Development Approach of Automated Recognition for Isolated and Intersection (Complex) Manufacturing Features for Prismatic Mechanical Parts

Dr. Hussein. S. Ketan*

Received on: 5/1/2010
Accepted on: 7/10/2010

Abstract

The intersection between part features caused ambiguousness in feature representation because the topology in this case will be change. To overcome this no unique and ambiguousness by combine the topology and characteristics to extract and recognize the intersection features. This paper introduces new general algorithm to: (1) construct developed Attributes Adjacency Matrix (DAAM) and (2) analysis the DAAM to extract and recognize the isolated and intersection (complex) manufacturing features. This algorithm consists of two stages, pre-processor stage which performs extraction of information from Design Exchange Format (DXF) file, and post-processor stage which recognizes parts features depending on the relations included in DAAM. The parts are represented in AutoCAD using Constructive Solid Geometry (CSG) technique and the algorithm built in visual basic. Several parts tested and succeed to recognize several types of intersection (complex) manufacturing features. The main contributions of this research include building the adjacent relations between faces of the part by geometrical characteristics in form of matrix, and use clustering operation to extract the exact faces of feature and use different classes of geometrical characteristics to assisting to recognize interacting depression prismatic features.

Keywords: CAD/CAM, DXF, Feature Extraction and Recognition, Attribute Adjacency Matrix, Intersection (complex) feature.

الاسلوب المطور للتمييز المؤتمت للسمات التصنيعية المنعزلة والمتداخلة (المعقدة) وللاجزاء الميكانيكية المضلعة

الخلاصة

التداخل الحاصل بين سمات الجزء الهندسي والتي تسبب الغموض في تمثيل السمات بسبب طبولجية الشكل في هذه الحالة سوف تتغير. وللتغلب على هذا الغموض وعدم التوحد في التمثيل تم دمج طبولوجية الشكل مع الخصائص الهندسية لاستخراج وتمييز السمات المتداخلة. يستعرض هذا البحث خوارزمية عامة جديدة لــ : (1) بناء مصفوفة تجاور الخواص المطورة (2) تحليل هذه المصفوفة لاستخراج وتمييز السمات التصنيعية الغير مترابطة او المنعزلة والسمات المتداخلة (المعقدة). هذه الخوارزمية تتكون من مرحلتين : المرحلة الاولى تتضمن المعالجة الاولية لبيانات الملف القياسي (DXF) والخاصة بالبيانات التصميمة للسمات, اما المرحلة الثانية تتضمن تمييز سمات الجزء بالاعتماد على العلاقات الموجودة في مصفوفة تجاور الخواص المطورة. تم تمثيل الاجزاء باستخدام برنامج التصميم المعان بالحاسوب (AutoCAD) والاعتماد على تقنية هندسة الاجزاء الصلبة البناءة وبنيت الخوارزمية باستخدام برنامج الفجول بيسك. العديد من الاجزاء الميكانيكية اختبرت ونجحت في تمييز العديد من انواع السمات التصنيعية المتداخلة (المعقدة). ان المساهمات الرئيسية في هذا البحث تتضمن بناء علاقات التجاور بين وجوه الجزء الهندسي على شكل مصفوفة, ثم استخدام عملية المجاميع (clustring) لاستخراج الوجوه الخاصة بالسمة واستعمال خواص هندسية مختلفة لتمييز السمات المضلعة المتداخلة (prismatic) المقعرة ذات الاوجه المتعددة.

* Production Engineering and Metallurgy Department, University of Technology/Baghdad

https://doi.org/10.30684/etj.28.21.1
2412-0758/University of Technology-Iraq, Baghdad, Iraq

Introduction

Automatic feature recognition (AFR) techniques applied to three-dimensional (3D) solid models are an important tool for achieving a true integration of computer-aided design (CAD) and computer-aided manufacturing (CAM) processes. In particular, AFR systems allow the identification in CAD models of high-level geometrical entities: features that are semantically significant for manufacturing operations [1]. The gap in information between CAD and computer aided process planning (CAPP) or automated inspection planning is reflect by the fact these applications require as input form of features, where traditional CAD representation can provide only faces, edges and vertices[1,2].

