ELSEVIER

Journal of Materials Processing Technology 139 (2003) 267–272

Journal of Materials Processing Technology

www.elsevier.com/locate/jmatprotec

A holonic architecture of the concurrent integrated process planning system

Jie Zhang [a], Liang Gao [b], Felix T.S. Chan [c,*], Peigen Li [b]

[a] CIM Research Institute, Shanghai Jiao Tong University, China
[b] School of Mechanical Science and Engineering, Huazhong University of Science and Technology, China
[c] Department of Industrial and Manufacturing Systems Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong, China

Abstract

This paper describes a conceptual architecture of applying holon to process planning (PP) for integrating design, PP, and shop floor scheduling so that a concurrent integrated process planning system (CIPPS) is constructed. The problem in PP has been mapped onto a holonic architecture based on multistage cooperation. A holonic architecture for CIPPS integrates all the activities of PP into a distributed intelligent open environment. Holons for CIPPS can be organized dynamically, and cooperate with each other to perform an appointed task flexibly. In addition, using CORBA technology, a prototype system of the CIPPS is implemented.

Keywords: Process planning; CAD; Production scheduling; Integration; Holon; CORBA

1. Introduction

Traditionally, the activities of product design, process planning (PP) and shop floor scheduling are viewed as discrete stages in manufacturing enterprise and developed, respectively, into automation systems. However, decisions taken in one stage affect the decision in downstream stages [1]. Computer aided PP has been recognized as playing a key role in computer integrated manufacturing (CIM) that integrates these islands of automation. It forms an imperative connection between design and manufacturing operations in CIM. However, most of the PP is generated without consideration of real-time dynamic status information in the shop floor, and assumes an infinite capacity of resources on the shop floor, and usually a factory is empty without any work-in-progress when assigning resources to jobs [2,3]. These assumptions lead to the repeated commitment of certain popular resources to numerous process plans [4,5]. Over the past two decades, considerable efforts have been expended in developing integrated computer aided design (CAD) and computer aided manufacturing functionalities. Based on the philosophy of concurrent engineering (CE), a concurrent integrated process planning system (CIPPS) is proposed in this paper to integrate CAD, PP, and production scheduling system (PSS) so that it is expected to significantly enhance the ability of manufacturing companies to adapt efficiently to changing conditions, and yield significant performance improvements (e.g., shorter lead times, increased resource utilization, enhanced due-date performance and coordination between customers and suppliers). In order to implement CIPPS, a holonic architecture is presented, which has characteristics such as distribution, autonomy, interaction, and openness to meet the requirement of CIMS.

The rest of this paper is organized as follows. Section 2 proposes a concurrent integrated PP model. Section 3 describes a conceptual architecture of applying holons to PP for integrating design, PP, and production scheduling. The needed holons are defined. Section 4 describes the cooperation between holons. Using CORBA technology, the CIPP prototype system is constructed in Section 5. Section 6 is the conclusions.

2. Concurrent integrated PP model

CE is an important method of the integration from information to function for CIMS, and an overall optional method for the complicated manufacturing systems. A problem in the traditional product development cycle is that the communication between different perspectives is linear in nature.

* Corresponding author.
E-mail address: ftschan@hkucc.hku.hk (F.T.S. Chan).

0924-0136/03/$ – see front matter © 2003 Elsevier Science B.V. All rights reserved.
doi:10.1016/S0924-0136(03)00233-4

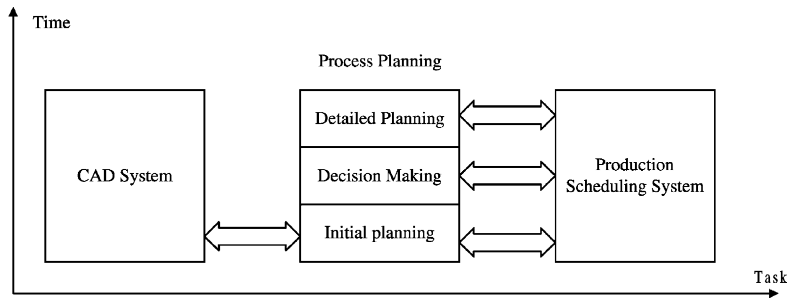

Fig. 1. PP model.

This may lead to long and costly development cycles as design mistakes are often not discovered until downstream stages of product development. In contrast to the traditional sequential approach to design and manufacturing, CE advocates a rapid, simultaneous approach, where concept development, design, manufacturing, and support are carried out in parallel [6]. This approach prompts developers, from the outset, to consider all the relevant element of product life cycle from conception to disposal, including quality, cost, schedule, and user requirements [7]. From the implementation point of view, the CE paradigm can be viewed as an integration of functional software tools. Based on the philosophy of CE, in this paper an integrated PP system is proposed to integrate CAD, PP, and PSS. It can provide not only a tool for the early stage of design but can also reach nearly an optional process plan by working with PP and PSS in parallel.

PP involves multistage decision making so that its tasks may be divided into three levels, namely initial planning level, decision making level, and detailed planning level to complete the task of PP. The activities with each level take place in different time periods, as shown in Fig. 1. Initial planning should be executed in a very early stage, e.g., as soon as the product design is finished. Initial planning level generates a serial of alternative processing routes of part based on processing potential in the shop floor. Decision making is executed in a later stage, i.e., when the orders have been released to the shop. In the decision making level, one suitable process plan can be selected for a part from alternative process plans generated in the initial planning level based on the current status of the shop floor. The detailed planning is executed just before manufacturing begins. The detailed planning level generates a detail PP for the process route by the decision making level. The interaction between PP and CAD takes place in the first level, but the interaction between PP and production scheduling takes place in all the three levels (Fig. 1).

3. Holonic architecture for CIPPS

3.1. Applying holon to PP

In order to implement CIPPS, a holonic architecture is presented, which has characteristics such as distribution, autonomy, interaction, and openness to meet the requirement of CIMS. The holonic manufacturing system (HMS) consortium introduced “holonic” as a hierarchical architecture of self-consistent, cooperating modules. A holon is autonomous and co-operative and sometimes intelligent. It can be made up of other holons. Thus, holon means simultaneously a whole and a part of the whole. This feature distinguishes holons from agents. Sousa and Ramos [8] introduce a dynamic scheduling holon for manufacturing orders.

From software engineering point of view, holons can be thought of as a natural extension to object-oriented programming. Each holon has its own thread of control, and runs independently of the other holons. Holons interact among themselves by sending and receiving messages, but the messages are not in the form of function calls. It is possible to multicast a message to a group of holons, and each recipient holon is free to ignore a message or deal with it at a later stage. Using the holon conception, a complicated system can be divided into different and efficient holons that are more realizable. By this way, the flexibility, expandability and stability of the CIPPS are improved. In order to implement a holonic architecture for CIPPS, the first task is to partition the holons in a system. The principles of division mainly lie in function grouping and sizing. Different functional modules will be grouped into different holons. However, the size of a holon cannot be too large or too small. If it is too large, it will be insufficiently configurable and difficult to change. If it is too small, it will need to define more interface messages and will be more difficult to integrate. According to the above principles and a new PP model (as shown in Fig. 1), the CIPPS is partitioned into several holons, such as task holon, initial planning, decision holon, detailed holon, etc. These holons can be mapped to different functions and objects of the PP. They can be organized dynamically, and perform flexibly and cooperatively the task of PP.

3.2. Holonic architecture

Holonic architectures are robust and dynamic; they can quickly react to unexpected events, and adapt to changing conditions. They are inherently distributed and scaleable: more holons and more computers can be added as necessary to increase the performance or the capacity of a system.