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An architecture for the vertical integration of tooling considerations from design to process planning

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Abstract

To meet the competitive demands of modern manufacturing, it is necessary to reduce design times and enrich decision making by integrating process planning into the design activity using Concurrent Engineering principles. Although this is traditionally done through the interaction between designers and process planners, it is perhaps more desirable for a CAD system to have the functionality necessary to automatically advise the designer of the shop floor implications of design decisions. Cutting tool selection is an essential thread linking feature-based design of machined parts to process planning. Thus, the implementation of tooling considerations into design is an important requirement for an integrated CAD/CAPP system. This paper defines an architecture to enable the vertical integration of tooling considerations from early design to process planning and scheduling. The architecture is based on a five-level tool selection procedure which is mapped to a time-phased aggregate, management and detailed process planning framework. This paper draws on literature and the results of an industrial survey to identify the tooling methods suitable for integration within a CAD system and categorises them into the five levels of tool selection. The functions are then placed on a time-dependent framework that covers the progression of a product from design to process planning. The new functionality is being implemented as an object-oriented application called VITool, which is being developed so that it can be fully integrated within an existing CAD system.

Keywords: AMD; Tool selection; CAD; CAPP; Capability analysis

1. Introduction

The organisation of a manufacturing facility of any kind is a highly complex task involving a myriad of different skills. Examples of the different tasks involved include routing, tool selection, set-up analysis, cutter path optimisation, machinability assessment and time and cost estimation. The subject areas and methods that encompass these functions are also wide ranging and include feature technology, artificial intelligence, mathematical modelling and manufacturing philosophies (cellular manufacturing, just in time, agility, etc.) amongst others [1,2]. To provide enough time for the decision-making process associated with these tasks, it is desirable to integrate process planning within all the stages of product development from conceptual design through to the introduction of the finished design on to the shop floor. Since many activities within design and process planning have been implemented as computer software in the form of computer-aided design (CAD) and computer-aided process planning (CAPP), it is now becoming feasible to automate process planning tasks as a design takes place and information about the component being designed becomes available. The three key elements required for successful CAD/CAPP integration are [3]

1. A framework for structuring manufacturing information.
2. Procedures for mapping form features to manufacturing considerations.
3. Procedures for utilising available information about components already machined.

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This paper describes the characteristics of an intelligent design system with embedded process planning functionality within the context of the above key elements. Emphasis will be placed on the following.

- The need for an integrated system to carry out process planning in a time-phased manner, such that methods are invoked when the data they need become available.
- The importance of tooling issues as a link between design and process planning.
- The use of object-oriented methods to enable an integrated system to be implemented as a module of an existing CAD system.

As well a carrying out a review of existing research, a limited survey was carried out to establish Industry requirements for intelligent manufacturing. The survey involved 400 companies from various manufacturing sectors (small job-shop firms to large flow manufacturers in various industrial sectors including tool manufacturing, aerospace, shipbuilding and general batch manufacturing) from which 38 useful responses were returned. Interviews with the five collaborating companies involved with the project were also carried out to gain more opinion about the topics covered in the survey. The key findings of this survey are presented in the appendix and are referred to throughout the remainder of this paper.

2. CAD/CAPP integration

In the Introduction, the three key elements of successful CAD/CAPP integration were outlined. Each of these will now be discussed in turn.

2.1. Structuring manufacturing information

The framework used within this research for structuring manufacturing information is that of the time-phased aggregate, management and detailed (AMD) architecture for the classification of process planning methods according to input data requirements and the required interfaces with design [4]. The AMD architecture and its links with design are shown in Fig. 1. The objectives of each stage of AMD are as follows. Aggregate process planning, corresponding to conceptual and embodiment design, involves identifying processing options for a component and creating production routings. Management process planning assesses and rationalises the processing options identified at Aggregate level and takes place during the final, detailed stages of design. Detailed process planning, which takes place once the design is complete, optimises the remaining options to provide approved process plans. As can be seen from Fig. 1 and from the discussion above, the nature of AMD facilitates a link to scheduling activities with the result that

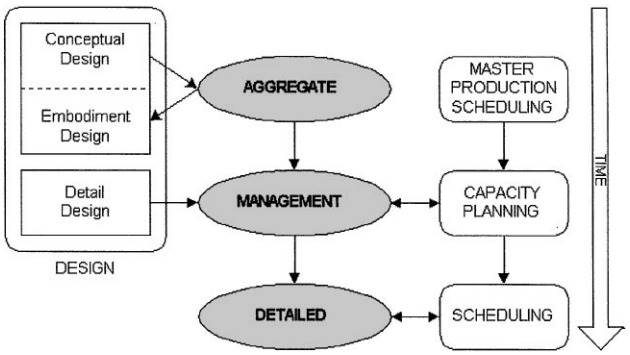

Fig. 1. The AMD process planning architecture.

complete manufacturing planning can be carried out as a design progresses.

The most important stages of design are the conceptual and embodiment stages, since the greatest scope for cost reductions exists during the early stages of product development [5–7]. Hence, aggregate process planning is by implication a very important process planning stage. Any proposed architecture for the implementation of process planning activities within CAD has to consider the fact that during the early stages of design, there is insufficient data available to construct a detailed product model, without which it is impossible to prepare detailed process plans [8]. Aggregate methods use the limited data available during the early stages of design to formulate processing options. The methods invoked during management process planning carry out multi-criteria assessment of the options identified during the aggregate stage in order to create a short list of options that are most likely to be used. These methods are different from those required for detailed process planning, which use data analysis and optimisation methods along with shop floor expertise to determine the accurate data necessary for machine programming, scheduling and shop floor control.

2.2. Mapping form features to manufacturing considerations

As previously indicated, the tasks carried out by various CAPP systems are highly varied. However, the process planning function that can most easily be integrated into design, is the task of tool selection [9]. The three main reasons for this are as follows.

Firstly, the building blocks for component design are features which represent the technology required to manufacture the component being developed [10]. Tooling issues can be mapped to both geometrical feature representations and manufacturing requirements and so act as a bridge between the geometry of design and the technology of manufacture. Since tool selection is one of the first steps of process planning, tooling