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RESEARCH ARTICLE OPEN ACCESS

Developing the B-rep of extruded objects for CAD/CAM applications

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ABSTRACT
Developing B-rep for engineering solids are essential for CAD users for visualizing the objects and designing it. Again, for CAM users it is a must for programming automated CNC machines. B-rep may be considered the transmission link between CAD and CAM systems. Intensive work has been done in this field. Much effort has been done by researchers to construct the frame boundaries of solid models and objects. This paper is trying to approach the problem by identifying various vertices, edges and features of the object and to get the interrelation between the connections between the surfaces. Extraction of features from CAD files is discussed to simplify the CAM users. Proper methodology is suggested applied to solve this problem. The methodology was applied using built up packages written by C#. The B-rep at the various levels is identified to facilitate determining the cutter path in CNC programming in CAM systems. The packages were tested and verified through applying case study and proved applicable.
Keywords: B-rep, Faces interaction, Identifying surface connection, C# programming.

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I. LITERATURE REVIEW

Computer utilization in modern life and in industry has become a must. It invaded all branches of engineering applications. All designers are using the CAD systems in their design stages. No manufacturer is not using the CAM system for proper and efficient manufacturing. Both systems must start with the recognition of the part to be designed or manufactured, which start by modeling and visualizing the part. But, modeling a part begins from extracting the geometrical data from CAD drawings. So, researches proceeded along several routes in research. One is making the geometrical data available from previously saved CAD drawings as a research line. Another providing different techniques of modeling (particularly in 3D) and a third [1& 2] is to overcome the problems of processing 3D geometric constraint in boundary representation models.

Thus. knowing the boundary profile of any part may be considered the important step when designing or manufacturing the part using CAD/CAM systems. So, this paper is proceeding in this line of research. As been mentioned the source of the part geometry is mainly from CAD files (DXF, IGES, … or STEP).

Omar Monir Koura [3], presented a comprehended study to extract the entities from the International Standard for the Exchange of Product coding system (ISO Step AP-203) in the attempts to facilitate the transfer of design data and geometry between the huge varieties of CAD/CAM systems. The work done was on prismatic parts and a feature extraction methodology has been presented and implemented.

Jaider Oussama et al. [4], worked on the extraction of features for rotational parts. The data was first extracted from STEP AP203, then applying a rule-based technique to isolate the features. It proceeded by the third step of recognizing the adjacent surfaces and determining their perfection.

Sivakumar &Dhanalakshmi [5] extracted manufacturing features from STEP AP203 file for cylindrical parts. The information obtained are first saved in text file and then analyzed through logic rules to identify the features such as tapers, plans, cylinders. It did not include some other features such as grooves and did not analyzed interacting features.

Abouel Nasr &Kamrani [6] gave a methodology for extracting geometrical data from 3D prismatic parts using as input the Initial Graphics Exchange Specification (IGES) format. The algorithm used identified the different features such as steps, holes, and others.

Nafis Ahmed & A.F.M. Anwarul Haque [7] worked with getting the geometrical data from the

Drawing Exchange File (DXF). They applied their methodology to extract the data from rotating parts and translated them for use in manufacturing. They verified the applicability of their procedure by a case studied.

ArmasoiuGiorgiana Elana and Gheorghe Marian [8], working on process planning for prismatic parts used the DXF to extract the geometrical features. They presented a methodology for automated transfer of the extracted data to be integrate with CAPP system.

Omar Monir Koura [9], extracted the features of line and arcs with their vertices from the date saved in DXF files for parts previously drawn and saved in 2D dimensional information. The work was to deduce the 3D shape of the part from the 2D orthogonal projection of the part.

