Algorithms for Recognition of Geometric and Parametric Features in prismatic parts using IGES

Sunil I. Sangolli , S.C. Pilli*

Research Scholar

* KLE Dr. M S Sheshgiri College of Engineering & Technology, Belagavi

*Email : sunsan12@rediffmail.com

Professor

Acharya Institute of Technology, Bengaluru

Email: scpilli@yahoo.co.in

Abstract

Automatic recognition of geometric and topological features from solid models has a great impact on the various levels of integration. The commercial CAD systems contain information of a component which is not suitable for the use in the next level of product life cycle such as process planning. Various solid modeling software's hold the design data in their individual files. The structures of the files differ from each other based on the modeling software. To have a common structure which can communicate with various CAD systems a recognition algorithm using any of the neutral file formats is necessary. This paper presents geometric algorithms to recognize features from various 3D CAD models of prismatic parts. The features are recognized by three approaches; Hhint based approach, Volumetric decomposition approach and Hybrid approach. A program in Java is developed to recognize geometric entities, with their directrix contained in a solid model.. The algorithm developed to extract the information from the IGES translator uses an inference engine which can handle complex feature libraries. The algorithm works efficiently for complex models built using volumetric decomposition as well as hybrid of hint based and volumetric decomposition approaches. The model is reconstructed for validation using the recognized entities.

Keywords: Feature, IGES, Object orientation, Algorithm, Java programming

Introduction

A solid model provides a framework for modeling and representation of a physical solid object and also to perform certain operations on the object. Solid modeling techniques are used to describe 2D and 3D products unambiguously through commercial CAD systems [1]. These parametric CAD systems today use features in some way to construct and represent the solid models. Feature is a portion of a solid model that finds interest in any phase of the product life cycle namely: conception, design, manufacture, service, and

repair. From a production engineer's point of view features can be seen as specific geometric shapes on a part that can be associated with certain manufacturing processes

[2,3]. The features which are highlighted during the modeling phase of the product's design process and the subsequent production planning phases would help the engineers to take the advantage of this information in accessing data regarding the production of these features. Grayer in the 1980's was the earliest researcher on recognition of solid models. The primary objective of the work was to partially automate the machining of 2.5 B pockets or cavities [4].

Kyprianou introduced the recognizing of topological and geometric patterns in CAD models and comparing them to features that need to be found [5].

Today design and machining features diverge in meaning even though they are representing the same object. The entire solid model is not made up of features and more over features are domain dependent. This fact has triggered the research on feature recognition. Feature recognition refers to the examination of solid models for the identification of features that have been predefined. The primary objective is not feature extraction parse but identification of specific feature. There have been numerous techniques proposed in the literature for the subsequent phase of feature extraction and the use in solid modeling. Research efforts have been made in the recent past to develop extraction methods that would examine parts, solid models for the existence of geometric features which have not been predefined and extract them. The features could then be classified and coded for future use in a group technology based CAD system. These features could continue to be a part of the overall solid model of the component, but can be extractable by user initiated search for the most similar feature.

Commercially available CAD systems support solid modeling techniques that combine the following approaches; i) constructive solid geometry, ii) feature based representation, and iii) sweep operations for constructing the solid model and extracting the features and using the features for developing a process plan, generating the CNC part program or for finite element analysis [6].

Feature recognition approaches

Features may be broadly classified into 3 types based on data used as i) 3D-BREP, ii) 2D-BREP, and iii) 3D-CSG base models. Mainly three approaches can be seen in literature for feature recognition.

1. Graph based method,
2. Hint based method,
3. Volumetric decomposition method.

Graph based approach uses B-REP model of a component to create an Attributed face Adjacency Graph (AAG). The faces are represented as nodes, the edges as arcs and concave convex attributes are assigned to the arc edges corresponding to the angle between adjacency faces.

Hint based approach methods uses face patterns as hints to the existence of features. Feature hint is a specific pattern present on the boundary of the part characterized by geometry and topological relationships. The hint based approach is totally dependent on the procedures of rule formalization and the knowledge database has to be consistently updated to include more features [3].

