF	EC	Sur...	Sra...	Ax	Ay	Az	Co...	Cr...	cx	cy	cz	T/F
75	49...	cyl...	50	0	0	30	cir...	50...	0,0,	0,0,	0,2...	T,F...
92	80...	--	--	--	--	--	--	--	--	--	--	--
132	10...	cyl...	20	0	0	30	cir...	20...	0,0,	0,0,	20,...	T,F...
149	13...	--	--	--	--	--	--	--	--	--	--	--
177	12...	pl...	--	0	20	60	cir...	20...	0,0,	0,0,	60,...	T,T,
217	19...	cyl...	5	35	0	10	cir...	5,5,	35,...	0,0,	19,...	T,F...
234	22...	--	--	--	--	--	--	--	--	--	--	--
274	24...	cyl...	5	-35	0	10	cir...	5,5,	-3...	0,0,	19,...	T,F...
291	27...	--	--	--	--	--	--	--	--	--	--	--
341	63...	pl...	--	0	50	20	cir...	50...	0,0,	0,0,	20,...	T,T,
372	35...	cyl...	10	35	0	195	lin...	10...	35,...	0,0,	20,...	F,F...

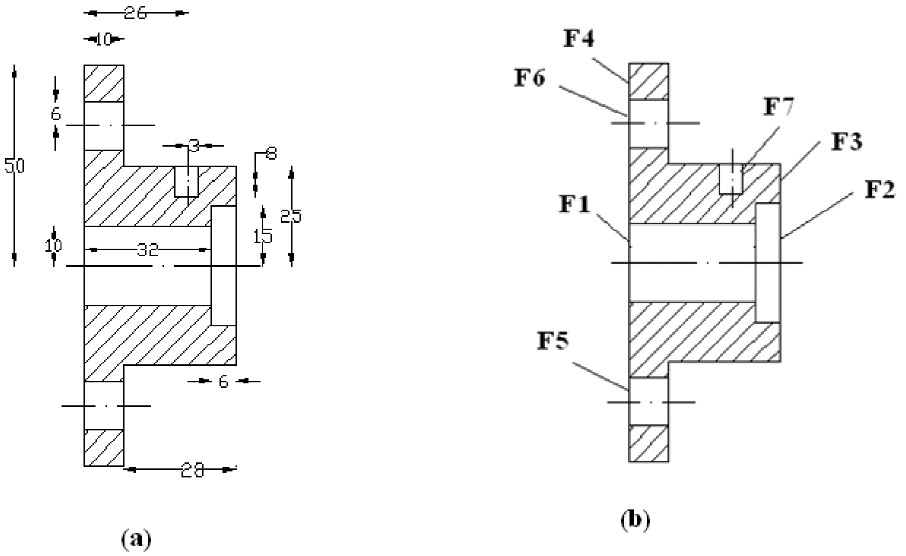
Figure 7. Geometric extracted from STEP file displayed in FOB, FB, PLANE, CIRCLE and MAIN tables

4. Case study to illustrate the developed feature recognition methodology

The part shown in Figure 8(a) is considered to explain the methodology. This consists of seven features. Two external cylinders, four internal cylinders (holes) and one cross hole. This cross hole is at a distance of 26mm from cylinder of radius 50 and length 10. Figure 8(b) shows feature numbers. All features are recognized and also their parameters like length, radius, position of hole with respect to axis and nature of hole (through/blind) is recognized. Final output is shown in Figure 9. The results of experimentation showed that the proposed method for feature recognition is capable of automatically identifying the feature type, comprising faces and feature dimensions.

5. Conclusions

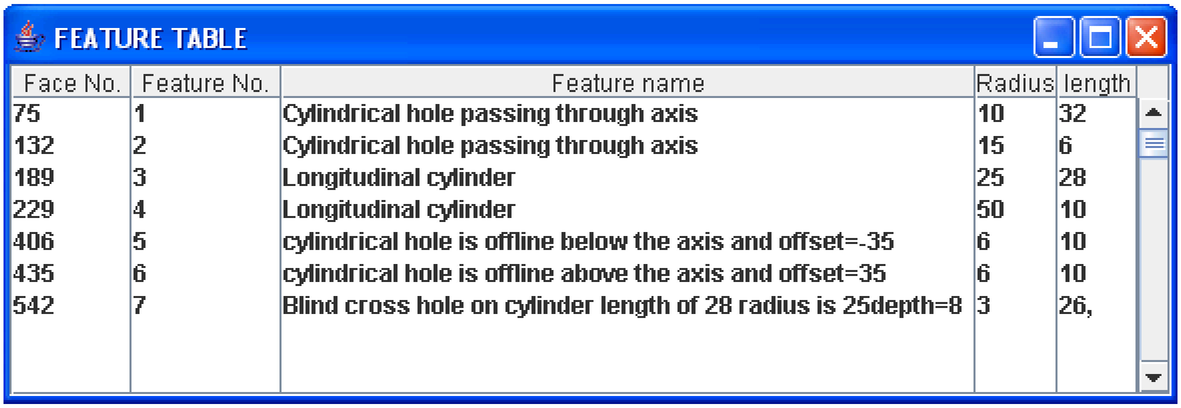
In the present work, a feature recognizer was developed to recognize cylinder and cylindrical cross hole features. The developed methodology is coded using the JAVA language. Various components are tested on a Pentium IV 2.4 GHz PC for its capability of handling combinations of more than one feature. The feature recognizer took a minimum amount of time to recognize the features and to generate the output. Some of the limitations and characteristics of the system and issues to be investigated in future research are as follows. The system is limited to rotational components. However, the principles and techniques can be extended to prismatic components with modification of the new coding scheme. The data extracted contain information such as feature type and dimensions of feature that is required for process planning functions for manufacturing a part.



(a)

(b)

Figure 8 (a) cast study (b) case study with feature numbers



FEATURE TABLE

Face No.	Feature No.	Feature name	Radius	length
75	1	Cylindrical hole passing through axis	10	32
132	2	Cylindrical hole passing through axis	15	6
189	3	Longitudinal cylinder	25	28
229	4	Longitudinal cylinder	50	10
406	5	cylindrical hole is offline below the axis and offset=-35	6	10
435	6	cylindrical hole is offline above the axis and offset=35	6	10
542	7	Blind cross hole on cylinder length of 28 radius is 25depth=8	3	26,

Figure 9 Output for case study

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