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A knowledge-based auto-reasoning methodology in hole-machining process planning

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Abstract

In process planning, how to obtain an optimal process planning is the essential of computer-aided process planning (CAPP) system. The main goal of CAPP system is to derive manufacturing features and machining operations from a design model and sequence the machining operations of the part in a feasible (by some technological constraints) and effective (by some economical standards) order. In this paper, we construct a process-planning model (PP model) for the hole's machining, which consists of three parts: the features framework, the precedent relation net and the sequencing mathematical model. The features framework makes a mapping from manufacturing features of hole into its machining operations. A semantic net named the precedence-relations-net reflects the precedence relationships among hole's machining-operations. Some vectors and matrixes are employed to construct a mathematical sequencing model. Usually, a hole should be machined in several operation directions, $v_1, v_2, \ldots, v_M$. In each operation direction, v_i, there are N^l basic geometrical units to be operated, namely, $U_1^l, U_2^l, \ldots, U_N^l$. For each operation direction, v_i, a vector and a matrix are defined to memory the process planning and its operation objects. The mathematical sequencing model will generate an optimal process planning in each operation direction by minimizing the number of tool-changes and decreasing the number of operation steps. Therefore, it can shorten processing times and consume less energy. Finally, two hole-machining examples are employed to illustrate our methodology.

Keywords: Manufacturing features; Machining operations; Precedence-relations-net; Sequencing mathematical model

1. Introduction

Manufacturing process planning is the method to get the necessary manufacturing process and their acceptable sequence in order to produce a given part in an economical and competitive way (a good way by some standards) [1,3–7]. In order to obtain the process planning, the process planner derives some appropriate information from a design model such as the design profile, accuracy, surface roughness, material and so on. All of those information are defined as manufacturing features. Therefore, most of computer-aided process planning (CAPP) systems uses the concept of manufacturing features to describe a part [6,8–10,13,14]. There are two main methods of representing manufacturing features: the superficial approach and the volume approach [1,8,9,13,14]. In this regard, manufacturing features link the computer-aided design (CAD) and computer-aided manufacturing (CAM) [3]. But the problem is how to derive the manufacturing features from a design model and build the bridge that can translate the manufacturing features into the machining operations sequence.

For several years, this problem has received more and more attention from researchers because it is the essential and the biggest problem for generating an optimal process planning. Some researchers construct a knowledge base to solve this problem [1,11,13–15]. To construct the knowledge-based process planning (or feature-based process planning), artificial intelligence technique such as the expert system [11], rule-based inference [12], the neural network [2] and the genetic algorithms [16–18] are always used. Recently, Park [1] employed the knowledge capturing methodology to construct a knowledge base that consists of three sub-models: the object model, the function model, and the dynamic model. Although he gives us a methodology on process planning, it is not a systematic model of process planning.

In this paper, we will employ semantic net and a mathematical model to construct a process-planning model.

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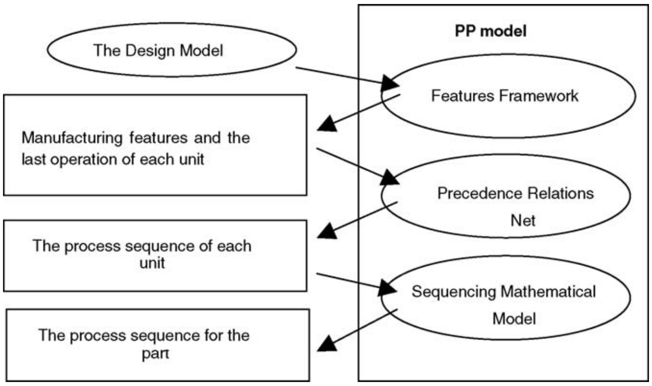

Fig. 1. Process-planning model.

The disadvantage of our method is how to recognize operation directions and basic geometrical units.

