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Development of a generic computer-aided process planning support system

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Abstract

Although there is significant industrial need for comprehensive computer-aided process planning (CAPP) systems, most traditional CAPP solutions have been fragmented in nature. This is because each CAPP domain (assembly, machining, inspection, etc.) has been treated independently. This paper argues in favor of adopting 'feature-orientation' as the unifying theme and describes a Generic CAPP Support System along with the geometric feature recognition algorithms involved. Finally, some case studies derived from diverse application domains are presented to illustrate the advantages provided by the approach.

Keywords: Feature recognition; Computer-aided process planning; Case-based reasoning

1. Introduction

Computer-aided process planning (CAPP) has long been recognized to be an important component and enabler of Concurrent Engineering (CE). CE is facilitated by the availability of a computerized system for estimating production costs and times that, necessarily, includes a comprehensive and robust CAPP system.

An effective CAPP system needs to be comprehensive because the production of a product (and, even, a single part) often needs a large variety of processes. Each of these processes may be a potential participant in the production process. These have to be individually evaluated in the context of the particular design specification of the part/product under consideration. A major hurdle faced by developers of a comprehensive CAPP system is that the processes it has to address have usually very little in common. The nature of each process and, hence, the knowledge base needed in its evaluation and design are quite distinct. As a result, the very subject area of CAPP has tended to be highly fragmented where each process domain is tackled in an independent and parallel fashion (see Fig. 1). Often, the resulting overall system is quite restricted in its scope and, even within this limited scope, there is considerable redundancy. In short, very little progress has so far been made with respect to meta-reasoning concerning the basic nature of process planning itself in terms data utilization and data processing methods so that one could hope to develop a comprehensive but more coherent and less redundant CAPP system. The present paper offers a solution that goes some way towards redressing this situation.

The proposed strategy is based on the following premise. The creation of any domain-specific process plan typically involves two interacting thought processes: extracting relevant high-level information from the part/product needs to be collected, and reasoning over it on the basis of the corresponding domain-specific knowledge bases (DSKBs). Of these, the latter are likely to have very little in common. Hence the concept of DSKB cannot be the key to the desired 'seamless' integration of CAPP. In contrast, *every* CAPP sub-module involves reasoning over the part/product specification (specifications of form, dimensions, tolerances, surface roughness, etc.). Hence, if one wishes to develop a CAPP strategy that is applicable to (almost) every domain-specific CAPP sub-system, the strategy used must recognize and exploit part/product information as the unifying theme.

An implication of the premise described above is that there *could* be a common 'front end' to every domain-specific CAPP sub-module that: (i) requires only the specification of the part/product as its input; and (ii) does not address issues requiring the use of a DSKB.

We will refer to this 'front end' as the *Generic CAPP Support System* (GCAPPSS).

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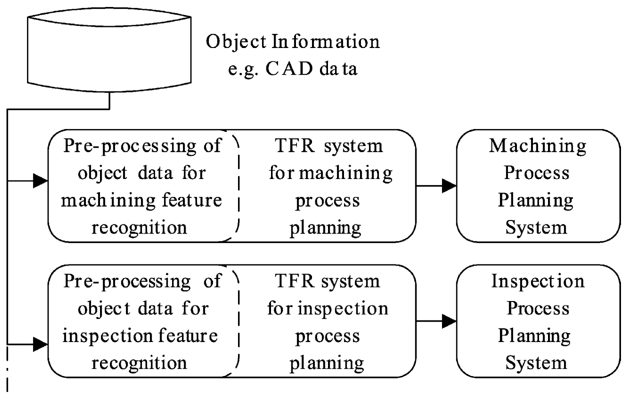

Fig. 1. Traditional approach to the development of a comprehensive CAPP.

