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Automated inspection process planning: Algorithmic inspection feature recognition, and inspection case representation for CBR

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Abstract

General metrological inspection planning is among the least explored computer-aided process planning (CAPP) domains. This paper explores certain basic issues involved in inspection planning using case-based reasoning in an environment of a Generic CAPP Support System. Firstly, algorithmic methods for characterizing and extracting inspection features are proposed and discussed. A sequential knowledge based filtering method is developed to reduce the number of inspection features typically encountered in metrological inspection planning. Finally, a formalized approach for case representation of relevant inspection domain knowledge using a newly developed parametric-list technological feature graph (PLTFG) is presented.

Keywords: Computer-aided process planning; Computer-aided inspection process planning; Inspection feature recognition; Case-based reasoning

1. Introduction

Concurrent engineering (CE) has emerged as a commonly accepted solution to the sharply decreasing time-to-market problem in manufacturing. In practice, the effectiveness of CE depends greatly on the availability of highly automated and reliable computer-aided process planning (CAPP) tools. As a result, a variety of algorithmic and artificial intelligence (AI) based methods have been developed in the last two decades to address different problems arising in CAPP [1–9].

The manufacture of any part/product involves several processes: machining, casting, injection moulding, inspection, etc. Under each of these processes, there are several sub-processes each with very distinct characteristics. For instance, machining may involve a variety of operations such as turning, milling, and drilling carried out on separate machines or on a single machining center. Likewise, inspection could be carried out through a sequence of operations each carried out with the aid of a different metrological instrument or on a single coordinate measuring machine (CMM). Further, one needs to evaluate several competing manufacturing processes at each stage in process planning. All this suggests that there is a strong need for a *comprehensive* CAPP system that encompasses most of the commonly found manufacturing processes in a seamless and integrated fashion. However, it appears that, in general, the currently available CAPP solutions do not meet this criterion. Firstly, the existing CAPP systems address very few of the commonly used manufacturing processes. While machining and assembly processes have been extensively supported in CAPP systems, many other manufacturing processes and inspection (with the

Abbreviations: AI; Artificial intelligence; CAIPP; Computer-aided inspection process planning; CAPP; Computer-aided process planning; CBR; Case-based reasoning; CE; Concurrent Engineering; CMM; Coordinate measuring machine; CvTA; Concave triggering algorithm; CxTA; Convex triggering algorithm; EWEDS; Enhanced winged edge data structure; GCAPPSS; Generic CAPP support system; GFR; Geometric feature recognition; IPP; Inspection process planning; MPP; Machining process planning; PLTFG; Parametric-list technological feature graph; QTC; Quick turnaround cell; RFSA; Root face segmentation algorithm; TFR; Technological feature recognition

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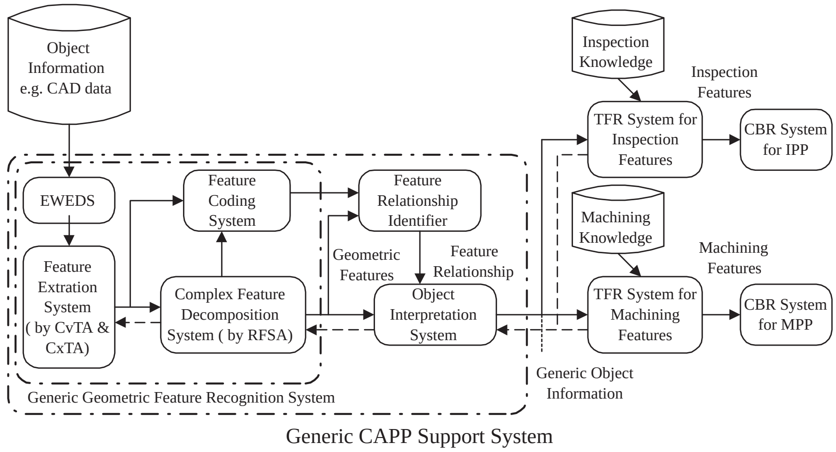

Fig. 1. The role of Generic Computer-aided Process Planning Support System in comprehensive computer-aided process planning.

exception of inspection using a CMM) have received very little attention. Secondly, since the planning of a manufacturing process requires reasoning based on process-specific technological knowledge, existing CAPPs tend to be fragmented rather than integrated with each process being dealt with by a totally independent module.

The issue of fragmentation of CAPP was brought into focus recently addressed by Yuen et al. [10]. It was suggested that, while each CAPP domain might be distinct in terms of the technological knowledge, the competing manufacturing processes at each stage of CAPP have one thing in common—they have to perform in only with almost the same part/product objective. It should therefore be possible to aggregate the reasoning processes related to diverse manufacturing processes into a common platform called the Generic CAPP Support System (GCAPPSS)—see Fig. 1—that precedes the individual process specific modules. Yuen et al. [10] suggested that the downstream process-specific modules could be integrated through a common technological reasoning strategy and that case-based reasoning (CBR) is a good candidate in this regard.

However, the implementation of the strategy outlined in Fig. 1 requires that we already have a fair understanding of the product-based reasoning strategies in the various CAPP domains. Unfortunately, at the present the degree of understanding is quite uneven across different CAPP domains. Amongst the most studied seems to be the domain of machining while the least studied seems to be that of inspection.

This paper aims to provide a deeper understanding of the product-based reasoning strategies required in implementing a computer-aided inspection process planning (CAIPP) system based on the notion of GCAPPSS. We will focus mainly on dimensional inspection of parts containing polyhedral and cylindrical features that need to be inspected by using a variety of commonly found metrological equipment. The next section will present an overview of the literature related to CAIPP. This will be followed by a brief review of dimensional inspection. The intention is to arrive at a reasonably complete and generalized set of observations regarding dimensional inspection and the logical characterization of inspection features.

2. Inspection process planning

A CAPP needs to include automated or semi-automated modules capable of performing the following tasks:

(i) Identifying and recognizing the inspection features.
(ii) Identifying and recognizing the associated constraints for the inspection features.
(iii) Recommending an appropriate method for each inspection feature.
(iv) Integrating the various individual inspection operations into an effective and efficient overall inspection plan.

Although much of the inspection carried out in industry continues to be conducted using conventional metrological equipment, most of the reported work on CAIPP has been about inspection operations performed on CMMs. For instance, all the seven basic types of CAIPP systems reported in [11] were directed towards CMM-based inspection. Likewise, many of the subsequent CAIPP developments were also directed towards CMM-based application: probe accessibility and orientation for prismatic parts [12]; optimum determination of measuring points and the associated paths, pre-hit distance, and probe collision prevention [13]; quick turnaround cell (QTC) inspection planner based on a feature-based part model [14], etc.