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Indexing and retrieval in machining process planning using case-based reasoning

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Abstract

To reduce the manufacturing time of a product, one effective way to develop a machining process plan for a new part is to retrieve a relevant case of process planning similar to a new desired part and then adapt the retrieved case to meet the new requirements. This paper proposes a mechanism for retrieval of process planning cases. The core of the retrieval mechanism contains: (1) a feature-based representation of a part and cutting processes; (2) indexing of a part; (3) a feature hierarchical structure based on cutting processes; and (4) a similarity metric used to measure the similarity between a new desired part and any old part in the case base. The application domain here is for axisymmetric part machining. A prototype based on the retrieval mechanism is implemented on a Sun workstation using the ACIS 3D-Toolkit from Spatial Technology Inc. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Case retrieving; Machining process planning; Feature-based representation

1. Introduction

Process planning is an important activity in CAD/CAM integration. In the past, expert systems have been widely used in automated process planning systems [1–4]. However, expert systems are successful only if the domain of applications is well defined and the experts' experiences can be clearly translated into rules. Unfortunately, the domain is difficult to define for most of the manufacturing processes, and the knowledge existing in an experts' mind is not in the form of rules but past successful process plans. Even though one expert system was built, it is static and difficult to change [5]. Besides, the current trend of minimum "time to market" requires that an automated process planning system be able to advance its own knowledge in response to the rapidly changing markets and manufacturing environments. The ability to learn has thus become critical for such a process planning system.

In past years, case-based reasoning has been successfully applied in various fields, such as JUDGE [6] for assisting judges in the field of law, CHEF [7] for cooking advisory, and ARCHIE [8] for helping in the design of buildings. The concept of CBR has also been used in design and manufacturing. Yang et al. [9] developed a simple process planning system in machining by employing case-based reasoning. Takahashi et al. [10] combined the concept of CBR and knowledge reuse to solve real, large-scale manufacturing process design problems. Maher and Gómez de Silva Garza [11] used the CBR in structural design.

It has been recognized that the retrieval mechanism plays an important role in the case based process planning system. The key factors affecting the performance of the retrieval mechanism are *representation*, *indexing* and *similarity metric* of parts. A good representation, indexing and similarity metric will enable the system to retrieve the most similar case rapidly and correctly. Therefore, the objective of this paper is to develop an appropriate representation and indexing mechanism, and an effective similarity metric.

The primary application domain of this study is process planning for axisymmetric parts. Two systems, CAP_{LAN}/C_BC [12–14] and PROCASE [9,15] were developed in this domain. The CAP_{LAN}/C_BC assumes that the outlines of a final part can be divided into three areas (two rising areas and a horizontal area) in the axial direction and each area is machined independently. In practice, these areas are not independent of each other in the machining process. Besides, the geometric feature includes only dimensions in their studies. Precision and material were not considered. In fact, precision and material are two important factors affecting the selection of cutting tools and process steps in machining process. On the contrary, PROCASE, though

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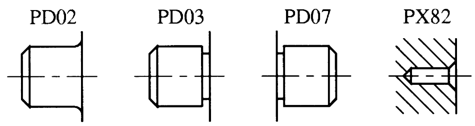

Fig. 1. Examples of geometric feature.

including the information about material and precision ignored them while retrieving the most similar case. In this paper, we extend the concept of the feature-based representation [9] to develop an effective indexing mechanism for retrieving similar parts based on a novel similarity metric. The proposed similarity metric not only covers the geometric shape of a part, but also considers precision and material. In addition, we also develop a bit-representation method to index parts when the number of cases is very large. This method is employed to narrow the searching scope within a large case base.

This paper is organized in eight sections. The overview of the retrieval mechanism is described in Section 2. Feature-based representation of parts and processes are discussed in Section 3. Section 4 introduces a case indexing mechanism. Retrieval techniques and similarity measures are presented in Section 5. An algorithm for indexing of massive cases is described in Section 6. In Section 7 three examples implemented in a solid modeling environment are given. Finally, discussions and conclusions are provided in Section 8.

2. Overview of the retrieval mechanism

The proposed retrieval mechanism consists of: (1) a feature-based representation of a part and cutting processes including geometric and material properties; (2) indexing of a part; (3) a feature hierarchical structure based on cutting processes; and (4) a similarity metric based on geometric shape, material, and precision in terms of indexing of a part. The similarity metric is used to measure the similarity between a new desired part and an old case based on the indices of the parts.

3. Feature-based representation

3.1. Part representation

In this paper, a feature-based representation is used to represent axisymmetric mechanical parts. Each part is represented by a feature code in the operation. Two key factors affecting the process plan of a part in the cutting process are its geometry and material. In order to retrieve the similar parts and their process plans, both geometry and material should be represented and considered in measuring similarity between parts. Hence, the feature code of one part consists of a main-string and a sub-string, which represent geometry and material property, respectively. A main-string is a list of part primitives representing the geometry of one part along the axial direction. Each primitive is represented by a geometric feature class storing its geometric data, such as geometric shape, tolerance, and surface finish. The sub-string represents hardness (HD), heat-treatment (HT) and other material properties. Fig. 1 shows several examples of part primitives. Fig. 2 shows an example of part representation. Based on the main-string and sub-string, a hierarchical representation discussed in the next section is developed to incorporate different perspectives of parts, such as material, surface finish, and tolerance.

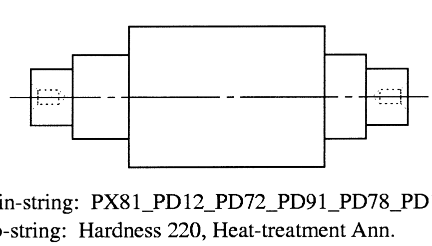

Fig. 2. Part representation.

3.2. Process representation

Each cutting process is expressed as the removal of a geometric feature from the current workpiece. An operation code is used to represent each cutting operation and stored in a plan case. Operation codes are also extended to other non-metal removing processes, such as HT, clamping, etc. Each descendent part results from the application of a cutting operation to its antecedent. Fig. 3 provides an example of using operation codes to model a grooving process and a chamfering process.

3.3. Case representation

A process plan case is a data file, which stores the process plan of a part. A data file contains the procedure of manufacturing raw material into the final product. Here, the procedure includes material removal and non-material removal, and each removal step is composed of an antecedent part, a descendent part, and a cutting operation. An example of case representation can be found in Fig. 4.

4. Case indexing

One of the powerful capabilities of a case-based reasoning system is its ability to retrieve relevant cases from the case base rapidly and accurately. Since the size of the case base is often large, indexing cases in a proper manner so that the system can identify the cases efficiently and find out the most similar case correctly is important. In this paper, a method called feature-based similarity measure is developed for case indexing and case retrieval. This method enables retrieval of the most similar process plan based on an effective similarity function in the proposed application domain.

Three perspectives of a part are considered in the