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An approach for interlinking design and process planning

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Abstract

Interlinking design and process planning plays a key role in realizing Computer Integrated Manufacturing (CIM). Given a part geometry from a CAD system, CAPP generates a sequenced set of instructions to manufacture the specified part. In order to do that, CAPP has to recognize manufacturing features of the part and the relevant information about precision requirements such as surface roughness as well as dimensional and geometric tolerances. Since geometric models from most of the current CAD systems do not incorporate this manufacturing information, human intervention at the first stage of CAPP is inevitable. This has been a major hindrance to information flow between design and process planning. This paper proposes an approach for interlinking CAD and CAPP, and describes the relevant efforts towards it: recognition of machining features, handling of manufacturing information, and implementation of a neutral interface using ISO 10303-224.

Keywords: Design; Process planning; Manufacturing information; Machining feature; Tolerance; Surface roughness; STEP

1. Introduction

Computer Integrated Manufacturing (CIM) is a conceptual basis for integrating the applications and information flow of product design, process planning, production planning, and manufacturing processes. The focus of CIM is on information as the crucial element linking all facets of the manufacturing enterprise. While the geometry information is created from the design activity, the manufacturing information is concerned with the process planning, production planning and plant operations. Given a part geometry, Computer Aided Process Planning (CAPP), the bridge between Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM), generates a sequenced set of instructions to manufacture the specified part. To do that, CAPP has to extract manufacturing information such as machining features and precision specifications including surface roughness, and dimensional and geometric tolerances in order to select the necessary processes and determine the operation conditions. Despite a lot of effort done in the past to interlink design and process planning, sharing of manufacturing information still remains a bottleneck [1–3]. One of the reasons is that tolerance and surface finish data are not embedded in the geometric model. At a glance, CAD models seem to incorporate these data as seen in the drawings. However, as a matter of fact, these data are not real attributes of CAD models but simply represented as text on the drawing the same as technical notes. This results from most of the current CAD systems not having the appropriate data structure to accommodate them. Therefore, when a CAD model is to be transferred to downstream users such as the process planner or the inspection planner, every user repeatedly needs to regenerate the necessary manufacturing information through human intervention. To avoid this inefficiency, an integrated product model should be achieved, in which manufacturing information and geometry data can be stored together. At the same time, a neutral format for the representation would be desirable for facilitating an interface between disparate computer systems. STandard for the Exchange of Product (STEP) model data, which is defined as the international standard ISO 10303 [4–6], includes not only geometry but also technical and managerial information, and thus gives a clue to the solution.

This paper proposes an approach to interlink design and process planning by representing manufacturing information together with part geometry in an integrated product model based on the STEP neutral format. Fig. 1 shows the problems to be considered for interlinking design and process planning, namely the recognition of machining features, the incorporation of manufacturing information such as surface

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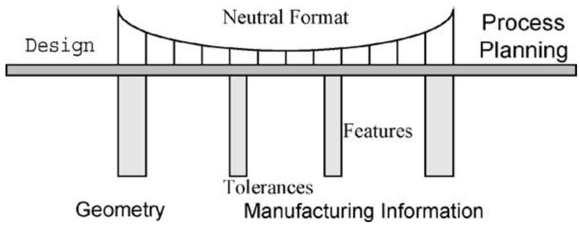

Fig. 1. Elements needed to bridge design and process planning.

roughness and tolerances, and the implementation of a neutral interface.

2. Previous work

2.1. Feature recognition

Feature recognition has been the subject of research since the seminal work of Kyprianou [7]. Among a number of methods, four distinct approaches are currently attracting attention: graph pattern matching, convex hull decomposition, cell-based decomposition, and hint-based reasoning. Consult [8] for a critical survey of these approaches. Despite two decades' research, the impact of features technology has been insignificant, and the results have rarely been transferred into industry. One of the reasons is that feature recognition approaches proposed so far have not been in accordance with the requirements of CAPP. Either the coverage of feature recognition is limited to some ideal geometric shapes, or they do not sufficiently take into account manufacturability issue such as manufacturing cost minimization [9]. At the same time, some feature recognition approaches focused on manufacturability are known. Gupta [10] used a branch-and-bound algorithm to generate an optimal feature model. Similarly, Sormaz [11] used A* algorithm for optimal process planning. However, feature precedence relations are not precisely defined in their systems. *Integrated Incremental Feature Finder* (IF^2) , utilized in this research, takes into account the manufacturing set-up cost minimization with the aid of a search algorithm [9,12–14].

2.2. Tolerance information processing

Technological information such as dimensioning, surface condition and tolerance of geometric characteristics dictates the machining requirements and crucially affects the product cost. Therefore, these specifications have been principally examined from the viewpoints of functionality and cost. Few works have been done on incorporating the technological information into the geometric model, and commercial CAD systems have disregarded this issue. Bley et al. [15] and Wittmann [16] suggested a concept of a tolerance information system which provides designers with an integrated environment to make use of tolerance related information such as cost, machining time, and feasibility. Even though they take into consideration both the functional and the manufacturing viewpoints of tolerance, their approach may be regarded a kind of technical information management dedicated to a CAD system in use. Ha et al. [17] proposed a tolerance representation scheme to integrate geometry and tolerance information. Through a user interface, tolerance types and values can be assigned to the selected entities. The outcome is an integrated geometry and tolerance model in an ad hoc format. Moreover, the system is bound to a specific geometric kernel, ACIS, requiring the geometric model to be exclusively in ACIS format. Thus, the suggested system is very restricted in its portability because of its geometry input method only through ACIS and the output format for the tolerance model that is neither standard nor neutral.

2.3. Neutral interface for manufacturing information exchange

Data exchange not only between CAD packages but also between CAD, CAPP, and CAM systems can be effectively done through a neutral standard format. Among many data exchange formats developed, Drawing Transfer File (DXF), Initial Graphics Exchange Standard (IGES) and STEP model data are the most widely accepted. In contrast to DXF and IGES, STEP is aimed to define a standard file that includes all information necessary to describe a product from design to production. It supports multiple application domains, for instance, mechanical engineering, electronics, architecture [4]. STEP AP224, mechanical part definition for process planning using machining features, contains all of the information needed to manufacture the required part, including materials, part geometry, dimensions and tolerances, applicable notes and specifications, and administrative information. The current scope of the STEP224 is restricted to a single mechanical part manufactured by a milling or turning process [6,18]. Although a lot of work applying STEP AP203, configuration-controlled design, has been reported in the literature [19,20], research dealing with STEP AP224 is rarely found yet.

The South Carolina Research Authority (SCRA) team has conducted a couple of researches investigating the CAD-independent applicability of STEP standards in interfacing design and process planning [21,22]. An attempt has been made to implement information flow from design to manufacturing in a distributed and networked environment by describing manufacturing information such as material, process property, specifications, surface property, and administrative data in a note block of a STEP file. However, the relationship between these data and geometric entities is not represented, and therefore the intervention of a process planner is still required to retrieve the manufacturing information. In addition, tolerances are stored as plain text, which results in the format and meaning of every position in the text having to be specified when a STEP file is delivered.