This paper is organized four sections. In Section 2, we will construct a process-planning model (PP model) that has three parts: the features framework, the precedence-relations-net (PR-net) and the sequencing mathematical model and can be illustrated by Fig. 1. Firstly, a design model should be decomposed into several units in according with its geometrical profile. By features framework, we can get the manufacturing features and the final operation of each unit. Secondly, a semantic net, namely PR-net, will be build to reflect the precedence relations among machining operations. The final operation of each unit is input PR-net, and then a vector, which consists of operations, is output. The counter-order of this vector is an acceptable sequence for each unit. All of those vectors in the same operation direction are input into the sequencing mathematical model to obtain an acceptable and competitive process plan of this operation direction. In Section 3, two hole-machining examples are employed to illustrate our methodology. Finally, discussion and conclusions are given in Section 4.

2. Construction of the process-planning model

In this section, we will build a process-planning model (PP model). At first, a features framework will classify features of the parts and build a mapping from features to machining operations. Then, a semantic net will be build to reflect the precedence relations among machining operations. At last, a sequencing mathematical model will sequence an acceptable and feasible process planning.

2.1. Features framework

In the literatures [8,9,13,14], there have two main methods to representing manufacturing features: one is the superficial approach in which features are defined as sets of faces having topological relationships, and the other is the volume approach in which volumes are used to define features [1]. In this paper, we use the latter to define features.

Parts have many kinds of features such as the design profile, accuracy, surface roughness, material and so on. Therefore, parts can be classified by a kind of feature. For example, because parts can be classified by its design profile such as hole, slot ware, sidestep, etc., a design profile framework is built. So, we can build a framework for each kind of features. It can be shown in Fig. 2. The last level of each framework is corresponding machining operations of the feature in the framework. For example, from Fig. 2(b), a circle hole has three corresponding machining operations—boring, drilling, and reaming.

A part always consists of several basic geometrical figures. A basic geometrical figure is a geometrical unit. So the design model can be decomposed into several basic geometrical units. A unit has several features, namely, feature1, feature2, feature3, feature4, etc. Each feature has a corresponding operation set generated from features framework. Suppose the intersect set of those sets is non-empty. Therefore, the final operation of this unit can be obtain by intersect those sets. Then, we can derive the final operation of one geometrical unit from the features framework. As Fig. 3 shows, feature1 is the geometrical feature; feature 2 is the accuracy feature and feature3 is the surface roughness feature. Each feature is input the features framework to get an operation set. The intersection of all operation sets is the final operation for each unit.

2.2. Precedence-relations-net

In process planning, there are some technological constraints. For example, a boring operation cannot be performed without a previous machining operation such as drilling because of tool accessibility. Then we construct a semantic net

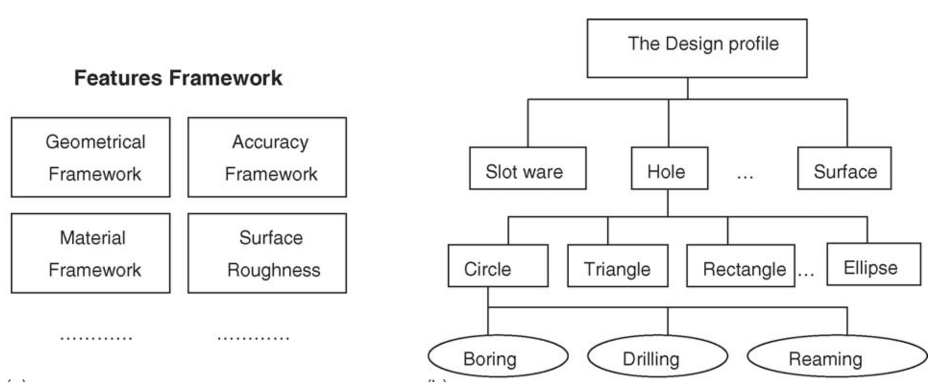

Fig. 2. (a) Features framework; (b) geometrical framework.