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A framework for extending computer aided process planning to include business activities and computer aided design and manufacturing (CAD/CAM) data retrieval

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Abstract

Computer aided process planning (CAPP) systems have had limited success in integrating business functions and product manufacturing due to the inaccessibility and incompatibility of information residing in proprietary software. While large companies have developed or purchased complex order management and engineering applications, smaller manufacturers continue to use semi-automated and manual methods for managing information throughout the lifecycle of each new product and component. There is a need for reconfigurable and reprogrammable systems that combine advances in computer aided design (CAD/Computer Aided Manufacturing (CAM) technology and intelligent machining with product data management for documentation and cost control. The goal of this research is to demonstrate an architecture in which customer service, CAPP and a costing methodology known as activity based costing (ABC) are incorporated into a single system, thereby allowing companies to monitor and study how expenditures are incurred and which resources are being used by each job. The material presented in this paper is the result of a two year university and industry sponsored research project in which professors and students at the Costa Rica Institute of Technology developed a software application for FEMA Industrial S.A., a local machining and fabrication shop with sixty five employees and both conventional and CNC capabilities. The final results represent not only a significant contribution to local industry and to the students' education but, also to the continuing growth of CAPP. Implementing better decision making tools and standardizing transactions in digital format would reduce the workload on critical personnel and archive valuable knowledge for analyzing company methods and expertise.

Keywords: Capp; Activity based costing; CAD/CAM; Product data management

1. Introduction

The Costa Rica Institute of Technology (ITCR) is very conscious of its role and responsibility in contributing to the growth and modernization of the national manufacturing industry. Companies are constantly looking for new tools to optimize the use of their resources and to remove the divisions which exist between administration, engineering and production on the shop floor. While many years of experience in component and assembly fabrication have provided engineers and machinists with extensive knowledge related to processes and machines, companies continue to struggle in the areas of automation, information management and computerized design and planning techniques. The goal of this research is to develop a software framework that demonstrates how computer aided design (CAD)/computer aided process planning (CAPP)/computer aided manufacturing (CAM) technology can be combined with costing and business tools and made available to small and medium sized firms.

There are various well documented approaches that integrate cost analysis with CAPP. The first involves providing immediate feedback to designers as they work so that the economic implications of their decisions are understood at the earliest possible time and unnecessary costs can be avoided [1]. The second utilizes methods focused on optimizing process plans on the basis of time

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or cost or on some weighted combination of the two. Tool selection, process selection, tool path design, process parameter selection and operation sequencing are the most common areas for optimization in process planning. Mathematical methods such branch-and-bound for tool selection, dynamic programming for parameter selection and genetic algorithms for operation sequencing are among the examples [2].

This research proposes an activity based costing (ABC) methodology which does not optimize the process plan but, instead provides a tool for identifying the origin of each cost associated with designing, engineering and fabricating a part using company resources. ABC has proven to be very effective in product manufacturing and where automated processes are prevalent. The proposed system utilizes a Visual Basic 6 (VB6) interface that ties together customer service, process planning, a commercial 3D CAD solid modeling system, a CAM system that has built in CAPP and various business functions such as databases and document generation. This unique approach also addresses the complex problem of retrieving design and manufacturing data, critical to the overall cost of the part, using commands from the CAD/CAM Application Programming Interface (API) library of functions.

Fig. 1 outlines the specific areas of work related to the research presented in this paper. Phase one consisted of identifying the level of soft automation and CAD/CAM/CAE system usage in the local industry, specifically at component and assembly manufacturers who use CNC equipment. An evaluation of questionnaires and interviews led to the selection of a company that met the criteria of having the personnel, software capabilities and infrastructure necessary for developing a working program and a corporate vision toward automated manufacturing. A team from the university was composed of professors and students with multidisciplinary skills and backgrounds such as design and manufacturing, cost analysis and computer programming. A detailed analysis of company operations and interviews were used to determine the flow of information and specific software functionality. Program design and development, testing, presentations to representatives and documentation completed the project.

2. Background information

Process planning is 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' [1]. It is the bridge which connects the engineering department to the shop floor and includes all of the steps required to convert design specifications into detailed manufacturing instructions [3]. Process planning is defined by Chang and Wysk [4] as the function within the manufacturing facility that establishes which processes and parameters are to be used (as well as those machines capable of performing these processes) to convert a work piece to a finished part from its initial form to the final one predetermined in a engineering drawing. A typical plan includes detailed drawings, routing sheets, material, tooling, fixtures, part programs and cost data [5]. Process planning is difficult to automate because of the practical experience required to make technical decisions and the company specific knowledge utilized by planners to produce and optimize final plans.

2.1. Review of existing work in computer aided process planning (CAPP)

CAPP systems automate some or all of the manual process planning areas mentioned above, thus minimizing user interaction and drastically reducing the time to produce usable plans. CAPP optimizes and computerizes process planning by using software programs and optimization techniques. Due to the disappearance of experienced process planners in industry, shorter product life cycles and the importance of CAD/CAM integration, research in areas related to CAPP is receiving widespread attention and growing more than ever before [2]. Significant benefits can result from the implementation of CAPP. In a detailed survey of twenty-two large and small companies using CAPP systems, the following estimated cost savings were achieved: 58% reduction in process planning effort, 10% saving in direct labor, 4% in material, 10% in scrap, 12% in tooling and a 6% reduction in work-in-process [6]. Other benefits include the standardization of company practices, increased productivity for planners and better interfaces to related programs [3].

Traditional CAPP systems were classified as either variant or generative. Variant systems follow the principle that similar parts require similar plans. Therefore, the process requires a human operator to classify a part, input part information, retrieve a similar process plan from a database (which contains a library of previous process plans), and edit the plan to produce a new variation of the pre-existing plan. Planning for a new part involves retrieving an existing plan and modifying it based on the new conditions. In some variant systems, parts are grouped into a number of part families, characterized by similarities in manufacturing methods and thus related to group technology [2]. Generative process plans utilize decision logic, mathematical formulas, manufacturing rules and geometric data to determine the processes required to convert the raw material into a finished part. This type of system develops a new plan for each part based on input about the part's features and attributes. Due to the complexity of this approach a generative CAPP system is more difficult to design and implement than a system based on the variant approach. But, a generative CAPP system does not rely so much on the aid of a human planner, and can produce plans not belonging to an existing part family [2].

Different researchers distinguish dynamic process planning from static one in different ways. Usher and Fernandez [7] proposed that the static process plan is