Various approaches have been developed for automatic feature recognition mechanisms that can be informally classified into the categories [3,4]: Syntactic pattern recognition approach, Graph-based approach, Rule-based approach, Volumetric approaches (including "cell- based" techniques) and Evidence-based reasoning approaches. Syntactic pattern recognition characterizes the overall part shapes as the composition of certain geometric primitives. Feature recognition proceeds by parsing the input syntactic expression of a part using grammar rules to identify the syntactic patterns representing the geometric primitives. In graph-based feature recognition, a graph is used to describe the topological shape of a part as well as that of a primitive feature. Feature recognition is performed by searching graph representation of the part to identify a sub-graph that matches that of a primitive using sub-graph isomorphism. The idea of the rule-based method for feature extraction is that rules are used to capture the knowledge about geometric and topological properties of form features. Features are recognized on the basis of certain pre-specified rules that are characteristic to the features. Volumetric approaches are based on the idea of finding the materials that must be removed from a raw stock to produce a part. Instead of relying on pattern matching like the techniques previously mentioned, this approach exploits convex hull algorithms and Boolean operations for feature analysis. The convex hull is the smallest convex set that contains the polyhedral object.

The classification or taxonomies of features is very importance to recognizing the features and depended on the context, the application that the model built to it. In this research we will deal with the polyhedral depression features such as slot, step, pocket, blind step, and blind slot and so on as primitive of simple features.

2. Literature review

The proposed approach depended on graph –based approach. Several researchers are concentrate their efforts based on this approach. **Joshi (1988)** represents parts and definitions of features by an Attributed Adjacency Graph (AAG). An attribute value (zero or one) is assigned to each arc of the AAG depending on edge convexity or concavity. The graphs are stored as adjacency matrices internally. Joshi assumes that "a face that is adjacent to all its neighboring faces with convex angles does not form part of a feature." Based on this assumption, the algorithm decomposes the AAG into sub- graphs by deleting the nodes which are only connected by convex edges. These sub graphs are further analyzed by the algorithm to determine the feature type [1].

C. Zhang (1997) presents a method for recognizing the presence of feature interactions and for determining the feature components within the interactions. First, two general feature types, namely depression and protrusion features, are identified from B-rep models based on a modified convex hull concept. Secondly, the identified features are represented by a modified AAG (Attributes Adjacency Graph) for facilitating their classification into two-level feature components, such as slots, pockets and bosses [5].

Marefat (1997) combines and propagates evidences to determine a set of correct virtual links to be augmented to the cavity graph representing a depression of the object so that the resulting super graph can be partitioned to obtain the features of the object. The hierarchical belief network is constructed based on the hypotheses for the potential virtual links [6].

Ketan (1999) He suggests the Improved Attribute Adjacency Graph (IAAG) algorithm has the capability to connected the topological information in addition to the geometric relationships of faces that comprise the feature to overcome some shortcomings of AAG algorithm by used values (+0,-0,0,1,+1,-1) in addition to the values (0,1) of the AAG [7].

Sophiayati and H. B. Haron (2002) discusses Adjacency list as an alternative way of representing AAG, its matrix representation and the comparison between these two methods of representation [8].

Ji and M.M. Marefat (2003) introduce an evidential reasoning-based approach for recognizing and extracting manufacturing features from solid model description of objects. They introduce a Dempster–Shafer approach for generating and combining geometric and topologic evidences to identify and extract interacting features [9].

Shu-Chu Liu (2004) proposes a method that can extract and classify turning (including symmetric and non-symmetric) and non-turning features that are concave, convex, or complex for rotational parts taking a 3D data file as input. The proposed method consists of three basic procedures. The first procedure extracts concave, convex and complex features from a3D CAD data file. The second procedure classifies the extracted features. The third procedure merges and decomposes extracted features [10].