In the work of deriving the boundary representation several researchers since early 1980 worked on this field of research. They are well represented in the book of Ian Stroud [10], who also described the methods of forming the data structure and their functions as related to the modelling algorithms. He shows different ways of representing the model

From the above, it is seen that the data extracted from any available files (STEP, IGES, DXF) are not ready to be used directly by model developer nor by CNC programmers as, it is not in the order or sequence suitable for use. The order given by the files depends mainly on the sequence by which the drawings are originally been done. Hence, it is essential to re-order the sequence of the features when they fed to the CAM system. So it is important to focus on developing an easy system to re-order the sequence of the features and to build the B-rep link between the CAD and CAM.

II. METHODOLOGY

i. Module 1: Availability of the geometrical data and classifying it

As, extracting the data from the CAD files is not the aim of this paper, so the procedure presented in references [3 & 9] is used. The geometrical features extracted from this procedure is listed in a text file, fig 1. It may be noted that this text file can be filled manually. It is a simple geometrical description for the features which can be written from the initial sketch of the part, thus eliminating the use of CAD files which needs an expert or at least a software interface to extract the suitable data needed. However, as previously mentioned the order by which the data are listed will not be in the sequence needed for further applications. Hence, the data given in the text file with its FORMAT shown in fig. 1 will be used as input to Module 1. The explanation of the FORMAT is given in Appendix "A".

Line , X_s , Y_s , Z_s , X_e , Y_e , Z_e
Arcr , X_s, Y_s , Z_s , X_e , Y_e , Z_e , R
Arcc , X_s, Y_s , Z_s , X_e , Y_e , Z_e , X_c, Y_c , Z_c
Hole , X_s , Y_s , Z_s , D , H
Slot , X_s , Y_s , Z_s , X_e , Y_e , Z_e , W , H , L
Groove, X_s , Y_s , Z_s , X_e , Y_e , Z_e , W , H , L

Fig 1: FORMAT of the text file

All the points are classified according to their levels and whether they fall on a continuous contour or as isolated features. This is done through:

- Determining the number of the levels (location of the points w.r.t. "Z" values) in the part.
- Classifying the features according to their location in the different levels.
- confirming that each of the vertices that lies in a level will belong to a continuous contour through being the intersection with at least two other features (lines and/or arcs), fig 2 (a).

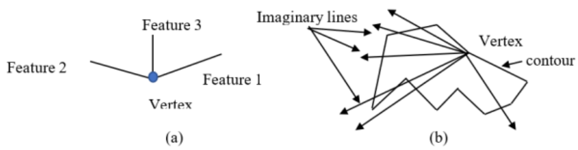


Fig 2: Verifying conditions

- Features not belonging to any contour are stand alone features (holes, slots, grooves ….).

The output of this module is:

- Number of levels j = 0 or 1 or 2 or …
- Heights of each level z[0], z[1], z[2], …...
- Grouping the features according to the following 4 groups:
    - o Features located in level 0 and forming a contour
    - o Features located in level 1 for forming a second contour and so on
    - o Features located between level 0-1, 1-2 …. and so on and forming the enveloping faces
    - o Features don't belong to any B-reps or faces.

Module 2: Determining the B-reps at the different levels

This is achieved through tracing the continuity of the end point of a feature to be the starting point of another feature on the conditions that:

- all the features in one level are included in the profile
- the end point of the last feature is the starting point of the first one.

Verifying that the outputs of the above two modules are correct, through that:

- all points are used only twice
- any imaginary vector passing through the considered vertex and a point in space and extended to infinity on either side (except those in the B-rep) must intersect with odd number of intersections with all the other features on the contour (profile), fig 2 (b).
- any imaginary vector passing through any point which don't belong to any B-rep (i.e. group 4) and is extended to infinity on either side (except those in the B-rep) must intersect with an even number with the derived profile.

Module 3: Defining the faces connecting different levels

Knowing the sequence of the features forming the B-reps on any two successive levels, the inter-related vertices which forma a face are determined. Fig 3 gives the flow chart for this part.