Volumetric decomposition method is used to recognize feature interactions and recovered lost regions. The method typically subtracts the part model from the stock model to get one or more separate volumes or lumps. The lumps represent the volumes to be removed by machining [4]. There are two variations of this method namely the convex hull method and the cell based decomposition method. Convex decomposition method computes the convex cell from a non convex part and then obtains convex deficiency by subtracting the part model from the convex hull. Cell based decomposition was initially explored in detail by Sakurai [7] early 1990's. There are three steps in cell based decomposition methods;

   i.   The part model is subtracted from the stock model to determine the delta volume. This volume is decomposed into cells.

  ii.   Cells are combined to form macro volumes

 iii.   The macro volumes are classified as machining volumes.

Chandru et. Al. presented a critical review of the major modeling paradigms CSG, B-Rep, non manifold and voxel models .They are of the opinion that Voxel models have attributes that would emerge as the choice of the representation scheme in geometric modeling [8].

Handerson developed an expert system in Prolog to perform feature recognition. In this system rules are used to define feature instances. An important aspect of Handersons work is to create general rules The system contains definitions for classes of 2.5 dimensional features such as holes, slots and pockets [6].

Jaha and Gurumoorthy have developed an algorithm to propagate modifications automatically across different domains such as modeling, machining and analysis. This algorithm takes multiple feature interpretations of the part as input [9].

Nagraj and Gurumoorthy developed an algorithm to create machinable volumes that need to be removed from the stock given a boundary model of the part. This algorithm directly identifies the primitive volumes that when combined from the cavity volumes corresponding to the machining features [10].

Nasir and Kamrani have proposed a methodology for 3 D prismatic parts that are created by CSG technique for recognizing machining features. The system takes a neutral file in IGS format, has input and translates this information into manufacturing information [11].

Surmaz has proposed an approach to recognize volumetric features based on hints on a 3D B-Rep model. In this approach the model is built mainly by using sweep modeling technique.

The present work deals with building 3D prismatic models using both the B-REP and CSG approaches and recognizing features using hint based combined with volumetric decomposition approach and cell based decomposition approach. The input to the system is a neutral file in IGES which is translated as geometric information by using 2D hints. The algorithm recognizes both geometric and topological features from the models [12].

Working Methodology

In this work the feature extraction and recognition of prismatic parts for CAD/CAM applications based on hint and volumetric decomposition using JAVA is developed and presented. The objective of this approach is to achieve the integration between CAD and CAM. The present research deals with developing a Feature Recognition methodology which has the ability to communicate with the different CAD systems.

The part design is introduced through a CAD software and it is represented as a solid model using CSG technique as a design tool. The solid model of the part consists of small and different solid primitives combined together to form the required part design. The CAD software generates and provides the geometric information of the part design in the form of an ASCII file [IGES] that is used as a standard format which provides the mechanism for the proposed methodology to communicate with the different CAD systems.

Feature Recognition using IGES Translator

Figure 1 shows the CAD model of a block with a raised face and 8 through holes and a sleeve with a web is modeled in CATIA using the B-rep approach. The data is stored in the IGES format. The feature recognition is carried out using the hint based approach.

