An artificial intelligence planning approach to manufacturing feature recognition

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ABSTRACT

Within manufacturing, features have been widely accepted as useful concepts, and in particular they are used as an interface between CAD and CAPP systems. Previous research on feature recognition focus on the issues of intersecting features and multiple interpretations, but do not address the problem of custom features representation. Representation of features is an important aspect for making feature recognition more applicable in practice. In this paper a hybrid procedural and knowledge-based approach based on artificial intelligence planning is presented, which addresses both classic feature interpretation and also feature representation problems. STEP designs are presented as case studies in order to demonstrate the effectiveness of the model.

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1. Introduction

Within industrial systems, features have been used for different purposes, such as product design [1], manufacturing process planning [2,3], manufacturability analysis, product model storage and retrieval [4], etc. Enterprises require efficient information flow from one stage to the other within Product Lifecycle Management, for fulfilling customer's requirements and being competitive. Product information must be shared among different enterprise levels and activities in order to make decisions. Hence, several views of the same product information are required. In particular, while CAD is mainly concerned with geometric and topological aspects of the product, CAPP is mainly focused on manufacturing aspects, which yields the need of automated translation of product data as an interface activity.

Within feature recognition, two main issues have been researched, namely intersecting features and multiple interpretations of solid models in terms of features [3]. It is difficult to define a complete universal feature library [3], so it is likely that these libraries will need changes or extensions. However, the creation of methods for making customization and extension of manufacturing feature libraries easier and less costly has received little attention.

In this paper a hybrid procedural and knowledge-based system, based on artificial intelligence planning (AI-Planning) for automatic feature recognition is presented. The knowledge-based part of the proposed method is in charge of the feature recognition task, and follows a declarative approach. Thus, the method focuses on both the classical feature recognition issues and also on the simplicity and expressiveness of feature representation.

2. Previous works related to feature recognition and representation

Feature models can be generated in several ways: interactive feature identification, feature-based design and feature recognition. Within feature recognition, several approaches have been proposed: graph-based pattern matching, volumetric decomposition, hint-based reasoning and hybrid methods [3,5].

In graph-based approaches, both part solid models and features are represented as graphs, and feature graphs are searched within the graph of the part. They allow easy modeling of features, but since exact feature patterns are searched they do not handle intersecting features correctly. For example, Fig. 1(a) shows a simple slot pattern, Fig. 1(b) shows the graph of a slot with intersections, and Fig. 1(c) shows a single slot recognized as 2 features due to the intersections. Graph isomorphism is also computationally expensive [3].

Volumetric decomposition algorithms decompose the delta volume into smaller parts and either directly classify them as features, or combine them into new volumes to be classified. The two main approaches are convex hull decomposition (which only supports polyhedral parts) and cell-based decomposition (which has a great algorithmic complexity) [3]. Several methods have been proposed for decomposing volumes, e.g. rules based on the concavity of edges [6], and optimized cell-based decomposition approaches for reducing the global effect of local geometry [7].

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(a) Simple slot feature pattern.

(b) Slot feature with intersections.

(c) Slot patterns identified.

Fig. 1. Limitations of graph-based methods for intersecting features.

(a) Graph pattern matching.

(b) Hint-based methods.

Fig. 2. General architecture of graph-based and hint-based approaches.

Fig. 3. Proposed feature recognition system architecture.

Hint-based methods search for partial traces (hints) left by features on the part, so they are robust in the presence of intersecting features. Hints detection has been performed using rules based on geometry and topology of faces [2], using feature taxonomies [8,9], and using probabilities for ranking potential feature hints [10]. After detecting hints, they may be directly matched to features by applying rules [2,8,9], but some works propose a generate-and-test phase for constructing feature volumes from hints [10,11].

Some hybrid approaches restore edges and faces lost due to feature intersections, using rules and virtual links [12], evidential reasoning [13], and finding maximal cross-sections [14]. In [15] identification of simple features was added. Recognition of complex features as combinations of simpler ones was proposed in [16]. Other works propose the use of genetic algorithms [17], rules applied on 2D feature patterns [18], and combinations of multiple techniques [19].

Table 1 summarizes the properties of each approach (details may be found in [3,5,11]). In graph-based methods features are decoupled from recognition algorithms (Fig. 2(a)), but they are not robust in the presence of intersecting features. Volumetric decomposition, hint-based and hybrid methods are implemented through specific algorithms containing embedded feature definitions (Fig. 2(b)). Thus, addition or modification of features requires

changes in the software. Previous research on representation of features is related to feature-based design [1].

3. Proposed customizable feature recognition system

One of the biggest challenges addressed in this work is to decouple feature definitions from the recognition algorithms (as in graph-based methods), having at the same time robustness for handling intersecting features (as in hint-based methods). In this section we present a novel hint-based system in which both feature definitions and hints are modeled separately from the algorithm that manipulates them for detecting features. The novelty of this separation is that hints are modeled through the knowledge they entail, instead of the procedure with which they are detected. The most difficult aspect is turning the "recipe" for detecting a hint (the "how", an active component) into a static representation (the "what", a passive input).

Fig. 3 shows the system architecture. The system is hybrid since the Coordination Module, the BRep Parser, and the Knowledge-based Model Generator are procedural while the ai-planner is declarative. Since feature definitions and hints are represented with a declarative logic language separated from the ai-planner,