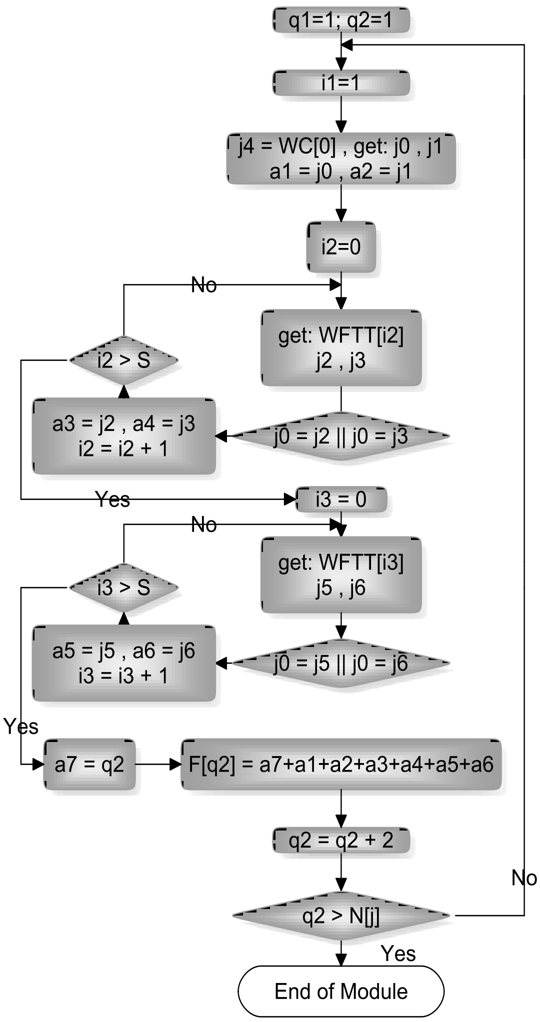


Fig 3: Flow chart for module 3

The function linking those inter-related vertices is determined. It forms a face which may be a plane or part of a cylindrical surface.

<u>For a plane, if:</u>

F[j , i1] is a feature with a feature number "i1" in level "j" has P[j , s] and P[j , e] as its two vertices with "s" indicates the start point and "e' is the end point

F[j+1 , i2] is a feature with a feature number "i2" in level "j+1" has P[j+1 , s} and P[j+1 , e] as its two vertices with "s" indicates the start point and "e' is the end point

Then, if P[j+1 , s] = P[j , s] or P[j+1 , s] = P[j ,e] , then the two features F[j , i1] and F[j+1 , i2] forms a plane with an equation of the cross product for the normal vectors between P[j+1 , s], P[j , s] and P[j , e].

The fourth point P[j+1 , e] is checked to know if it falls on the same plane or forms another plane.

A further verification check is that, if P[j+1 , e] forms a different plane with P[j , s] and P[j , e], then there must be two features in the geometry one is P[j+1 , e] and P[j , s] and the 2nd is P[j+1 , e] and P[j , e]

<u>For cylindrical surface</u>

Any point on the cylindrical surface has cylindrical coordinate (r , Θ , z) where r is the radius, Θ is an angle included between Θ_s and Θ_e . Same procedure is followed provided that:

- the center location P[j , c] is the same along z-axis
- same radius along z-axis

Module 4: Motion blocks for machining centers and Defining possible interference

After defining the B-reps and the type of face connection, the system is aimed to produce the motion blocks necessary for CNC machining centers. That only leaves to the programmer to complete the initial blocks for the zero setting, the cutting conditions and the necessary miscellaneous functions.

When machining the outer contour possible interference may occur between the cutting tool and the part surfaces if the inter connection between the intersected faces are of the recessing type. So, it is important to highlight the zones at which interference is likely to take place. This is checked through the method of calculating the angle "ϕ" between the two normal vectors to the faces following the procedure described in [10 & 11].

Hence, for any two neighboring faces "1 & 2", the normal vectors are "n_1" and "n_2" respectively.