Fig. 1: Block

The IGES file is used as input by the program as shown in the flow chart in Fig.2. The program uses 2D hints to identify simple entities like lines, curves and their coordinates.
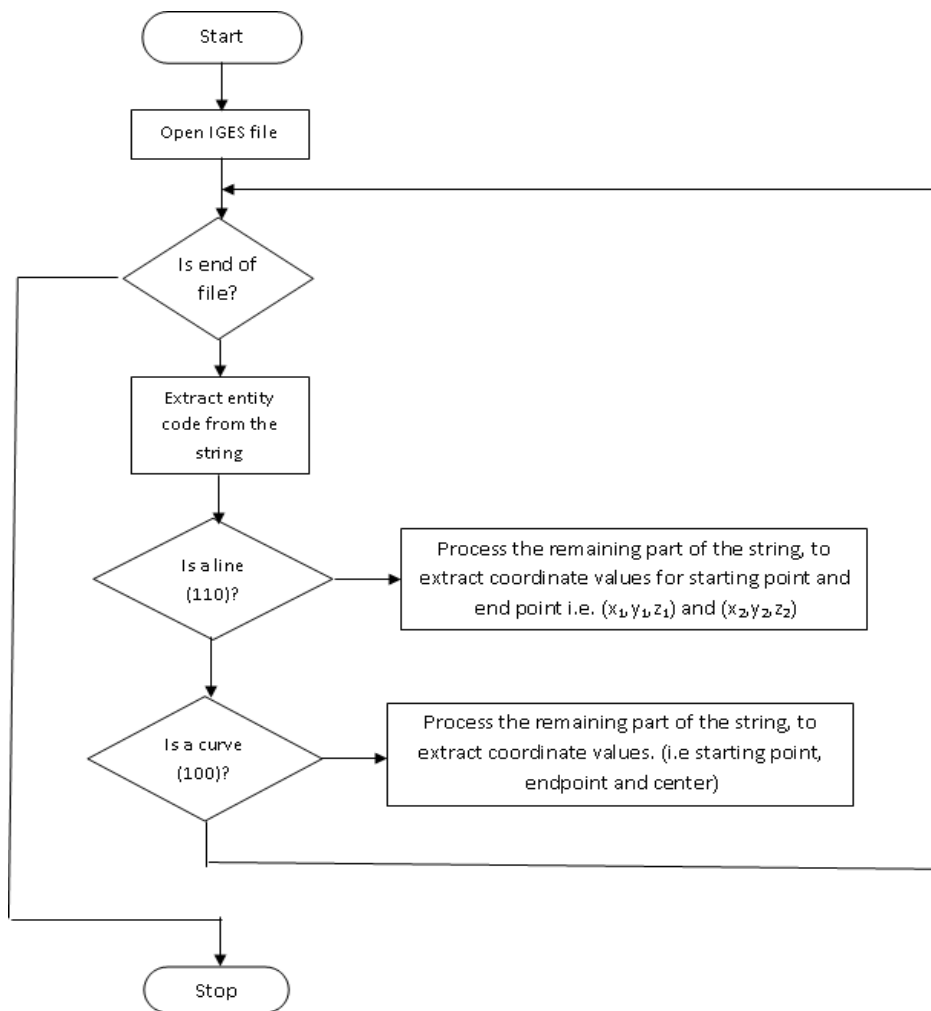
Fig. 2: Flow chart to recognize lines and curves

The flow chart in Fig.3 shows the algorithm for identifying the type of the line, the start and end coordinates and based on the coordinates the program recognizes whether the identified line is a horizontal line or a vertical line or an inclined line.

```
                    ┌─────────┐
                    │  Start  │
                    └─────────┘
                         │
         ┌───────────────────────────────┐
         │ Read the string corresponding to │
         └───────────────────────────────┘
                         │
         ┌───────────────────────────────┐
         │ Extract the coordinate values and │
         │ store in the variables: (x1,y1,z1) and │
         └───────────────────────────────┘
                         │
         ┌───────────────────────────────┐
         │ Display starting point           │
         │ (x1,y1,z1) Display end point     │
         └───────────────────────────────┘
```
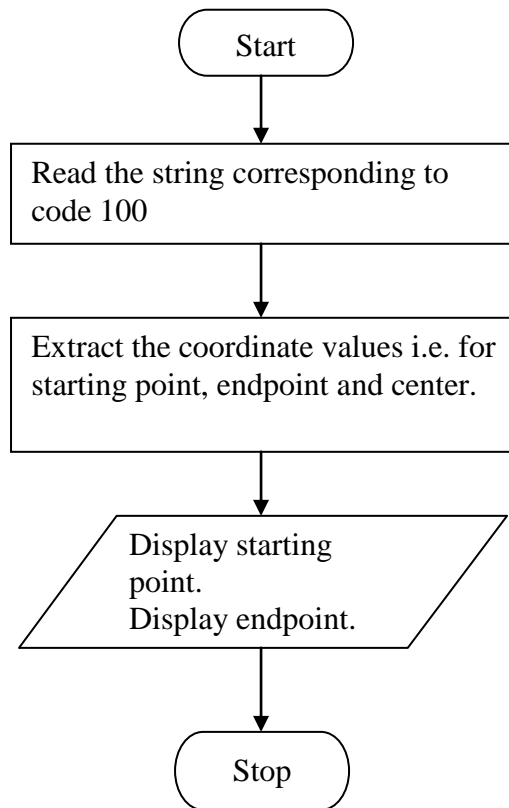
Start

