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FEATURE RESEARCH: REVIEW AND FUTURE DIRECTION

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ABSTRACT

Feature research is the work involved in searching or identifying distinctive shape that exists on the CAD model. To a computer, this distinctive shape is just a low-level geometrical definition, which is incomprehensible to engineers, designers or process planners. To make this low-level definition more easily understandable, engineering knowledge has to be integrated to the model. This integration transforms the low-level geometrical definition of a CAD model into high-level product definition. Hence, downstream activities can be incorporated even during modeling. This paper outlines the feature technology by reviewing some of the current methodology. Lastly, it points out its future direction.

Keywords: *Feature recognition, CAD, CAM, Process Planning, Modelling.*

1.0 INTRODUCTION

The implementation of computer modeling is becoming a crucial stage in design. Computer model is used to detect faults in the design prior to prototyping. Even, the usage of computer can be extended to incorporation of manufacturing characteristics during modeling. To achieve this, understanding of model representation is essential. Utilizing the data structure of the model accordingly with the integration of engineering knowledge results into a more meaningful data structure, which is comprehensible by engineers, designers and process planners.

One of the ways to integrate manufacturing aspects in a model is by means of feature technology. A feature is a distinctive characteristic that is present on a part. To a computer, this feature is described by a low-level data structure that comprises of topological and geometrical information. In order to transform this low-level data structure into meaningful high-level product definition, engineering knowledge must be integrated to the model.

This paper is about feature technology. It begins with reviewing model representation and the glossary of terms. This is followed by discussion of methods to integrate engineering knowledge by review of current research. The paper then concludes by pointing out the future direction of feature technology.

2.0 MODEL REPRESENTATION

There are 3 types of representation; wire-frame, surface and solid representations. Wire frame representation is a 'skeleton-structure' comprising of a collection of corner points that are connected by edges. When this wire-frame representation is incorporated with a collection of surface bounded by a collection of corner points and edges, the representation now becomes surface. However, surface representation lacks volume. When volume is added to representation, it becomes solid. Figure 1 illustrates the distinction between the three representations by considering a cross-sectional plane.

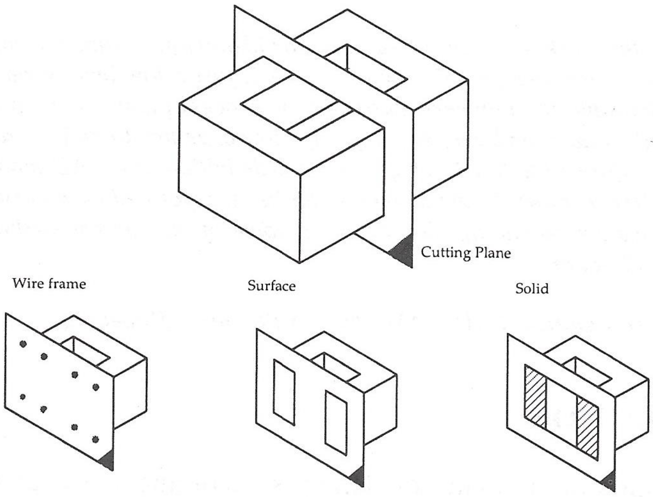


Figure 1 Difference of wire, surface and solid representations

In the following, the paper will discuss in detail the solid representation as it is widely used. Today, Boundary-Representation (B-Reps) modeler is the common representation of solid modeling.

B-Reps modeler stores the information of the model in structured hierarchical data of topology. The simplest representation of a solid is a collection of corner points (Figure 2a). These corner points are called vertices. The connectivity of the vertices is the next level of representation, which is called edge (Figure 2b). When a collection of edges makes a loop, another topology is formed, called loop (Figure 2c). The edges and loops will then form a face (Figure 2d). Lastly, a collection of faces forms a solid (Figure 2e).

However, topology information alone is not sufficient to describe its position in space. It must be accompanied by the geometrical information. Surface, curve and lastly point are the geometry for faces, edges and vertices, respectively. A loop does not have geometry. However the direction of the loop determines the direction of the surface normal and eventually the key factor in deciding whether the position of a point in relation to the solid; inside, on or outside the solid.