$\Phi = \cos^{-1}[(n_1 * n_2) / (|n_1| * |n_2|)]$

For convex connection $0 < \Phi < 180$ and for concave connection $180 < \Phi < 360$ provided that there is a common line. If interference ever exist it will be in the case of concave.

III. CASE STUDY

The developed system will be based on:

- maximum number of vertices in the object will not exceeds 100 from 00, 01 …. 99
- maximum number of features in any profile will not exceeds 100
- features of the third group will be limited to holes and slots

Within the above limitations a computer package was developed considering the previous methodology and written in C# - version 2017.

To check the validity of the system, the case shown in fig 4 is analyzed. The part description is shown in the text file given in Appendix "A".

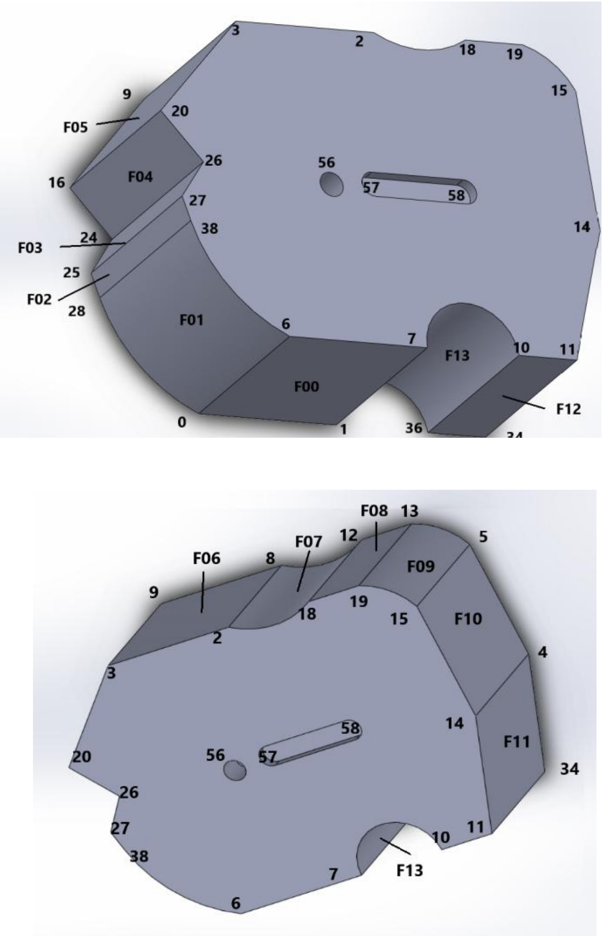


Fig 4: Isometric views of a case study

Appendix "B" contains the extracted points as been read from the text file. The points are in the sequence as given in the file.

Fig 5 shows screenshot for the features after been coded. The code is designed such that:

- the 1st 2 digit indicates the feature number
- the following 3 digits quote the index of the starting point of the feature
- the next 3 digits quote the index of the end point of the feature
- the last 2 digit indicates the type of the feature whether being a Line (LL), arc (AC), hole (HT) or slot (SB).

```
List of Features after modifying their code
==========================================
Feature no. = 0   code = 00000001LL      Feature no. = 1   code = 01002003LL
Feature no. = 2   code = 02004005LL      Feature no. = 3   code = 03006007LL
Feature no. = 4   code = 04008009LL      Feature no. = 5   code = 05010011LL
Feature no. = 6   code = 06012013LL      Feature no. = 7   code = 07014015LL
Feature no. = 8   code = 08016009LL      Feature no. = 9   code = 09018019LL
Feature no. = 10  code = 10020003LL      Feature no. = 11  code = 11010014LL
Feature no. = 12  code = 12024025LL      Feature no. = 13  code = 13026027LL
Feature no. = 14  code = 14028025LL      Feature no. = 15  code = 15016024LL
Feature no. = 16  code = 16020026LL      Feature no. = 17  code = 17034004LL
Feature no. = 18  code = 18036034LL      Feature no. = 19  code = 19038027LL
Feature no. = 20  code = 20007010AC      Feature no. = 21  code = 21028000AC
Feature no. = 22  code = 22015019AC      Feature no. = 23  code = 23012008AC
Feature no. = 24  code = 24018002AC      Feature no. = 25  code = 25038006AC
Feature no. = 26  code = 26005013AC      Feature no. = 27  code = 27001036AC
Feature no. = 28  code = 28056056HT      Feature no. = 29  code = 29057058SB
Feature no. = 30  code = 30008002LL      Feature no. = 31  code = 31001007LL
Feature no. = 32  code = 32012018LL      Feature no. = 33  code = 33024026LL
Feature no. = 34  code = 34028038LL      Feature no. = 35  code = 35016020LL
Feature no. = 36  code = 36034011LL      Feature no. = 37  code = 37036010LL
Feature no. = 38  code = 38005015LL      Feature no. = 39  code = 39013019LL
Feature no. = 40  code = 40009003LL      Feature no. = 41  code = 41025027LL
Feature no. = 42  code = 42000006LL      Feature no. = 43  code = 43004014LL
```