Read the string corresponding to

Extract the coordinate values and store in the variables: (x_1, y_1, z_1) and

Display starting point (x_1, y_1, z_1) Display end point

Is $y_1 = y_2$?   N

Yes

Is (x1=x2)OR(z1 =z2) ?   Yes   Display "The line is horizontal"

N

Display "The line is inclined"

Is (x1=x2)AND(z1=z2) ?   Yes   Display "The line is vertical"

N

Display "The line is inclined"

Stop

Fig. 3: Flow chart to recognize the types of lines

The C3 technique is used to recognize planes, squares and rectangles.

```
        ┌─────────────┐
        │    Start     │
        └─────────────┘
               │
               ▼
┌──────────────────────────────────┐
│ Read the string corresponding to  │
│ code 100                           │
└──────────────────────────────────┘
               │
               ▼
┌──────────────────────────────────┐
│ Extract the coordinate values i.e. for │
│ starting point, endpoint and center.   │
└──────────────────────────────────┘
               │
               ▼
      ╱──────────────────╲
     ╱ Display starting    ╲
    ╱  point.               ╲
    ╲  Display endpoint.     ╱
     ╲──────────────────────╱
               │
               ▼
        ┌─────────────┐
        │    Stop      │
        └─────────────┘
```

Fig. 4: Flow chart to recognize planes rectangles and squares

The sample of the IGES file is shown in Fig.8.

Figure 5 shows a bracket modeled using the CSG technique in Pro-Engineer having, a rectangular slot within pocket and a projection, where features are identified by the volumetric decomposition approach.
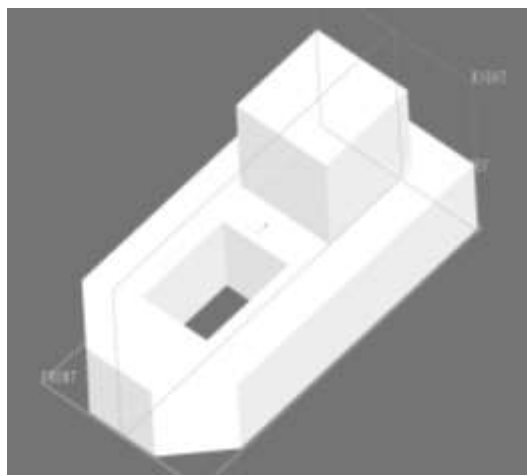
Fig. 5: Bracket

The JAVA program process the IGES file and using the Algorithm 1 generates an output of recognized entities.