Dimov, Brousseau, and Setchi (2007) they presents a new hybrid method that facilitates the deployment of Automated feature recognition (AFR) systems in different application domains, the method includes two main processing stages: learning and feature recognition. During the learning stage, knowledge acquisition techniques are applied for generating feature-recognition rules and feature hints automatically from training data. Then, these hints and rule bases are utilized in the feature-recognition stage to analysis boundary representation (B-Rep) part models and identify their feature-based internal structure [11].

O. H. Hassoon (2009) presents an algorithm for extract and recognizing the only isolated features. The proposed algorithm called Developed

Attribute Adjacency Matrix DAAM to represent the topology relationships between part's faces. The algorithm consists of two stages, pre-processor which performs extraction of information from DXF file format in CAD, and post-processor which recognizes part's features, Then used clustering operation to group the exact faces of the feature [12,13].

V. B. Sunil (2009) presents an intelligent system for recognizing prismatic part machining features from CAD models using an artificial neural network. A unique 12-node vector scheme has been proposed to represent machining feature families having variations in topology and geometry. The B-Rep CAD model in Application Computer Internal Standard (ACIS) format is preprocessed to generate the feature representation vectors, which are then fed to the neural network for classification [14].

In this paper a general algorithm proposed for extract and recognizes two classes of features for prismatic polyhedral part:

1. Simple or isolated feature.
2. Complex or intersection feature this happen when two or more of simple features intersected together.

The extraction of the faces corresponding to particular feature depended on the topological properties between the faces. The DAAM was developed to include the intersection features by built the relationship between the faces (which extract from DXF file Figure (1) show flowchart for extraction the entities) and used the clustering operation to extract the exact feature's faces. Each cluster represented only one cavity region (this cavity region represented simple or interaction feature) the algorithm consist of three extraction steps: simple feature, intersection feature and combine the topology and geometrical characteristics to extraction and recognizing the intersection faces in same feature that corresponding to one of simple feature.

3. Intersection (complex) features:

In our previous research [12] we deal with extraction and recognition of isolated (simple) features which are used process planer for machining operation. Due to the ambiguous and non- unique in feature relationships and topology, this will create a big problem for extract and recognize intersection (complex) features included in cavity region of a part (cluster) to generate a process plan (P.P) automatically. To overcome this deficiency, in this research the extraction and recognizing algorithm of isolated features is developed and extended to deal with the intersection features by combined the topology and different geometrical characteristics which are used to illustrate the topological and ambiguousness of intersection features are as follow:

1. The geometric plane.
2. Normal vector of the face.
3. Parallelism and opposite normal vector of the faces.
4. Cavity region which is include a group of faces that represent one or more features. Figure (2) show the part with intersection features, the blue region represent the cavity region (cluster), the geometric plane to two faces (f1,f2) and its normal vectors as the same.

The intersection features happen when each of the following done [11]:

1. Type I (figure 3) interaction (face splitting). Faces fa and fb could be affected by an interaction of this type if they lie on the same plane and their normal vectors have the same orientation and lie in same concavity region, and one can be extended to merge with the other face without intersecting any other face in the part model.

2. Type II interaction (face merging). This type of interaction can be identified if a planar face, face, shares a concave edge with two other planar faces, fb and fc, and if these two faces share a convex edge between them.

3. Type III (face merging and splitting). A type III faces fa,fb splitting with adjacent faces fd,fc matching the description of type II faces, could be the result of this type of interaction. Figure (3) shows parts contain interaction features of type II and III.

3.1 The new general algorithm for Extracting and Recognizing the isolated and intersection features:-

This algorithm used to construct the new DAAM that are used for extracting and recognizing of isolated and intersection features(not in pervious approach that recognize the isolated features only) included general and extended steps as are follows:

A- General steps for isolated features:

Step-1:
Step-2:
Step-3:
Step-4:

} mentioned in our previous research [12] Appendix (A)

B- New extended steps for extracting and recognizing of intersection features:

Step-5: Define all faces (for every cavity region) which contain one or more cells that have value (1).

Step-6: Define the faces which have the same normal vector and same geometrical plane and which lie in same cavity region and then combine the columns for these faces by replace (*) with (0) (if face 1 contains (*) and face 2 contain (0)), and replace (1) with (*) (if face 1 contains (1) or (*) and face 2 contains (1) or (*)).