Fig 5: Snapshot for the coded features

Two levels were detected in this case (one at z = 10 mm and the second at z = 80 mm). Fig 6 is a snapshot of the features after been grouped to.

- 1st group includes the vertices in the 1st level (level 0)
- 2nd group includes the vertices in the 2nd level (level 1)
- 3rd group stand alone features such as holes, slots, …... etc
- 4th group includes features other than the above.

```
Group of stand alone features
==========================
Feature no. = 28  Feature code = 28056056HT
Feature no. = 29  Feature code = 29057058SB
Other group of features between levels
======================
Feature no. = 30  Feature code = 30008002LL
Feature no. = 31  Feature code = 31001007LL
Feature no. = 32  Feature code = 32012018LL
Feature no. = 33  Feature code = 33024026LL
Feature no. = 34  Feature code = 34028038LL
Feature no. = 35  Feature code = 35016020LL
Feature no. = 36  Feature code = 36034011LL
Feature no. = 37  Feature code = 37036010LL
Feature no. = 38  Feature code = 38005015LL
Feature no. = 39  Feature code = 39013019LL
Feature no. = 40  Feature code = 40009003LL
Feature no. = 41  Feature code = 41025027LL
Feature no. = 42  Feature code = 42000006LL
Feature no. = 43  Feature code = 43004014LL
Group of features in level no. 0
==================
Feature no. = 0   Feature code = 00000001LL
Feature no. = 2   Feature code = 02004005LL
Feature no. = 4   Feature code = 04008009LL
Feature no. = 6   Feature code = 06012013LL
Feature no. = 8   Feature code = 08016009LL
Feature no. = 12  Feature code = 12024025LL
Feature no. = 14  Feature code = 14028025LL
Feature no. = 15  Feature code = 15016024LL
Feature no. = 17  Feature code = 17034004LL
Feature no. = 18  Feature code = 18036034LL
Feature no. = 21  Feature code = 21028000AC
Feature no. = 23  Feature code = 23012008AC
Feature no. = 26  Feature code = 26005013AC
Feature no. = 27  Feature code = 27001036AC
```

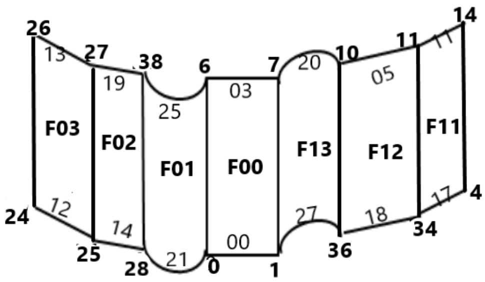
Fig 6: Output of Module 2

Fig 7 gives the output of Module 3 showing the B-rep order for the two levels both in Clockwise direction and Counterclockwise direction.

```
Level = 0   B-rep is given by  = 00021141215080423062602171827OO   in CW direction
Level = 1   B-rep is given by  = 10110161319250320051107220924O1   in CCW direction
```