The figure 6 shows a bearing bracket modeled using the CSG technique in solid works having a semi circular cylindrical hole and a through hole and a rib. A combination of hint based and volumetric decomposition is used to recognize simple geometric and topological features and parametric features. The recognized features can be used for down stream applications.
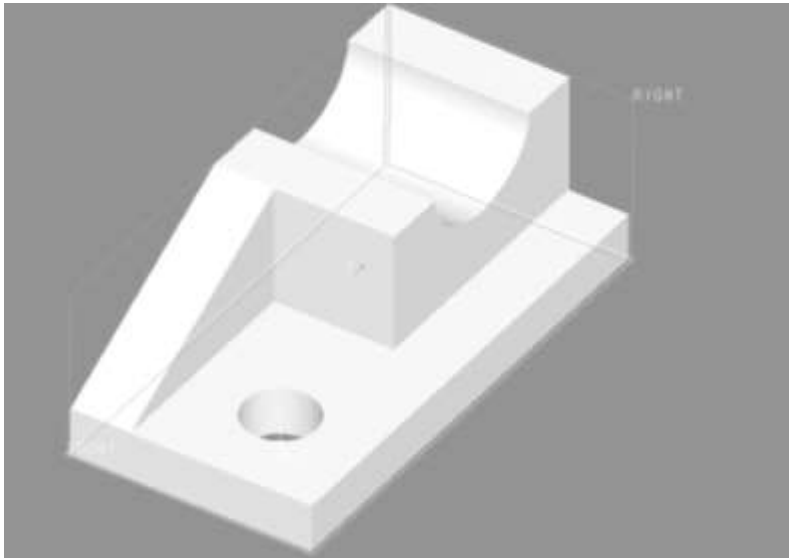
Figure 6: Bearing Bracket

The Figure 7 shows the flow chart for recognizing the geometric, topological and parametric entities using the combination of hint based and Volumetric decomposition approaches.
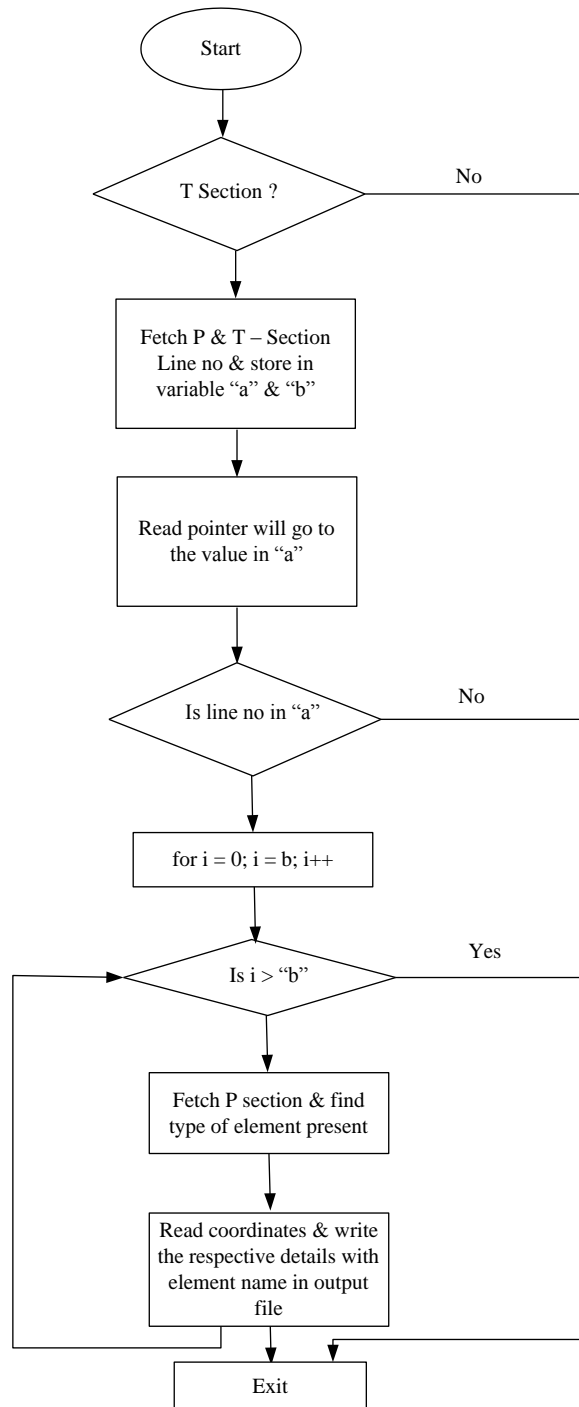
Fig. 7: Flow chart for recognizing parametric features using a combination of hint and volumetric decomposition approach