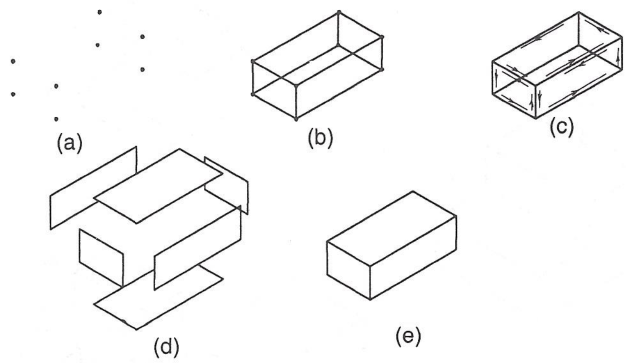


Figure 2 B-Reps Representation

Figure 3 shows the relationship between topology and geometry. This relationship differs from one software to another.

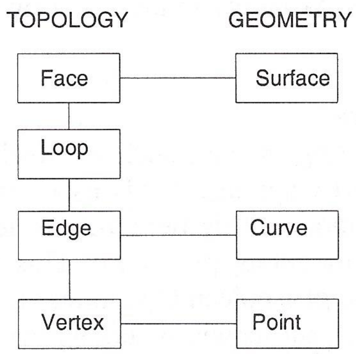


Figure 3 Topological and geometrical relationship in B-Reps models

3.0 GLOSSARY OF TERMS

This section explains various terms and nomenclature used in the next section.

3.1 Feature Taxonomy

Designers and process planners have traditionally viewed the same feature with contrasting interests and concerns in mind. Work inspired by designers has centred chiefly on the functional aspect. However, work seen through the eyes of process planners has focused mainly on the machining method. For instance Figure 4 shows an identical feature being defined differently. Figure 4a has been recognised as a rib by designers as they consider the rib as a form feature to be attached on stock. Whilst, process planners prefer to remove the two machining features (Figure 4b) from the stock and therefore identifying the feature as two steps.

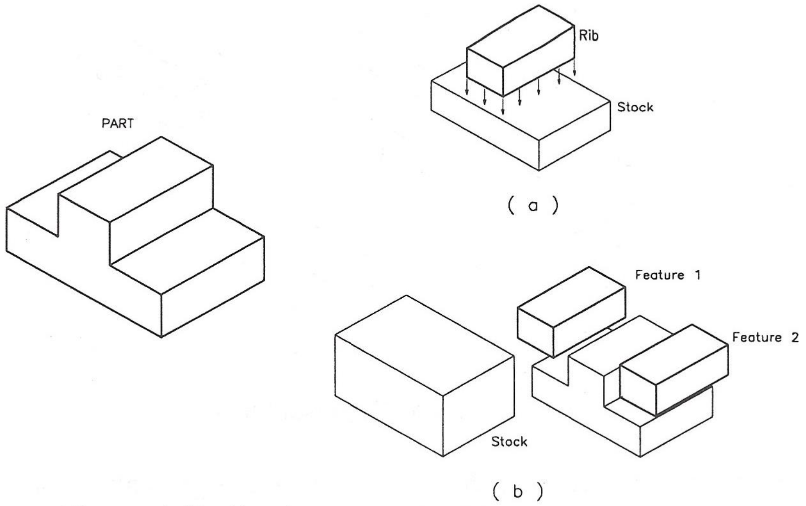


Figure 4 Similar feature with different interpretations

The fundamental of feature taxonomy is proposed by Gindy [1]. This taxonomy is illustrated in Figure 5.

3.2 Importance of feature

Today, feature based modeling system, such as Mechanical Desktop and Solid Work, is gaining in popularity amongst CAD users. It is due to its versatility in editing and modifying the model. This flexibility is achieved through structured binary-tree that stores the modeling procedure. This binary tree reveals all the features after the application of Boolean Operation on the base-stock. Editing the features or the base stock will subsequently modify the model.