Step-7: Search the faces which have normal vector opposite to each other (*). In each column of these faces, search the common cell corresponding in each column which contains (0), then build the matrix which contains these faces and common faces in the two column and determine the relationship between these faces (step-1)

Step-8: apply step-4 in general algorithm to recognizing feature type.

Step-9: merging primitive features that to correspond to suitable manufacturing feature, some of features can be merging to create different primitive such as step with another one merging as simple slot, a blind step with another one merging as a blind slot and blind slot with another one merging as pocket and so on. This is done by applied some geometrical characteristics of the feature and its faces.

The flowchart in figure (4) show new general algorithm.

3.2 The application of algorithm:

The mechanical part shown in figure (5) include some of isolated and intersection feature types. The results After applied the new two primitive clusters are resulted, a: (primitive features) simple step (faces 1, 2) simple slot (faces 3, 4, and 5) and b: two interacting clusters (C1=(faces 6,7,8,9,10,11)),and (C2=(faces 12 ,13 ,14 , 15, 16, 17)). These two last cluster must be decomposed to represented the suitable primitive features, based on the cavity region for any cluster contains at least one convex edge {one cell in matrix contains (1)} and all faces in cluster contains at least one concave edge (one cell in matrix contains (0)). The two simple steps can be merging as single primitive feature that correspond the suitable process. In this example the simple step (faces 1,2) and simple step{faces 6,(7,8 merge as one face)} can be merging as simple slot. Several interacting features can be recognizing through this procedure to decompose these features to represented suitable manufacturing primitive feature.

The extracting and recognition procedure is shown in figure (6)

The extracting and recognition procedure is shown in figure (6)

Conclusion:

The main contributions of this research include building the adjacent relations between faces of the part by geometrical characteristics in form of matrix, and use clustering operation to extract the exact faces of feature and use different classes of geometrical characteristics to assisting to recognize interacting depression prismatic features. This approach deal with the intersection features which is critical region of the feature recognition technique and overcome the ambiguous of part topology. The future work is to develop this approach to extract and recognize the rotational features and its intersections with prismatic features.

References

[1].S. Joshi and T.C. Hang "Graph-based heuristic for Recognition of Machined Features from a 3D solid Model" Computer-Aided Design, Vol. 20, No. 2, March 1988.

[2].M.R. Henderson, Computer recognition and extraction of form features: a cad/cam link, Comput. Ind. 5 (1984) 329–339.

[3].A. Kusiak "Intelligent Manufacturing Systems" Book, University of Lowa, 1990.

[4].Q. JI and M. M. Marefat "Machine Interpretation of CAD Data for Manufacturing Applications", ACM Computing Surveys, Vol. 24, No. 3, September 1997.

[5].C.Zhange, K. w . Chen and Y .h. Chen " A Method for Recognition feature interactions and feature components within the interactions" The international journal of Advanced manufacturing Technology Vol. 13, PP713-722,1997.

[6].M. M. Marefat and Q. Ji "Hierarchical Bayesian Methods for Recognition and Extraction of 3-D Shape Features from CAD Solid Models" IEEE Transactions on Systems and Humans, Vol. 27, No. 6, November 1997.

[7].H. S. Ketan "Integrating Design and Inspection Activities Using AI Technique" Ph.D, Thesis, U.O.T, 1999.

[8].S. B. Yuhaniz and H. B. Haron "Improving Attributed Adjacency Graph Data Representation" CoGRAMM" 2 National Conference on computer

Graphic and Multimedia pp. 371-374.

[9].Q. Ji and M.M. Marefat "A Dempster–Shafer approach for recognizing machine features from CAD models" Pattern Recognition, Vol.36, PP.1355-1386. 2003.

[10].*Shu-Chu Liu (2004)"Feature Extraction and Classification for Rotational Parts Taking 3D Data Files as input"* journal of the Chinese institute of industrial Engineering, Vol. 21, No. 5, PP 432-443. 2004.