Results and Discussions

```
1H,,1H;,20HCNEXT - IGES PRODUCT,10H2ndraw.igs,44HIBM CATIA IGES -
CATIA G     1
    108    1    0    0    0    0    0    001010001D    1
    108    0    0    1    0                     0D    2
    110    2    0    0    0    0    0    001010001D    3
    110    0    0    1    0                     0D    4
.
.
.
110,-100.0,50.0,30.0,100.0,50.0,30.0,0,0;                89P    45
102,4,83,85,87,89,0,0;                         91P    46
142,0,81,0,91,2,0,0;                         93P    47
S    1G    4D    96P    48                         T    1
```

Fig. 8: IGES sample of the block

The features are recognized usig the 2D hints by the hint based approach.

```
    Line 1:
    ---------
    Start Point:     x1 = 25.00          y1 = 25.00          z1 = 30.00
    End Point:       x2 = 25.00          y2 = 25.00          z2 = 30.00
    The Line is Horizontal.

    Line 2:
    ---------
    Start Point:     x1 = 25.00          y1 = 25.00          z1 = 30.00
    End Point:       x2 = 25.00          y2 = 25.00          z2 = 30.00
    The Line is Vertical.

    Circular Hole  2:
    -------
    Start Point:     x1 = 0.00           y1 = 0.00           z1 = 0.00
    End Point:       x2 = 25.00          y2 = 0.00           z2 = 0.00
    Center (o =      0.00)
```
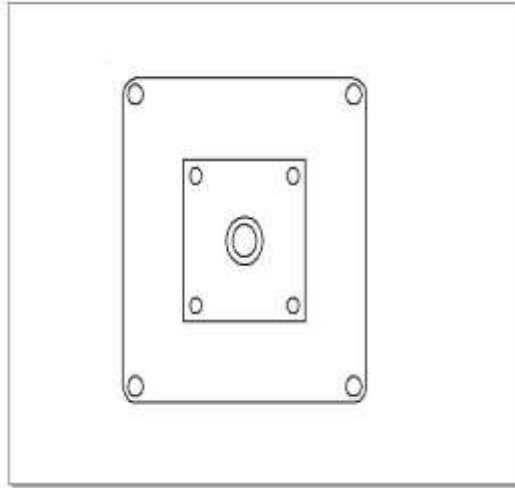
Fig. 9: Sample output of hint based approach of block

The output is used to reconstruct the model for validation. The schematic and projected views of the model are shown in Figure 10.

Fig. 10: Reconstructed model of the Block

```
PTC IGES file: C:\TURBOC2\igs\fig22.igs                    S    1
1H,,1H;,5HFIG22,24HC:\TURBOC2\igs\fig22.igs,              G    1
49HPro/ENGINEER by Parametric Technology Corporation,7H2002180,32,38,7, G    2
 ;                                        G    4
   124    1    0    0    0              00000000D    1
   124    0    0    1    0                   0D    2
   110    3    0    0    0        1    00020000D    5
   110    0    0    1    0                   0D    6
   110    4    0    0    0        1    00020000D    7
  . 110,92.289118262,0.,-17.077486677,92.289118262,15.,       641P    923
 -17.077486677;                          641P    924
 110,5.,0.,44.579579859,5.,15.,44.579579859;          643P    925
 110,-5.,15.,44.579579859,-5.,0.,44.579579859;        645P    926
 110,-5.,0.,-44.579579859,-5.,15.,-44.579579859;      647P    927
 S    1G    4D   648P   927                   T    1
142,0,429,445,435,1;                         447P   370
144,429,1,0,447;                             449P   371
110,-2.2D1,0D0,3.5D1,-2.2D1,-1D0,3.5D1;           451P   372
110,-1D1,6D-1,3.5D1,-1D1,-3.06D1,3.5D1;           453P   373
120,451,453,3.078760800518D0,6.346017160251D0;        455P   374
124,-1D0,0D0,0D0,-2.2D1,0D0,0D0,-1D0,-3D1,0D0,-1D0,0D0,3.5D1;   457P   375
100,0D0,0D0,0D0,1.2D1,0D0,-1.2D1,0D0;             459P   376
110,-1D1,-3D1,3.5D1,-1D1,0D0,3.5D1;               461P   377
102,4,81,71,459,461;
```

Figure 11 shows the sample IGES of the bracket shown in Figure 5.