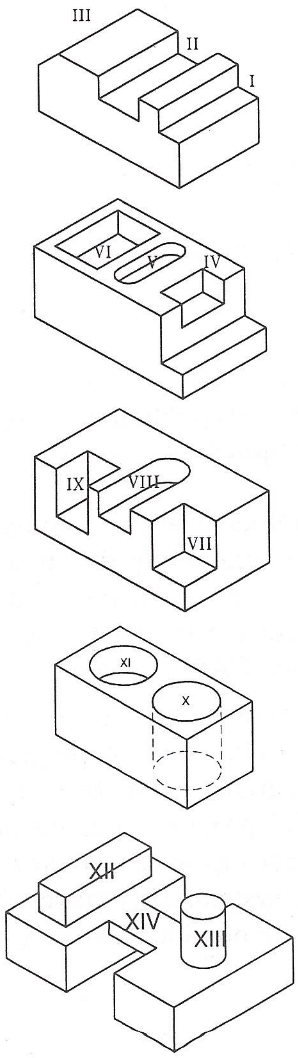
However, feature-based system lacks manufacturing information. This drives researchers to integrate the manufacturing aspect even during modeling and hence, will expand the capability of the system. Finally, a complete CAD/CAM can be achieved in a single system. Currently, machining is the most common manufacturing process that has been reported in the literature.

Since designers and process planners differ in viewing features, some of the features have conflicting characteristics. For instance, boss and ribs are added to the base model. However, the feature related to machining is cavity, which has to be removed from the stock. This causes some features in the feature-based system cannot be machined. Therefore, feature conversion has to be carried out in order to integrate the manufacturing aspect especially machining. This feature conversion is the main focus of the researchers.

Apart from recognizing machining features from binary-tree of the feature-based system, there is a number of researches that recognize features from geometric model. This type of research is categorized as feature recognition. Unlike, feature-based research that manipulates the information stored during modeling, feature recognition manipulates the topological and geometrical properties of the B-Reps model.

Both feature-based and feature recognition systems search for machining features. When machining features are recognized, automation of downstream activities, such as producing NC coding, can be achieved. The main question arises whether the research has a benefit over the current CAM software. Undoubtedly, the current research produces a comprehensive CAD/CAM system.

Currently, most CAM systems convert the model into surfaces, prior to generating the NC code. This conversion causes the critical information on machining useless. The features on the model can indicate the machining method, such as hole signifies the drilling process. When CAM software does not utilize this information on the features, it is a waste of valuable information. In fact, Gindy's taxonomy on the classification of features is based on tool approach. Therefore, the research on features is in fact using the machining information during modeling, as current CAM systems fail.



I : Step
II : Slot
III : Wedge

IV : Side Pocket
V : Blind Slot
VI : Pocket

VII : Notch
VIII : Blind Slot
IX : Side Pocket

X : Hole
XI : Blind Hole

XII : Island
XIII : Boss
XIV : Bridge

Figure 5 Feature Classification

4.0 INTEGRATION WITH ENGINEERING KNOWLEDGE

To enhance the capability of computer in understanding product with a higher-level product definition, engineering knowledge has to be integrated into the CAD model. In the area of feature research, the method to search or identify the features on the CAD model is the main task and the recognition of features will transform low-level model definition into high-level product definition.

To identify the features, several approaches can be employed, as shown in Figure 6. Programming with geometry is one of the ways to implement these approaches in understanding the CAD model, which will be discussed in detail in Section 4.1. Whilst, Section 4.2 reviews some related work.

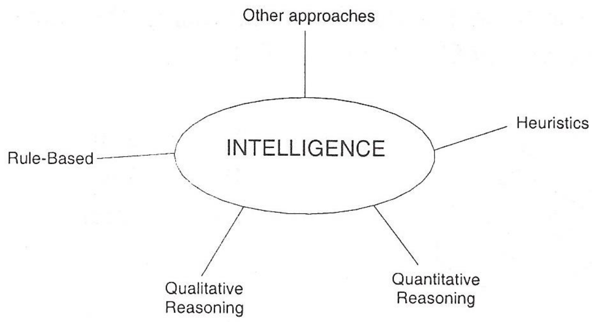


Figure 6 Method for engineering integration

4.1 Programming with geometry

Programming with geometry can be in three types;

i. **List programming**: It is a macro-type programming using built-in functions. The program can be written, compiled and executed within the CAD package itself.

ii. **Application program interface (API):** Similar type to list programming; however interfacing via API makes API programming different from list programming. Moreover, API programming can be written and compiled using commercial programming language outside the CAD packages. The executable file generated can be run within the CAD packages.

iii. **Via neutral file**: The last type of programming uses the neutral file to retrieve the information from the drawing. This kind of programming is independent of the CAD packages. The program can be written, compiled and executed on its own using commercial programming language. The model can be created using any CAD packages as long as their neutral file is similar to the one that is accepted by the system. This makes the system more open than a system developed using both previous methods, which are dependent on the specific CAD package.

