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A cooperative agent modelling approach for process planning

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Abstract

A well designed computer-aided process planning (CAPP) system bridges the gap between CAD and CAM. A number of systems have recently been developed relying on a standalone expert system. However, because of over-complexity, many such systems cannot be effectively applied to industrial enterprises in practice. Moreover, the modern computer integrated manufacturing system (CIM) requires the CAPP system to be extendible and flexible for practical industrial applications. It is hardly possible to develop the extensive industrial CAPP system by using only one large expert system. To overcome these weaknesses, a new cooperative agent model is presented for process planning in this paper that satisfies five major requirements: Autonomy, Flexibility, Interoperability, Modularity and Scalability. In accordance with this framework proposed, a machining cooperative process planning system (Machining CoCAPP) is specifically developed for demonstration purpose. The system modelling, agent structure design, cooperation and coordination mechanism, and case study of the Machining CoCAPP are presented. © 2000 Elsevier Science B.V. All rights reserved.

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1. Introduction

Process planning provides information to the shopfloor on how to produce the designed products. It addresses each part of the product separately and collectively. It defines the process, cost and production lead time under the constraints such as the designed geometry, material, quantity, machine and tooling availability, labour capacity and suitability, etc. In the past, process plans were often generated by human process planners who had plenty of manufacturing domain knowledge and worthy experience. In the recent decades, computer technologies have stimulated the advance toward computer-aided process planning (CAPP).

Generally, there are two CAPP approaches: variant and generative. The variant approach is a data retrieval and editing method. Some standard or mature process plans are collected based on the group technology and stored in a database. When a new part is required to be produced, a similar process plan is retrieved from the database and edited to adjust it to suit the new part. The generative approach is a knowledge-based method which automat-

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ically generates a process plan according to the part's features and manufacturing requirements.

The success of the variant approach depends on the group technology, planner's experience and a sufficient collection of standard or mature process plans. This method is especially suitable for companies with few product families and a large number of parts per family. Most earlier CAPP tools can be categorized under the variant process planning approach [1]. Typical examples are CAPP [2], MIPLAN [3], etc. The generative process planning approach has attracted more attention in recent years. It offers a potential of producing an optimal plan. Typical examples are APPAS [2] EXCAP [4], KRONOS [5], XCUT [6], QTC (Quick turnaround cell) [2], PART [7], OOPPS (object-oriented process planning system) [8], MePlans [9], COMPLAN Process Planner (CPP) [10], etc. Generative process planning systems are mostly oriented towards the needs of large companies and research organizations, especially those which have a number of products in small lot sizes. However, there is still difficulty in developing a truly generative process planning system which can meet industrial needs and provide an appropriate and compatible generic framework, knowledge representation method, and inference mechanism.

Cooperative agent systems attempt to distribute activities to multiple specialized problem solvers and to coordinate them to solve complex problems [11–14]. A cooperative agent system consists of many individual agents with cooperation engines. Each agent which has its own knowledge base and inference engine is responsible for a specific task. It provides a cooperation interface to communicate with other agents in the cooperative environment. A different language and different knowledge representation may be employed by each agent which may well be located in a different machine. Such a system organization provides an integration environment of heterogeneous and scalable architecture suitable to solving different problems.

2. Process planning problem

A machining process generally involves many machine tools, operations, fixtures, and cutting tools. Its planning requires knowledge from diversified fields. Generally, a machining process planning includes the following parts:

- feature recognition;
- machining operation selection;
- machine selection;
- cutting tool selection;
- fixture selection and design;
- sequencing operation and cost estimate.

The feature recognition part identities manufacturing features from the product design data. The machining operation selection part selects the relevant machining operation according to the feature characteristics and the manufacturing environment. The required machine equipment is selected for implementing the selected operations after considering the nature of the parts and the machine processing capabilities such as the working volume, accuracy, power, fixturing, and other functions. The fixture selection part chooses the fixtures according to the part geometric shapes and dimensions as well as manufacturing features. The main concerns of the cutting tool selection include the tool types, materials, shapes, and tool dimensions.

3. The proposed method

From the technological viewpoint, CAPP is still a very complex and difficult problem. Many research efforts have focused on CAPP system development, using different methodologies and strategies. However, most systems are developed by using standalone expert systems. Due to the complexity of CAPP, such a system structure is hardly able to solve the problems normally found in the manufacturing industry.

A cooperative CAPP framework is proposed to reduce the limitation of currently available CAPP systems. In particular, it highlights the requirements that a modern CAPP system should meet in order to facilitate practical development: flexibility, modularity, interoperability, autonomy, and scalability [15,16].

- *Autonomy* means that the CAPP system is developed as an independent system. Once developed, it can readily be integrated into the CAD/CAM