Fig. 11 : IGES sample of the bracket

The sample output of the volumetric decomposition approach is shown in Figure 12.

Line 3:

Start Point: x1 = 0.00   y1 = -19.00   z1 = 0.00
End Point: x2 = 0.00   y2 = 19.00   z2 = 0.00
The Line is Vertical.

Line 4:

Start Point: x1 = 0.00   y1 = 19.00   z1 = 0.00
End Point: x2 = -64.00   y2 = 19.00   z2 = 0.00
The Line is Horizontal.

Line 6:

Start Point: x1 = -75.00   y1 = 8.00   z1 = 0.00
End Point: x2 = -75.00   y2 = -8.00   z2 = 0.00
The Line is Vertical.
Line 7:

Start Point: x1 = -60.00   y1 = 8.00   z1 = 0.00
End Point: x2 = -38.00   y2 = 8.00   z2 = 0.00
The Line is Horizontal.

Rational B spline curve :
Start Point :   x1 = 1   y1 = 1   z1 = 1
End Point :   x2 = 0   y2 = 1   z2 = 0

Transformation matrix :
Start Point :   x1 = 6   y1 = 4   z1 = 1
End Point :   x2 = 62   y2 = 7   z2 = 1

Fig. 12 : Sample output obtained using hint based approach

The volumetric decomposition approach recognizes simple 2D geometric entities, topological features and the transformation matrix.

The IGES file of the bearing bracket is shown in Figure 13.

```
PTC IGES file: C:\TURBOC2\igs\fig22.igs                          S    1
1H,,1H;,5HFIG22,24HC:\TURBOC2\igs\fig22.igs,              G    1
49HPro/ENGINEER by Parametric Technology Corporation,7H2002180,32,38,7, G
2
38,15,5HFIG22,1.,1,4HINCH,32768,0.5,13H071227.191238,0.0096043,96.0469,   G
3
2Hhp,7HUnknown,10,0,13H071227.191238;                    G    4
    124    1    1    1    0    0    0    001000000D    1
    124    0    0    1    0             XFORM    1D    2
    100    2    1    1    0    0    1    001010000D    3
    126  161    1    1    0    0    0    001010500D   199
    126    0    0   17    0           B_SPLINE   4D   200
    102  178    1    1    0    0    0    001010500D   201
    102    0    0    1    0             CCURVE   12D   202
    142  179    1    1    0    0    0    001010500D   203
    142    0    0    1    0             UV_BND    6D   204
    144  180    1    1    0    0    0    000000000D   205
    144    0    0    1    0             TRM_SRF   4D   206
    128  181    1    1    0    0    0    001010000D   207
    128    0    0    4    0             SPLSRF    3D   208
    110  185    1    1    0    0    0    001010000D   209
```

Fig. 13 : IGES sample of the Bearing Bracket

The Figure 14 shows the sample geometric entitles and the Figure 15 shows the parametric entities of the bearing bracket using a combination of the hint based approach and volumetric decomposition approach.

Circular Arc 1:

Start Point: x1 = 0.00   y1 = 0.00   z1 = 0.00
End Point: x2 = 6.00   y2 = 0.00   z2 = -6.00
Center (o =   0.00)

Circular Arc 2:

Start Point: x1 = 0.00   y1 = 0.00   z1 = 0.00
End Point: x2 = 6.00   y2 = 0.00   z2 = -6.00
Center (o =   0.00)

Line 19:

Start Point: x1 = -44.00   y1 = -30.00   z1 = 35.00
End Point: x2 = -44.00   y2 = -30.00   z2 = 10.00
The Line is Horizontal.