4.2 Current Method

Feature can be recognized from the relationship of its properties. For instance, feature can be described as relationship between its top, wall and bottom faces. When these properties are represented as patterns, the part as well as the features can also be represented by combination of these patterns. Hence, a feature can be recognized when an identical primitive feature exists on the part. Matching process to recognize the feature can be carried out between the pattern of primitive features and the part. This approach is called pattern matching. Grammar, rule-based, string syntactic and graph matching are amongst the approaches that fall into this category.

Below are the approaches:
Grammar: assigning a specific shape on the model into characterological description. Hence, feature will be represented by a list of characters and the grammar method is utilized to define the feature.

Rule-based: identifying the features by satisfying series of 'IF', 'AND' and 'THEN'. Similarly, rule-based system can take in the form of a series of pattern that must be satisfied in order to identify certain feature such as used in grammar and syntactic pattern matching.

i.e. **IF** two faces are parallel, **AND** their surface normal is opposite to each other, **THEN** slot is recognized [2].

String syntactic: assigning specific character to represent specific shape. String-syntactic based system will compare every string representation of the model with the string representation of primitive features. Feature is identified when similar representation exists.

i.e. Pattern for hole: *HSS { HES } HBS* [3]
HSS: denotes a 'hole start surface'; circular inner loop
HES: denotes a 'hole element surface'; a cylindrical, conical, toroidal or circular plane with a circular inner loop
HBS: denotes a 'hole base surface'; a conical face, circular planar with a circular inner loop, or a circular outer loop of a plane face.

Graph-pattern matching: Especially B-Reps model, representing the model as graph to show topological relationship of the CAD model. The similar representation can also be applied to primitive features. Hence, comparing the primitive template with the model representation carries out the feature recognition. Figure 7 shows the sample of feature template for pocket used by Joshi [4].

5.0 FUTURE DIRECTION

This section discusses the future direction of feature research in terms of methodology and feature types. It also discusses the implementation of feature technology in the development of STEP, an ISO data exchange.

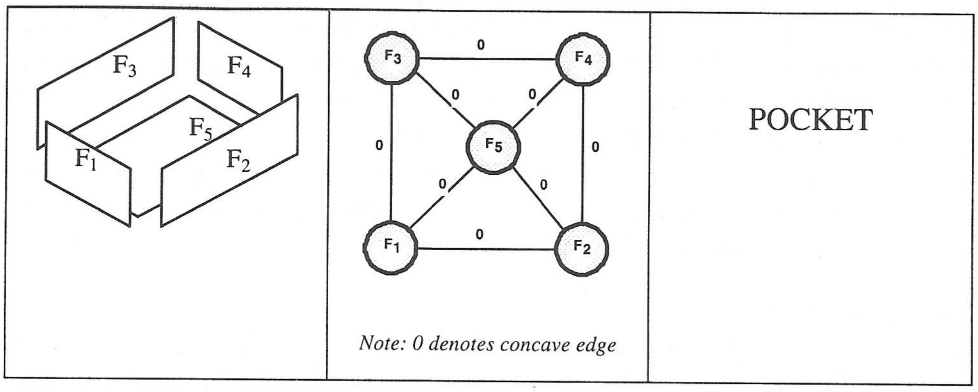


Figure 7 Sample of Feature template using graph [4]

5.1 Methodology

The principle of pattern matching is to compare the pre-defined feature template with the feature on the model. A feature is recognized when exact match is found. As a result of this, every single feature template must be compared with every single feature on the model. This causes the complexity of search is $O(n^k)$, where n is the number of features on the models and k is the number of feature templates [5]. Since k is constant, the computing time grows polynomially with the number of features on the part.