[11].S. S Dimov, E. B Brousseau, and R. Setchi "A hybrid Method for Feature Recognition in Computer-Aided Design Model" Proc. IMechE Vol. 221, Part B: J. Engineering Manufacture, 2007.

[12].O. H. Hassoon, "Automated Inspection Planning for 3D Mechanical parts" MS, Thesis, U.O.T, 2008.

[13].O. H. Hassoon and H. S. Ketan, "Attribute Adjacency Matrix Approach for Extracting and Recognizing Manufacturing Prismatic Features from CAD Models" Eng & Tech Journal Vol. 27. No 10, 2009.

[14].V. B. Sunil and S. S. Pande " Automatic recognition of machining features using artificial neural network" The international journal of Advanced manufacturing Technology Vol. 41, PP932-7947, 2009.

Appendix (A)

Constructing Developed Attribute Adjacency Matrix (DAAM) for Extraction and Recognition of Isolated Features:

The algorithms proposed in [12] and [3] based on the AAG are used [1]. The steps of algorithm for construct the DAAM and feature recognition, reprocess extract the entities from DXF file this is show in figure (1) :

Step- 1: Construct the whole part matrix (N, M) which is equal to the number of faces in part, and then find the adjacencies faces to arbitrary face which is selected .If in analysis an adjacency is found between two faces then it is documented by entering (0, +0,-0, 1) into the cell (Ni, Mj) of the matrix which represents the row and column number. The procedure is continued until the whole part is analyzed

Step- 2: By examination of the column for any face in DAAM, if all cells in column contain (1) or empty (*); then this face dose not represent cluster, because we deal with the depression features otherwise if the column contains (0),(-0) ,(+0) in any cell , then this face represents cluster and the cluster corresponding to the face which has relation to analysis face is added.

$w_j=\{u \cup w_i\}$ …….(1)

And the process is continues until the all faces are examined. The results from this step represent the set of clusters.

$w_j=\{w_j, w_{i+1}, w_{i+2}, \ldots, w_n\}$ …...(2)

Step- 3: From the results in previous step by examine any cluster do the following:

a) W=Φ (empty set) ,then end ,if no, do the following :

b) $w_{o+1}= w_o \cup$ the underlying set of cluster w_o corresponding to the clusters from step 2 …….(3)

c) If $w_{o+1} - w_o= \Phi$, then $F_r = w_o$ and delete the underlying set for any set in w_o (W – every underlying set in w_o) from (a) because any face lies only in one cluster due to applying isolated features . If no, repeat (b).The results from this step are set of clusters:

$F_r = w_o$, $F_{r+1} = w_{o,}$
$F_{r+2} = w_o$ …..(4)

These clusters represent explicitly set of features and these results are used in next step.

Step- 4: For each cluster F_r examine this cluster to recognize feature type corresponding to it, by doing the following:

a) By taking every column corresponding to the underlying set in Fr. Calculate the number of the cells contained p= (0), S= (-0) and A= (+0) and then match to the feature pattern to know the type of this feature.
b) After calculating the p, S, A for all columns corresponding to the underlying set in Fr (the columns in DAAM).
c) Calculate H (the number of the cell contains 0,-0, +0) (H= P/2+S/2+A/2).