Line 20:

Start Point: x1 = -34.00   y1 = -30.00   z1 = 35.00
End Point: x2 = -44.00   y2 = -30.00   z2 = 35.00
The Line is Horizontal.

Circular Hole 1:

Center (x = 12.00   y = 0.00   z = -12.00   )
Radius 5.00

Fig. 14: Sample output of the geometric and topological entities

Type	Form	Count	Name
102	0	34	Composite Curve
120	0	3	Surface of Revolution
124	0	10	Transformation Matrix
126	0	6	Rational B-Spline Curve
128	0	12	Rational B-Spline Surface
142	0	17	Curve on a Parametric Surface
144	0	15	Trimmed Parametric surface

Total = 239

Fig. 15: Sample output of the parametric entities

Conclusions

The work presented here deals with algorithms to automatically extract and recognize features from a three dimensional part. These algorithms are built up on existing technical literature in the field of feature recognition of 3D solid models. The broad objectives that the present work has accomplished are;

1. Both B – rep and CSG modeling techniques are considered for extracting the IGES output from the 3D solid model.

2. The hint based technique, volumetric decomposition and a hybrid of hint and volumetric decomposition algorithms are implemented. The hint based approach works on rules based on 2D hints and the execution time is less. It recognizes only 2D simple entities.

3. The volumetric decomposition approach recognizes geometric as well as topological entities, but the execution time is more. The combination of hint based and volumetric decomposition approach is scalable and recognizes even parametric features and has the advantages of both.

4. The recognized entities can be used directly for Computer Aided Engineering (CAE) applications.

Acknowledgement

References:

[1] Rossignac J.R., Requicha A.A.G., "Solid Modelling and Beyond," IEEE Computer Graphics and Applications, pp. 31-43, 1992.

[2] Owodunni O. and Hinduja, S., "Evaluation of existing and new feature recognition algorithms Part 1: Theory and implementation," J. of Engineering Manufacture, Vol. 16, pp.839-853, 2002.

[3] Han J.Y., "Survey of Feature Research," Technical Report: IRIS-96-346, Institute of Robotics and Intelligent Systems USA, 1996.

[4] Grayer A.R., "A Computer link between design and manufacturing," PhD. Thesis, University of Cambridge, 1975.

[5] Kyprianon L.K., "Shape Classification from CAD," PhD. Thesis, University of Cambridge, 1980

[6] Gavankar P.S. and Henderson M.R., "Graph-based extraction of two-connected morphological features from boundary representations," J. of Int. Manufacturing, 6, pp.401-413, 1995.

[7] Sakurai H., "Vol. Decomposition and Feature Recognition", Part 1: Polyhedral Objects. Computer Aided Design, 27(1): 833-844, 1995

[8] Chandru, V., Manohar, S. and Gurumoorthy, B., "Integrated Modeling and reverse engineering for layered manufacturing," Technical Report: CSA - IISC - 1996-02, Indian Institute of Science Bangalore, 1996.

[9] Jha, K. and Gurumoorthy, B., "Automatic propagation of feature modification across domains," Computer-Aided Design 32, pp.691–706, 2000.

[10]   Nagaraj, H.S. and Gurumoorthy, B., "Automatic Extraction of Machining Primitives with Respect to Preformed Stock for Process Planning," J. of Manufacturing Systems, 20, pp.210-222, 2001.

[11] .Nasr E.A. and Kamrani A., "IGES Standard Protocol for Feature Recognition CAD System," Presented in Springer's Journal, pp.24-62, 2006.

[12]   Sormaz D. N. and Tennety C., "Recognition of interacting volumetric features using 2D hints," Int. J. of Assembly Automation, Emerald Group Publishing Ltd., 302, pp.131-141, 2010.