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Object-oriented knowledge-based computer-aided process planning system for bare circuit boards manufacturing

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Abstract

The manufacturing industry is time, quality and information driven. In the current highly competitive international marketplace, these factors are especially crucial to the electronics industry. In this paper, an object-oriented model of a computer-aided process planning (CAPP) system for the manufacturing of bare circuit boards is proposed. Process constraints and planning knowledge are all represented and modelled by respective constraints objects. The system is then implemented for the automatic process planning of double-sided circuit boards. The performance of the system is then compared with that of experienced process planners. The advantages in the use of the constraint and knowledge objects approach in a computer-aided process planning system are revealed. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Computer-aided process planning; Object-oriented systems; Electronics manufacturing; Knowledge-based systems

1. Introduction

Over the years, there have been numerous efforts directed toward the development of computer-aided process planning systems. With the rapid introduction of new products in the globalised and highly competitive market, the need for fast product development and short manufacturing turnover time is great. The development and inception of electronic products are thus time, quality and information driven [1,2]. This is especially important in the manufacturing of printed circuit boards (PCBs), which is one of the crucial components of electronic products.

This paper presents the efforts to model and implement a computer-aided process planning (CAPP) system based on an object-oriented modelling approach. First, process planning and computer-aided process planning are examined. Then an object-oriented approach based on an object modelling technique (OMT) is used to model a PCB process planning system. Next, the object model, the dynamic model and the functional model of the system are presented and described. The OMT representations of the problem constraints and knowledge are then illustrated. The hardware and software implementations of the system are then explained. The paper concludes with a discussion of how the system is evaluated and the performance of the system is compared with those of experienced process planners.

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2. Process planning and knowledge-based CAPP systems

Planning is ''the activity of devising means to achieve desired goals under given constraints and with limited resources'' [3]. In other words, planning is a multi-perspective problem solving process aimed at reaching a pre-defined goal under a set of constraints and limited resources. The planning process may involve problem definition, constraint reasoning, goal achieving, resource utilisation and conflict resolution. Process planning in manufacturing is the deciding of how to translate a part design into the ''preferred'' method of manufacture. It was formally defined by the Society of Manufacturing Engineers as ''the systematic determination of the methods by which a product is to be manufactured economically and competitively'' [4]. In CAPP systems, computer systems are employed to capture human planning knowledge and information of a specific manufacturing domain and to execute inference procedures to produce process plans under specific constraints and resources to reach the desired goals.

Two CAPP approaches are commonly used; namely the variant approach and the generative approach [5–8]. The variant approach is based on group technology concepts and the retrieving of useful process plans from the database by recognising similarities among the parts. In the generative approach, no process plan is stored in the database. Instead, new plans for the product are generated based on planning knowledge and heuristics, such as decision logic, formulae, algorithms, equipment capabilities, process specifications and customer requirements. Most of the CAPP researchers concentrated on machining operations. Of the 156 CAPP systems recorded by Alting and Zhang [9], none is focused on process planning for the electronics industry. Likewise, in the survey paper of Cay and Chassapis [8] on CAPP research, there is no reference to research on computer-aided process planning in the PCB domain. With the rapid introduction of new electronic products, the need for fast product turnover is great. The use of computer technology to assist in the planning of bare PCBs in the electronics industry is a logical and timely development [10].

A knowledge-based CAPP system should be capable of performing process planning tasks that are routinely performed by human process planners. It should operate from a heuristic knowledge base that contains representations of process planning knowledge. The architecture of the knowledge-based CAPP system adopted in this project is presented in Fig. 1. It includes the following function blocks:

- planning system operators;
- a user interface for the interactive definition of the planning problem, and for general input/output;
- a knowledge base for the specific process planning domain;
- an inference engine for the planning problem solving;
- a set of planning problem constraints.

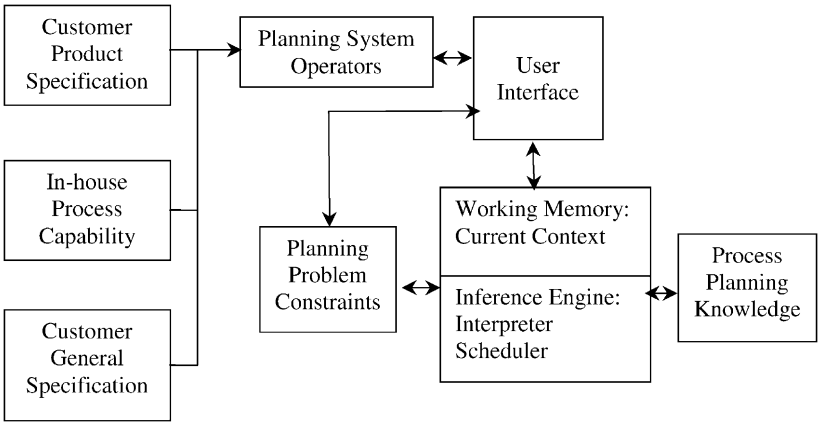

Fig. 1. Architecture of knowledge-based CAPP system.