Apart from the computing time, pattern matching fails to handle interacting features because some of the faces on the feature are either entirely absent, partially missing or fragmented into several regions when the feature interacts with one another. In order to handle these interacting features, some systems attempt to replace the lost information and properties with virtual properties. However this proves little help in extracting the exact feature of the virtual property, because of the vast number of possible virtual properties that replace the missing one. Substituting fewer arcs than necessary results in an unrecognised feature, while replacing more arcs than necessary generates false features. Based on this contingency, Ji and Marefat [6] employed the probability method to find the right combination. Although sophisticated techniques are employed, the problem of identifying the exact solution still remains.

The solution to this is a directed search process to reduce combinatorial complexity. Hint-based systems proposed by Vandenbrande [7] and Han [8] use the directed search process. Unlike pattern matching process that uses bottom-up approach, hint-based method uses top-down approach on which the search originates from a very general pattern. As the search goes deeper, a multilevel confirmation process is carried out to verify the existence of specific feature. Figure 8 shows both methods.

Utilization of mathematical tool is another method to solve the constraint of pattern matching. The previously discussed pattern matching can only recognize feature that matches its predefined pattern. Slight changes to this pattern cannot be recognized. When pattern matching is applied to a mathematical tool, such as

Neural Network or Fuzzy Logic, such variation can be recognized with certain amount of certainties.

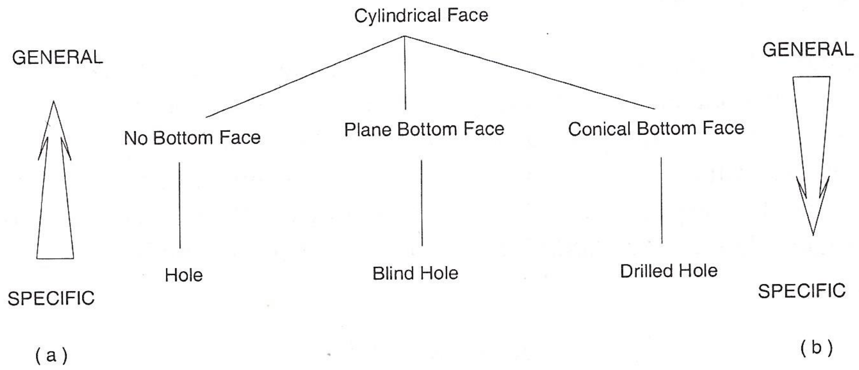


Figure 8 Bottom-up and top-down approach

5.2 Feature definition

From the top-down approach, multiple feature definition can be developed. This provides a number of possible machining features that can be suggested from a single shape. When a single shape can be classified into various features, a number of process planning can be suggested. Therefore, optimization of the process planning based on the acceptable feature definition is now becoming an issue. Regli et. al.[9] addressed this issue.

5.3 STEP

Feature technology is used as the basis for Standard for the Exchange of Product Model (STEP). STEP is standard according to ISO 10303. ISO 10303 or STEP will replace all current data exchange format with no error during conversion. Under STEP, there are a number of application protocols, amongst them are AP 203 designated for CAD model data exchange, AP 224 designated mechanical product definition for process planning and AP 238 for machining data exchange. STEP AP 203 is now widely utilized by CAD system. STEP AP 238 is not fully implemented. However, it will replace the G and M code by a set of 'working step' known as STEP NC that is structured by a part feature. Therefore, in the development of STEP NC, feature technology plays an important role. Albert [10] reports the importance of feature in the development of 'push-button' CAM.

Han et. al. [11] addresses the implementation of STEP-based feature recognition in manufacturing cost optimization. However, they use Parasolid[1] translator to convert the STEP AP 203 information to be compatible with the

[1] Developed within Integrated Feature Finder (IF^2) system, which the Parasolid Translator uses the commercial geometric modeler marketed by Unigraphics Solution Inc.

Integrated Feature Finder (IF^2) [8]. Kramer et. al. [12] utilized STEP methods and models to implement in machining and inspection of mechanical parts.

6.0 CONCLUSION

In summary, this paper reviews the feature research and points out its future direction. Of course, as with many other downstream activities, this paper is limited to only machining features. However, the important question is not its limitation, but rather how far this approach can be integrated with downstream activities. In this respect, the link between features with downstream activities is how to manipulate the available information to a specific activity.

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