Fig 7: Output of Module 3 – B-rep

Fig 8 shows part of the connected faces with the vertex numbers (0, 1, 36, 34, …. 7, 6, 38 , …24 .), the feature codes (00, 27, 18 ….03, 25, ...) and the Faces (F01, F02, …..). Fig 9 gives a screen shot for the detailed developed code for the enveloping faces for the part. The code indicates all the detected points that lie on the face. Some points are repeated and been filtered at later stage.




```
Group of features in level no.  1
====================
Feature no. = 1   Feature code = 01002003LL
Feature no. = 3   Feature code = 03006007LL
Feature no. = 5   Feature code = 05010011LL
Feature no. = 7   Feature code = 07014015LL
Feature no. = 9   Feature code = 09018019LL
Feature no. = 10   Feature code = 10020003LL
Feature no. = 11   Feature code = 11011014LL
Feature no. = 13   Feature code = 13026027LL
Feature no. = 16   Feature code = 16020026LL
Feature no. = 19   Feature code = 19038027LL
Feature no. = 20   Feature code = 20007010AC
Feature no. = 22   Feature code = 22015019AC
Feature no. = 24   Feature code = 24018002AC
Feature no. = 25   Feature code = 25038006AC
```

Fig 8: Part of the enveloping faces

```
i1 = 0   Face = 0100000100000600100 7
i1 = 1   Face = 02028000028038000006
i1 = 2   Face = 03028025028038025027
i1 = 3   Face = 04024025024026025027
i1 = 4   Face = 05016024016020024026
i1 = 5   Face = 06016009016020009003
i1 = 6   Face = 07008009008002009003
i1 = 7   Face = 08012008012018008002
i1 = 8   Face = 09012013012018013019
i1 = 9   Face = 10005013005015013019
i1 = 10   Face = 11004005004014005015
i1 = 11   Face = 12034004034011004014
i1 = 12   Face = 13036034036010034011
i1 = 13   Face = 14001036001007036010
```

Fig 9: codes for the enveloping faces

Fig.10 gives a screen shot for the last output of the system which is the cutter path for machining the part. This is given in the block FORMAT that suit the CNC machining centers. Only, 3 zones were highlighted for possible interference (after vertex 19, 7 and 17.

```
Motion Statement as a guide for CNC Part Program
========================================
Note: This is only the motion blocks. The followings must be added:-
        1. Zero positioning    2. Cutting conditions     3. Miscellanious f

N5   G00   X140   Y155   Z80
N10   G01   X80   Y155   Z80
N15   G01   X40   Y115   Z80
N20   G01   X55   Y95   Z80
N25   G01   X43   Y80   Z80
N30   G01   X45   Y70   Z80
N35   G03   X80   Y25   Z80   R40
N40   G01   X140   Y25   Z80
N45   G02   X180   Y25   Z80   R20
N50   G01   X205   Y25   Z80
N55   G01   X225   Y80   Z80
N60   G01   X225   Y125   Z80
N65   G03   X205   Y155   Z80   R40
N70   G01   X180   Y155   Z80
N75   G02   X140   Y155   Z80   R30
```

Fig 10: Screen shot for the cutter path

IV. Conclusion

The developed system is a powerful tool to derive the boundary representation of objects. It helps in the solid modeling for CAD objectives, as well as it facilitates the task of to the programmers of CNC machining centers as it shortens the use of complicated drafting packages and highlight the zones at which interference may occur while machining the contour. Although the system was fully tested and verified, but it needs further cases to be studied rather than the extruded shapes and in particular parts with more "z" levels with tapered and stepped faces. Also, the system is designed based on maximum number of features in one profile will not exceed 100.