In these steps we recognized the isolated feature

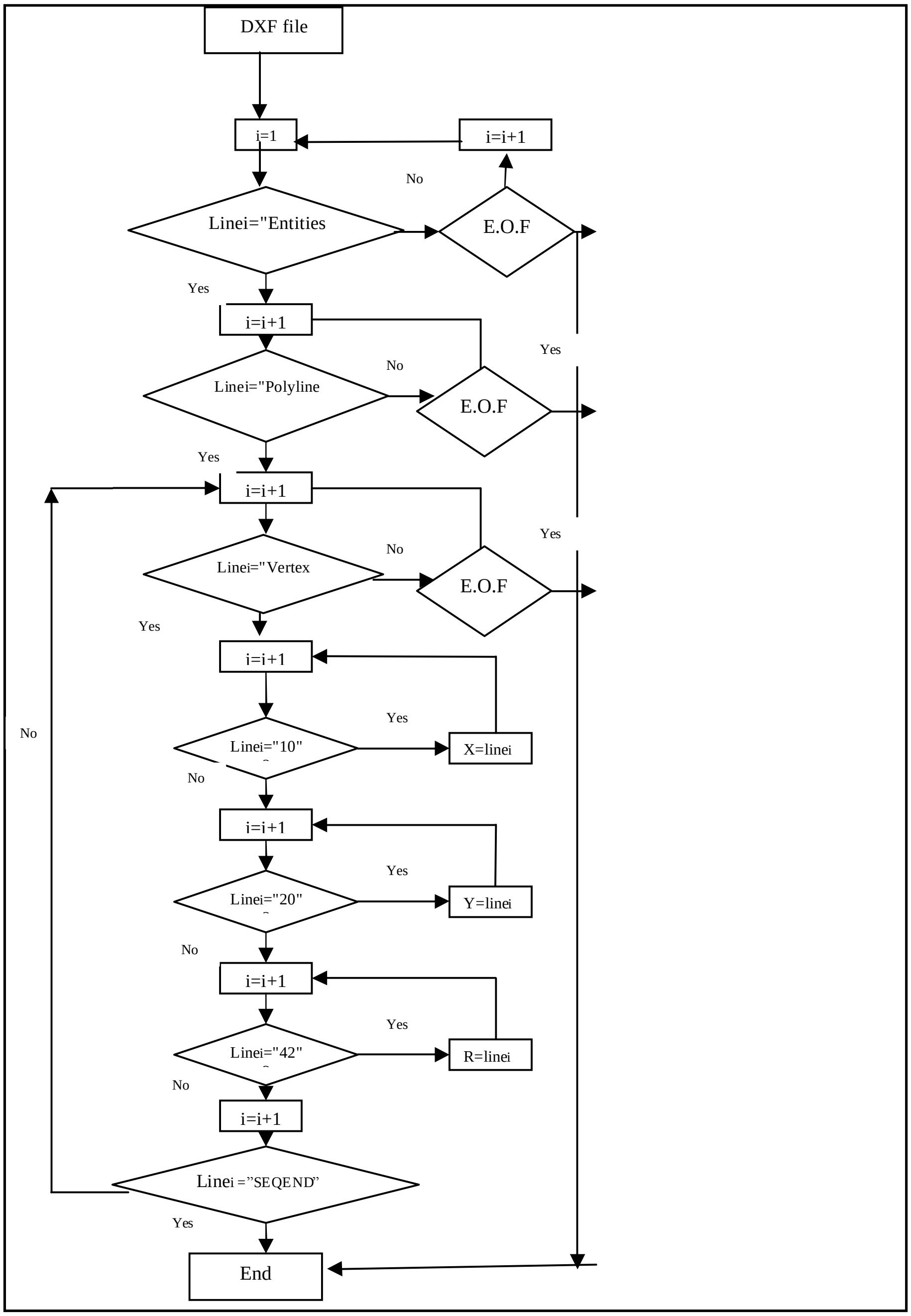


Figure (1) Flow chart for extraction the entities from DXF file

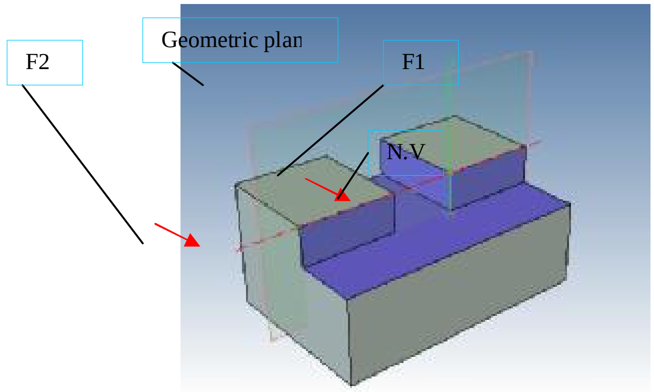
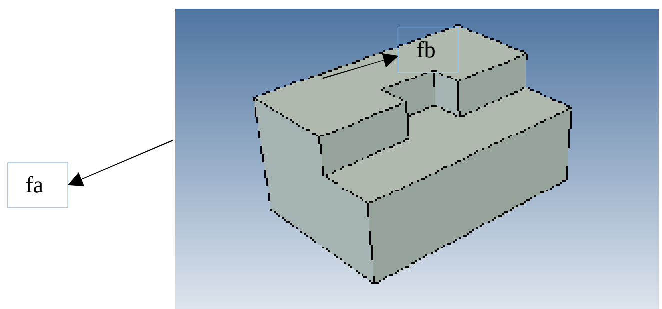
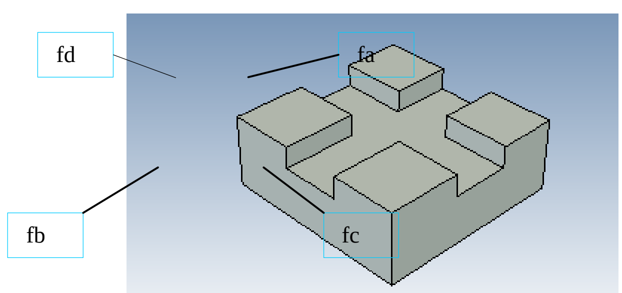


Figure (2): Show the cavity region, geometric plane and normal vector for two intersection features of a part.



Type I



Type II and III

Figure (3): An example to illustrate the feature interaction conditions (types).

