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Associative feature modeling for concurrent engineering integration

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Abstract

In typical product development processes, like plastic injection mould design, design information flow is not well supported by the current available IT systems. At different stages of a product life cycle, from documentation of requirement specifications, to conceptual design, detailed structure design and production, engineering knowledge is striped off except the bare minimum geometrical and control data, such as computer-aided design (CAD) solid models and cutting tool paths. Associative relations among engineering features are normally ignored; hence data consistency and design changes are difficult to be managed. In this paper, interfacing knowledge oriented tools and CAD application is identified as a technical gap for intelligent product development, and the concept of associative feature is introduced. For high-level reasoning and the execution of decisions, to define associative features in the form of self-contained and well-defined design objects is essential. As a case study, cooling channels in the design of plastic injection moulds with a CAD tool are modeled as an illustrating associative feature type. Potential integration among different applications based on such associative features is also explored.

Keywords: Associative features; Knowledge engineering; Design automation; Injection mold design; CADCAM

1. Introduction

In concurrent engineering [1], all the engineering processes are supposed to be supported with integrated computer-aided tools, and based on a consistent set of data with different application views. Such applications include conceptual design, structural design, detailed design, design analysis for certain specific engineering aspects (DFX), computer-aided process planning (CAPP), and computer-aided manufacturing (CAM) tool path generation, etc. Unfortunately, this proposed scenario has not been realized due to the interoperability limitations of different software packages. So far almost all the computer-aided design (CAD) system vendors have only implemented data exchange functions for un-parameterized two-dimensional (2D) drawings or 3D solid models. Such rigid geometry models are then used for other applications. International effort has been made to develop a standard, STEP, for engineering data representation and communication [2,3]. Although, it has contributed in a great way for product modeling, however, implementing this standard in real applications still requires a lot of information modeling and

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development, especially for the interrelated objects that reflects different perspectives and abstraction levels within the design domain [4].

It has been acknowledged that in concurrent engineering [5], interoperability should cover the relationship between a knowledge-based engineering (KBE) system and a CAD platform. However, to transfer information from CAD to KBE systems is very difficult because KBE systems rely heavily on the design intent to perform activities, such as cost estimation or DFX analyses. The intelligence added to CAD geometry is either stripped off by the translation software or unrecognizable by KBE system. In addition, many CAD systems are unable to completely and unambiguously capture design intent. On the other hand, transfer KBE intelligence to CAD systems is equally challenging because there is no mechanism to enable such information flow.

It has been highlighted in concurrent engineering that product and process models need to be addressed at three different levels of representations, knowledge, information, and data levels [1]. Geometrical entities are complex in nature and are usually integrated with KBE systems via another layer of object-oriented software in order to achieve effective reasoning and execution [1,6–8]. This is due to the fact that most knowledge-oriented systems use first-order logics as the foundation, and each predicate has to be self-contained, and well defined. The format of predicates with objects can be as:

Bigger-than (Object-A, Object-B); or
Bigger-than (x, bigger-of (Object-A, Object-B)).

One way to bridge these gaps is to build high-level design expertise and rules in a knowledge-oriented system [9,10] while low-level design intent into a CAD system in the form of information-rich objects, which can be referred to as features in general although there have been many different definitions in the past literature [11–14]. As shown above, with certain naming conventions, such objects can then be mapped as arguments of predicate calculus, and manipulated with artificial intelligence (AI) languages, such as Prolog. Knowledge-driven queries and operations on these objects become feasible. Once a complete product model is fully defined with self-contained objects, concurrent engineering throughout the product life cycle can be supported via aspect models and meta-models [7,12,15].

In this paper, interfacing knowledge-oriented tools and CAD applications is identified as a technical gap for intelligent product development, and a new concept, named associative feature, is introduced. The authors intend to expand the existing feature types to include a flexible group that has imposed great difficulties in traditional feature based design. For high-level reasoning and the execution of decisions, to define associative features in the form of self-contained and well-defined design objects are essential. As a case study, cooling channels in the design of plastic injection moulds with a CAD tool are modeled in the form of associative feature type. Potential integration among different applications based on such associative features is also explored.

This paper consists of seven sections including this introduction. In Section 2, the feature technology is briefly reviewed. Sections 3 gives a definition for the new feature type, namely associative feature. Then in Section 4, the design of cooling channel representation, after analyzing the detailed requirements, is presented. Section 5, the proposed solution and functionality are introduced. In Section 6, potential integration with other applications is discussed. Finally, summary discussion and conclusions are given in Section 7.

2. Feature technology review

There have been many kinds of definitions for features used in CAD/CAM arena. They are initially modeled based on machining features that can be used to integrate CAPP and CAM packages [11]. After many years of development on feature-based design or manufacturing, most of the implemented features are still CAD application oriented and related to machining processes (e.g. holes, slots, pockets, etc.) or design geometry (e.g. drafting angle). Their definitions are based on predefined parametric templates, which do not have the flexibility to be extended or reconfigured as required by some design processes, like mold-cooling channel design. Otto [16] recognized three groups of information consistency breakdowns to be addressed by feature technology, static, dynamic and hybrid breakdowns. Effort has been tried to overcome these issues, such as CAD and CAE feature information sharing [8]. For example, when plastic parts are to