Nomenclature

X, Y, Z Cartesian coordinates of points (suffix means start point, suffix e means end point & suffix c center of arc)
z[0], z[1] … levels
R radius of arc
D hole diameter
H hole or slot depth
W slot width
L slot or groove length
WC[j] code for the B-rep (1^{st} digit for the level, 2 digits for each feature included in the B-rep (i.e. if 14 features in the profile, then the code length is 29 digits)
WFTT[i] code for the features (1^{st} 2 digits for the serial number of the feature, 3 digits for the starting point, 3 digits for the end point and 2 digits for the type of the feature).
N[j] number of features in each level.
F[j , i] feature in level "j" with serial "i"
R, ϴ, Z polar coordinates for cylindrical surfaces
n_1 and n_2 are the normal vectors
Face is the code for the faces starts with the 1^{st} 2 codes for the serial number of the face followed by 3 digits for each point lies on the face.

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Appendix "A"
FORMAT of the text file

The FORMAT is a simple description of the part that can be obtained from the interface that extract the data from the CAD files. It consists of:

- Feature type: Line given by starting point (X_s , Y_s , Z_s) and end point (X_e , Y_e , Z_e)
- Feature type: Arcr which is an arc given by starting point (X_s , Y_s , Z_s) and end point (X_e , Y_e , Z_e), radius (R) and center sense (+ or -)
- Feature type: Arcc which is an arc given by starting point (X_s , Y_s , Z_s) and end point (X_e , Y_e , Z_e) and center coordinates (X_c, Y_c , Z_c)
- Feature type: Hole given by center line location (X_c, Y_c , Z_c), diameter (D) and depth (W)
- Feature type: Slot given by starting point (X_s , Y_s , Z_s), end point (X_e , Y_e , Z_e), Width (H) and depth (W)
- Feature type: Groove given by starting point (X_s , Y_s , Z_s), end point (X_e , Y_e , Z_e), Width (H) and depth (W)

The extracted data for the case study is given below.

```
Extracted Points from input data
=========================
P0  X= 80  Y=25  Z=10      P1  X= 140  Y=25  Z=10     P2  X= 140  Y=155  Z=80
P3  X= 80  Y=155  Z=80     P4  X= 225  Y=80  Z=10     P5  X= 225  Y=125  Z=10
P6  X= 80  Y=25  Z=80      P7  X= 140  Y=25  Z=80     P8  X= 140  Y=155  Z=10
P9  X= 80  Y=155  Z=10     P10  X= 180  Y=25  Z=80    P11  X= 205  Y=25  Z=80
P12  X= 180  Y=155  Z=10   P13  X= 205  Y=155  Z=10   P14  X= 225  Y=80  Z=80
P15  X= 225  Y=125  Z=80   P16  X= 40  Y=115  Z=10    P17  X= 80  Y=155  Z=10
P18  X= 180  Y=155  Z=80   P19  X= 205  Y=155  Z=80   P20  X= 40  Y=115  Z=80
P21  X= 80  Y=155  Z=80    P22  X= 205  Y=25  Z=80    P23  X= 225  Y=80  Z=80
P24  X= 55  Y=95  Z=10     P25  X= 43  Y=80  Z=10     P26  X= 55  Y=95  Z=80
P27  X= 43  Y=80  Z=80     P28  X= 45  Y=70  Z=10     P29  X= 43  Y=80  Z=10
P30  X= 40  Y=115  Z=10    P31  X= 55  Y=95  Z=10     P32  X= 40  Y=115  Z=80
P33  X= 55  Y=95  Z=80     P34  X= 205  Y=25  Z=10    P35  X= 225  Y=80  Z=10
P36  X= 180  Y=25  Z=10    P37  X= 205  Y=25  Z=10    P38  X= 45  Y=70  Z=80
P39  X= 43  Y=80  Z=80     P40  X= 140  Y=25  Z=80    P41  X= 180  Y=25  Z=80
P42  X= 45  Y=70  Z=10     P43  X= 80  Y=25  Z=10     P44  X= 225  Y=125  Z=80
P45  X= 205  Y=155  Z=80   P46  X= 180  Y=155  Z=10   P47  X= 140  Y=155  Z=10
P48  X= 180  Y=155  Z=80   P49  X= 140  Y=155  Z=80   P50  X= 45  Y=70  Z=80
P51  X= 80  Y=25  Z=80     P52  X= 225  Y=125  Z=10   P53  X= 205  Y=155  Z=10
P54  X= 140  Y=25  Z=10    P55  X= 180  Y=25  Z=10    P56  X= 110  Y=90  Z=80
P57  X= 150  Y=90  Z=80    P58  X= 190  Y=90  Z=80    P59  X= 140  Y=155  Z=10
P60  X= 140  Y=155  Z=80   P61  X= 140  Y=25  Z=10    P62  X= 140  Y=25  Z=80
P63  X= 180  Y=155  Z=10   P64  X= 180  Y=155  Z=80   P65  X= 55  Y=95  Z=10
P66  X= 55  Y=95  Z=80     P67  X= 45  Y=70  Z=10     P68  X= 45  Y=70  Z=80
P69  X= 40  Y=115  Z=10    P70  X= 40  Y=115  Z=80    P71  X= 205  Y=25  Z=10
P72  X= 205  Y=25  Z=80    P73  X= 180  Y=25  Z=10    P74  X= 180  Y=25  Z=80
P75  X= 225  Y=125  Z=10   P76  X= 225  Y=125  Z=80   P77  X= 205  Y=155  Z=10
P78  X= 205  Y=155  Z=80   P79  X= 80  Y=155  Z=10    P80  X= 80  Y=155  Z=80
P81  X= 43  Y=80  Z=10     P82  X= 43  Y=80  Z=80     P83  X= 80  Y=25  Z=10
P84  X= 80  Y=25  Z=80     P85  X= 225  Y=80  Z=10    P86  X= 225  Y=80  Z=80
```

