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FEATURE-BASED REPRESENTATION FOR ASSEMBLY MODELLING

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The aim of building an assembly model is to describe the component geometry and to define the relationships between parts of the final assembly. This requires a representation of features which include all the information needed to assemble the products and a data structure which stores information on how all the components and features are connected in an assembly. This paper outlines the development of an assembly model based on an established feature representation and a hierarchical assembly structure. Information needed to establish assembly relationships among features are included in the form of mating conditions such as "against", "fits" and the mating of two faces. The model is embedded in an object-oriented solid modeller kernel. The aim is to achieve an efficient assembly model that can be used to generate feasible sets of assembly plans.

Introduction

The main objective of assembly planning is to improve the efficiency of the assembly process in terms of time to assemble, cost and quality of finished products. The quality of the assembly plan and the cost of assembly eventually depend on the product structure, since the structure of a product describes its functionality. An efficient assembly plan needs information concerning the geometry and physical constraints as well as the representation of the parts and their relationships.

Feature-based design is now acknowledged as a key technology for many CAD/CAM applications (Case and Gao 1993) and many feature representations have been defined for various manufacturing applications. In assembly, feature representations have been used for design for assembly (DeFazio et al. 1990), assembly planning (Werling and Wild 1994) and assembly modelling (Shah and Rogers 1993). This paper discusses the application of feature representations for assembly modelling.
Related Work

The problem of assembly modelling has been studied extensively in recent years and several models have been developed. A data structure using the concept of virtual links was created by Lee and Gossard (1985) to represent the relationships between the components in an assembly. Virtual links represent a complete set of information required to describe the type of relationship and the mating conditions between mating pairs. The system supports a hierarchical assembly data structure. Ko and Lee (1987) define four types of mating condition, namely against, fits, tight-fits and contact. The against condition holds between planar faces of a pair of parts. The fit condition holds between the centrelines of a solid cylinder and a hole. Contact is a type of against condition in which there is no relative movement between the faces of the involved components while tight fit is the condition which constrains the fit relation. This was used to generate assembling procedures. The work described in this paper extends the concepts and methodologies proposed above using an established feature representation, described in Wan Harun and Case (1994). An important concept in feature-based design and manufacture is that a single feature representation should be capable of supporting a number of different applications. In this case the feature representation has previously been used in process planning and process capability modelling for the design and selection of processing equipment (Case 1994).

Assembly Structure

The process of assembly can be viewed at various levels. Figure 1 shows the hierarchical structure of an assembly. The highest level in the structure is the assembly, which is made up of one or more sub-assemblies. A sub-assembly is in turn made up of one or more components. The lowest level being the assembly of features to the components that make up the sub-assembly. Rn denotes a possible assembly relationship between a pair of features, as explained in the following section.

Using the object-oriented approach, each level in the assembly hierarchy is defined in a class which inherits the attributes of the class that is immediately above it. Each level is also linked to the next level above and below it by a link node. Each node contains pointers to the item itself, the previous item and the next item in the structure.

In general, an assembly part can be represented by the following structure:

- Identifier Name
- Pointer to assembly level above
- Pointer to sub-assembly below
- Pointer to a list of assembly relationship
- Location and orientation transformation (relative to level above)
- Pointer to component
- Pointer to list of features
- Other properties
Figure 1. The assembly hierarchical structure

The data structure of the assembly is shown Figure 2.
Representation of Mating Relationships

A physical contact between a pair of features in the assembly indicates that there is a mating relationship. The mating could occur over one or more faces. Four mating relationships among features have been defined according to the work of Ko and Lee (1987), in order to determine if the feature makes a given assembly possible. These mating relationships are assigned to each feature and used when two features are to be assembled to the base components or in the assembly of the base components to form the final assembly. For example, Figure 3 shows an assembly which consists of two components—a pin which consists of a rectangular boss feature and a block which contains a through hole of a similar profile. In this assembly, two types of mating conditions "against" and "fit" exist.

Figure 3: Example of a simple assembly

The general expression of representing the mating condition among features is by specifying the two features that mate and the mating condition type, as below:

feature1n-mating_condition-feature2n

for example: for an assembly shown in Figure 3, the representation is:

bossn-against-holen
bossn-fits-holen

For a plane contact of two surfaces:
surfacen-contacts-surface

where n denotes the feature index number in the assembly.

The data structure for the above relationship contains the following information:

- pointer to feature 1
- pointer to feature 2
- pointer to mating face of feature 1
- pointer to mating face of feature 2

Implementation

Feature classes which contain the above information have been developed in the feature library. When a feature in the assembly is selected from each of the two parts to be assembled, the system checks for the existence of a mating
relationship defined for the features. If a relationship is defined, then the user is asked to input the locations and dimensions of the features. The modeller then checks the dimensional and shape compatibility and other geometric constraints. If all conditions are met, the assembly is recognised to be valid and related functions to assemble the feature will be generated.

The feature library is integrated with a solid modeller kernel, ACIS® and developed in an object-oriented environment, using the C++ language.

Conclusions

The development of a formal structure for the representation of assembly information is considered to be an essential prerequisite to the generation of CAD/CAM systems that are capable of optimising product design and manufacture. Such a representation can form the basis of design improvement techniques (design for assembly) and manufacturing planning (assembly planning). This work has demonstrated the value of an object-oriented approach which is a natural method of handling the complex relationships between the parts and sub-assemblies of an assembly. The feature representation used is one that has previously been used for process planning and process capability modelling, thus establishing the possibility of using features as an integrating agent across a number of manufacturing applications.

References