This support system can be expected to act as the common starting platform for diverse domain-specific CAPP systems to be developed subsequently—thus reducing the overall effort needed in achieving a comprehensive CAPP system. The principal intent of the present paper is to argue in favor of the desirability, feasibility and utility of the concept of GCAPPSS. The rest of the paper is structured as follows. Firstly, arguments will be presented in favor of separating technological feature recognition (TFR)—a process implicit in any domain-specific CAPP—from geometric feature recognition (GFR) and making the latter as the 'front end' of GCAPPSS. Next, certain complexities associated with technological as well as GFR will be highlighted. This will be followed by a brief introduction of several GFR related algorithms developed by the authors.

These algorithms are not only capable of extracting and recognizing geometric features, but also decomposing complex features into simpler ones to facilitate the identification of all possible feature relationships. The information so gathered is then reorganized to yield a multi-layered part representation that facilitates multiple interpretations of the same part from different CAPP viewpoints. Finally, the implications of GCAPPSS with respect to downstream TFR and CAPP processes will be highlighted.

2. GFR: the 'front end' of CAPP

Usually, when a process planner initiates a planning exercise, the first thing that (s)he examines is the part to be manufactured. This is typically done with reference to a visual image of the part and never the raw data of the part's computerized model. The planner then abstracts high-level information from the image. In particular, the technological features are first extracted. For instance, a machining process planner might be interested in recognizing cylindrical holes, if any, existing in the part so that (s)he can plan the corresponding drilling and reaming operations. These technological features form a subset of the part model that are of interest in the context of the specific process planning domain. Hence, TFR cannot be used as the basis for GCAPPSS.

Although technological features are domain-specific, almost all of them seem to be rooted in certain geometric features implicit in the geometry of a part. For instance, while one is deciding whether there is a need to invoke drilling cycles (an activity of machining process planning (MPP)), or planning the measurement of a finished hole's diameter (an activity of inspection process planning (IPP)), the focus is on recognizing cylindrical depressions (essentially a geometric concept). Thus, GFR is the 'front end' of almost every domain-specific TFR. Further, the data needed for GFR are derivable exclusively from the CAD model of the part/product, i.e. GFR does not need the invocation of extensive domain-specific knowledge. Hence, it makes sense to build GCAPPSS around GFR as illustrated in Fig. 2.

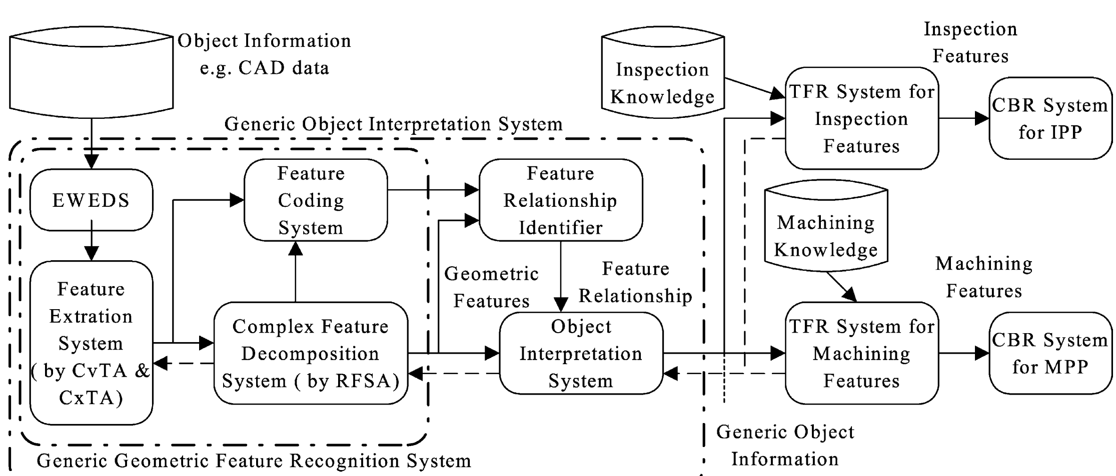

Fig. 2. The proposed structure of the GCAPPSS.