Input Data (as extracted from design files or manully prepared)

Line,80,25,10,140,25,10
Line,140,155,80,80,155,80
Line,225,80,10,225,125,10
Line,80,25,80,140,25,80
Line,140,155,10,80,155,10
Line,180,25,80,205,25,80
Line,180,155,10,205,155,10
Line,225,80,80,225,125,80
Line,40,115,10,80,155,10
Line,180,155,80,205,155,80
Line,40,115,80,80,155,80
Line,205,25,80,225,80,80
Line,55,95,10,43,80,10
Line,55,95,80,43,80,80
Line,45,70,10,43,80,10
Line,40,115,10,55,95,10
Line,40,115,80,55,95,80
Line,205,25,10,225,80,10
Line,180,25,10,205,25,10
Line,45,70,80,43,80,80
Arcc,140,25,80,180,25,80,160,25,80
Arcc,45,70,10,80,25,10,84.6511,64.728,10
Arcc,225,125,80,205,155,80,185.2899,
120.193,80
Arcc,180,155,10,140,155,10,160,177.3607,
10
Arcc,180,155,80,140,155,80,160,177.3607,
80
Arcc,45,70,80,80,25,80,84.6511,64.7286,80
Arcc,225,125,10,205,155,10,185.2899,
120.193,10
Arcc,140,25,10,180,25,10,160,25,10
Hole,110,90,80,110,90,80,20,15
Slot,150,90,80,190,90,80,10,5
Line,140,155,10,140,155,80
Line,140,25,10,140,25,80
Line,180,155,10,180,155,80
Line,55,95,10,55,95,80
Line,45,70,10,40,70,80
Line,40,115,10,40,115,80
Line,205,25,10,205,25,80
Line,180,25,10,100,25,80
Line,225,125,10,225,125,80
Line,205,155,10,205,155,80
Line,80,155,10,80,155,80
Line,43,80,10,43,80,80
Line,80,25,10,80,25,80
Line,225,80,10,225,80,80

Appendix "B"
Extracted Points from Text File