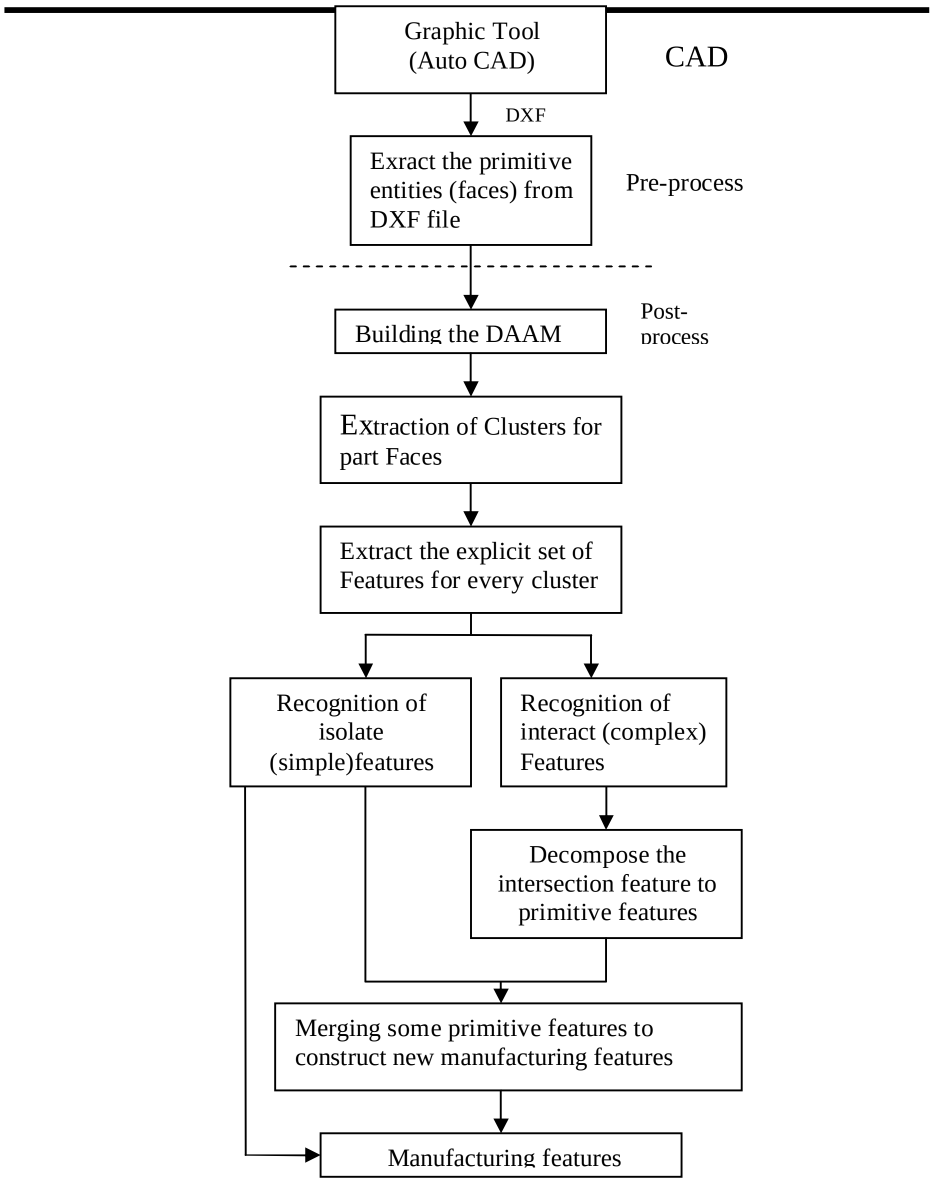


Figure (4) flowchart for feature recognition

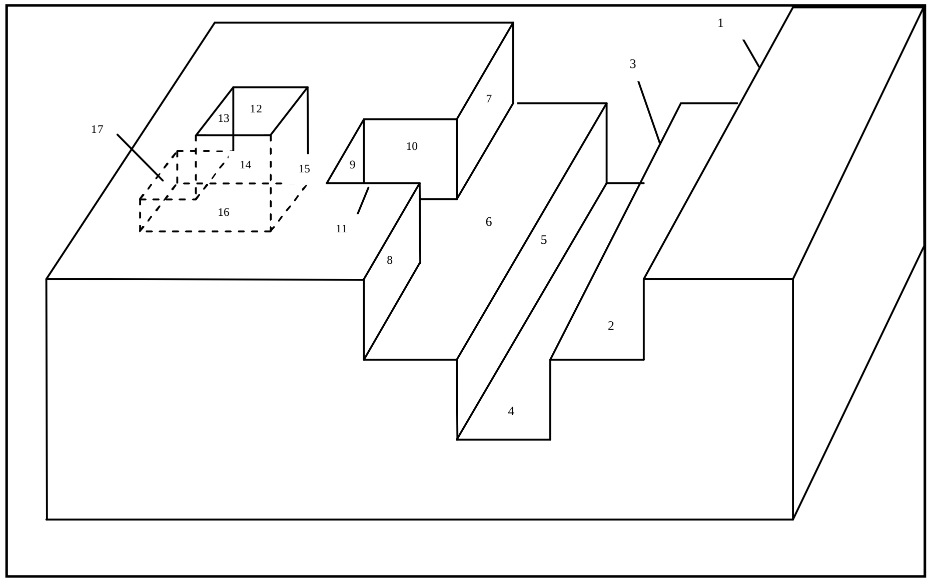


Figure (5) Test part (mechanical part) with two interacting clusters C1= (faces 6,7,8,9,10,11) and C2 = (faces 12,13,14,15,16,17)

Cluster 1

faces	6	7	8	9	10	11
6	*	0	0	0	0	0
7	0	*	*	*	1	*
8	0	*	*	*	*	1
9	0	*	*	*	0	0
10	0	1	*	0	*	*
11	0	*	1	0	*	*

Cluster 2

faces	12	13	14	15	16	17
12	*	0	*	0	0	0
13	0	*	0	*	*	1
14	*	0	*	0	0	0
15	0	*	0	*	*	0
16	0	*	0	0	*	*
17	0	1	0	*	*	*

Faces Same normal vector and same geometric plane then combine the two faces

Faces opposite

Faces opposite

Faces opposite

Faces 12,13,14,15,16 As Blind pocket

Faces 12,14,15,16,17 As Blind pocket

faces (7,8)
0
*
*
*
*
*

faces	6	9	10	11
6	*	0	0	0
9	0	*	0	0
10	0	0	*	*
11	0	0	*	*

Blind slot

faces	6	7,8
6	*	*
7,8	0	0

Simple step

Figure (6): The procedure to decompose the two (clusters) interacting feature