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Automatic Extraction of Machining Primitives with Respect to Preformed Stock for Process Planning

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Abstract

Machining features used to identify machining regions/surfaces in a part are usually defined with respect to regular stock such as billets or blocks. These machining features cannot be used for identification of the machined surfaces/machining volumes when the part has to be machined from a preformed stock such as forging or casting. Machining primitives are proposed as the building blocks for representing the volume of material to be removed by machining. As each primitive is associated with a machining operation, it is believed that process-based reasoning will become simpler. This paper describes an algorithm to identify and extract machining primitives when the part has to be obtained from preformed stock. Results of implementation are presented.

Keywords: *Machining Primitives, Features, Preformed Stock, Machining Volumes*

Introduction

The part model is the repository of geometry and product data in the tasks of CAD, CAPP, and CAM. A key problem in the seamless integration of CAD and CAPP is the automatic identification of machined surfaces/volumes in the part.* This is because the part model definition strategies/requirements are totally different in the two domains. This is illustrated in *Figure 1. Figure 1* shows the construction of the component from the building blocks available as performed by a designer. The figure also shows a model of the component that is consistent with the machining point of view. The process planner would prefer a model based on removal of volumes (so that the regions to be machined will be automatically available [Salomons, van Houten, and Kals 1993]), whereas the designer could have used addition of shapes/volumes to generate the component. This contradiction makes the automation of process planning difficult. Therefore, any approach to automate process planning has to resolve the issue of providing appropriate shape/geometric information to the planning system. This essentially boils down to extracting, from the CAD model, volumes that need to be machined to realize the part. Because volumes are removed from a stock, the extraction process must identify volumes with respect to a defined stock. This is because the nature of volumes to be removed by machining is different for different stock (see *Figure 2*). The stock could be a billet, bar, or preformed such as a casting or forging.

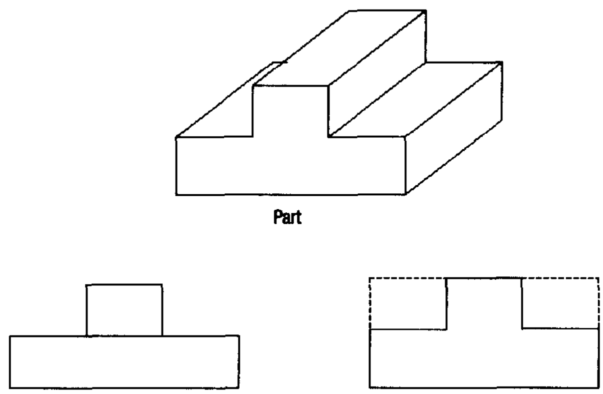

Figure 1
Different Views of a Part

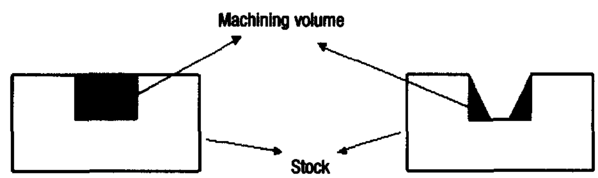

Figure 2
Different Machining Volumes for Different Stock

Machining features have been used to identify and represent the volumes to be removed by machining to obtain the part (Salomons, van Houten, and Kals 1993; Shah 1991; Subrahmanyam and Wozny 1995). In general, a feature is a geometric entity with which domain-specific information can be

*Here and in the remainder of the paper, the focus will be on the volume that has to be removed by machining rather than on the machined surface.

associated so that reasoning about geometry in that domain is possible (Shah 1991). Features defined in the domain of machining are referred to as machining features. Examples of machining features are Slot, Hole, and Step. These features contain information about the volume of material to be removed (to be discussed later) and the processes and process parameters to be used to obtain the feature. The machining feature information can be obtained in the following three ways.

Interactive Feature Definition. Here the CAD model is interactively interpreted manually, and the entities in the CAD model associated with each feature are identified manually (Chang and Wysk 1985). This approach has a very limited usage in the context of automating process planning.

Feature-Based Modeling. In this approach, the part model is constructed using the machining features only (Salomons, van Houten, and Kals 1993). In this approach, if the feature model is constructed using features defined for other domains, either a feature extraction process or a feature mapping process on top of feature-based modeling is required to overcome the mismatch in the features used in modeling and those required for reasoning about machining.

Automatic Feature Extraction. In this approach, machining features are recognized in the CAD model automatically and extracted. The advantage of feature extraction is that integrity of geometric information is protected and legacy models can be handled. Subrahmanyam and Wozny (1995) provide a review of the feature extraction techniques reported in the literature.

Volume Decomposition Based Approaches. Wang (1990) describes the concept of backward growing to identify machining features in a part. The approach essentially constructs a volume from a set of faces (that have to be machined) and then decomposes the volume constructed into predefined machining features. Machining of a part is a removal of a set of identified volumes from a stock to result in a part. These volumes are removed out of a stock through a machining operation that is essentially modeled as a sweep operation. A set of 14 unit elementary swept shapes is defined. The machining faces of the cavity volume are identified to be the originators of the elementary machined shapes, which form the cavity volume. A backward-growing approach is used to identify the manufacturing features and to extract associated information, which is of utility in the machining the cavity volume. The backward-growing approach uses the set of concavely connected faces, obliquely connected faces, or circular faces. The output of this procedure is the Feature Volume. The similarity between the backward-growing approach and the work reported here is that both fill up cavity volumes incrementally to identify the machining primitives. The concept of backward growing as described in Wang (1990) is, however, restricted to an orthogonal minimum circumferential block as stock. This approach is limited to handling simple parts of prismatic nature and cannot handle complex parts having combined rotary and prismatic features. This is because the basic machining shapes defined are restricted only for prismatic features and not for cylindrical and spherical stock.

One major limitation of the earlier feature-based approaches was the inability to handle interacting features (Tseng and Joshi 1994). Approaches based on volume decomposition (Tseng and Joshi 1994; Coles, Crawford, and Wood 1994; Shah, Shen, and Sirur 1994; Sakurai 1995) were proposed to handle this problem. In all these approaches, the delta volume* is decomposed into simpler volumes that can be cuboids (Tseng and Joshi 1994; Coles, Crawford, and Wood 1994) or maximal convex cells (Shah, Shen, and Sirur 1994; Sakurai 1995). These primitive volumes are then merged to identify machining features. While these approaches use volume decomposition, their goal is recognition of machining features. The simple volumes that are obtained after the decomposition step usually are restricted to cuboids or to shapes that have no direct significance to the machining process (convex cells). For the recognition of machining features, these simpler volumes (cuboids, convex cells) have to be merged. As there can be more than one way of merging these volumes, quite often the merging step results in many combinations that cannot be recognized as machining features (Shah, Shen, and Sirur 1994; Sakurai and Dave 1996). The number of combinations that can be obtained and that have to be considered by the recognition step can explode combinatorially for complex cavity volumes (Shah, Shen, and Sirur 1994; Sakurai and Dave 1996).

*The volume of material to be removed by machining, obtained by a Boolean difference of the stock and the part.