Towards a Multi-View Semantic Model for Product Feature Description

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Abstract. Multiple perspectives need to be included in a product development process. Engineers from different departments usually have different views on a product design. It is hence necessary to define information structures that support multiple views. This paper provides an analysis and approach to develop a multi-view semantic model of three levels to describe product features. We base our analysis on a three-level conceptulization of engineering design features. The base level is *substance*, the intermediate level is *view*, and the top level is *purpose*. A multi-view semantic model will enhance semantic integrity of feature information throughout the product development for sharing information, such as design intent, manufacturing capability, and quality requirements.

Keywords. Feature-based design, feature modeling, interoperability, multi-view model, semantic model.

1 Introduction

Multiple perspectives, including engineering, manufacturing, business, and marketing, need to be included in a product development process. Engineers from different departments usually have different views on a product design. Realizing the need for multiple views of a product, we propose a multi-view semantic model that has a three-level conceptualization of objects in the physical world. In this paper, only “shape features” are in the scope of discussion. When the term “feature” or “product feature” is used, it is meant as shape feature. Other features, such as functional features and aesthetic features, are out of the scope. Fundamental properties of a feature are specified on the base level. It is the

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substance level. These properties are independent of any application viewpoint. An application requires a specific set of properties, namely, application-centric properties. These properties are on the intermediate level, which is the *view* level. The design intent of a feature is addressed on the top level - the *purpose* level. This three-level conceptulizatoin assists information model developers to category feature properties. Proper categorization leads to unambigous feature definitions in communication between different applications of a feature. Meaningful communication between different application software systems requires features to be described with a predefined information structure, to be adaptable to various applications and to preserve the design intent.

The purpose of this model is to provide application-specific views including any relevant information related to a product and its features, to support unambiguous data exchange becomes intrinsic in an information model. Feature-based product data exchange faces some limitations when it occurs across the different phases in a product development process. Notably, the relation from Computer-Aided Design (CAD) to downstream applications is mainly done by feature recognition, based on the product geometry. The designer's intent is lost during the process. Feature-based exchange is also hindered by the divergent definitions of the feature. A feature can be described as an encapsulation of the engineering significance of portions of the geometry of a part or assembly [1]. The “engineering significance" is application-dependent. Thus, an application-specific feature, such as design, assembly, manufacturing, and inspection, associates a specific meaning with a portion of the part geometry, as shown in Figure 1.

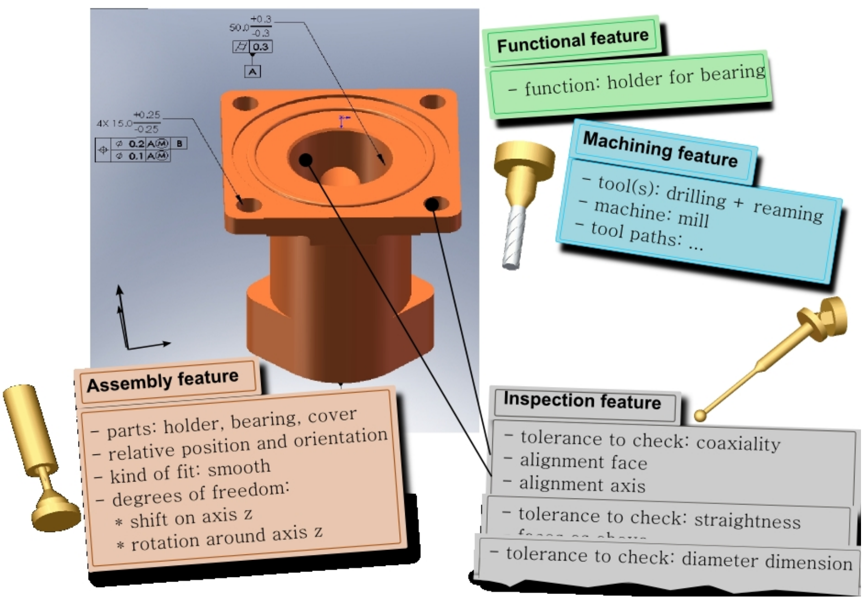

Figure 1 Application-specific attributes related to a hole feature

We explored a methodology to define the meaning of engineering terms more rigorously to enable interoperability among engineering and manufacturing software systems. Inferring from a conducted literature study on feature information models for data exchange, we found that different data exchange specifications have slightly different definitions and representations of feature. As a rigorous definition of feature is needed to enable interoperability, our focus is on semantic modeling.

The paper is organized as follows. Section 2 reviews various approaches to data exchange across applications in product design and manufacturing. Section 3 describes our proposal that the model should be composed of three specific levels of conceptualizing feature from different application perspectives. Section 4 presents a scenario with an example. Section 5 concludes that the three-level approach is a basis for mutli-view semantic modeling of product features.

2 Review of Approaches for Information Exchange Across Applications in Product Development

The ISO 10303 standard series (also known as STEP – STandard for Exchange of Product data) is intended for data exchange between heterogeneous engineering systems. STEP enables the transfer of information, such as geometry and topology [2], features [3], inspection data [4], and machining plan data [5]. The Dimensional Measuring Interface Standard [6] provides communication between CAD systems and Coordinate Measuring Machines. The STEP model of feature is manufacturing-oriented [7]. It lacks the generality that is needed for exchange of product data across different applications. It also lacks constraints between features and suffers from a limited implementation in commercial systems [8]. Exchange of CAD data through STEP does not transmit semantic information such as the axis and curve used to define a part by revolution, but only the raw geometry. The designer's intent that the part should be produced by turning is lost.

For exchange of neutral definitions of features, Shah et al. propose an application-independent declarative language for feature definition [9]. ``N-Rep'' describes the shape of form features with a B-Rep representation and maps them to a face adjacency graph for feature recognition. Features are related to one another through topological or geometric constraints, and feature parameters can be derived from other feature parameters by calculation of an arithmetic expression. Features are defined by their shape only. The model can be extended with user-features. The design intent is lost. Dartigues et al. propose to use an ontology as a neutral model, for “design intent”-preserving conversion between CAD and Computer Aided Process Planning systems. The approach consists in converting design features by mapping the ontological feature model of the system with a neutral ontological feature model. The approach would require that CAx systems publish an ontological model of their features, which has not happened until now [10, 11, 12, 13].

On multiple-view feature modeling, all the approaches focus on building a system where different views of features are defined, and the product model is progressively concurrently built. Consistency management and change propagation among views are the main concerns. The multi-view approach facilitates the exchange of information across domains, but does not aim at providing any means for an external application to relate to the system and exchange information. Bronsvoort and Noort [14] propose a system that supports conceptual design, assembly design, part detail design and part manufacturing planning. All views are updating each other. It is possible to add user-defined features. The design intent is made of constraints and connections between application-specific features.

The macro-parametric approach consists in recording the succession of construction steps (or history) with the parameters used, when building a model in a feature-based CAD system. Then the steps can be "replayed" in another CAD system. The approach is limited to the exchange between systems that have a same set of features. We do not know of any adaptation of this approach for exchange throughout the product development stages. Ding et al. [15] propose a model to annotate semantically a designed part, for improved communication. The approach provides little support for relating application-specific features.

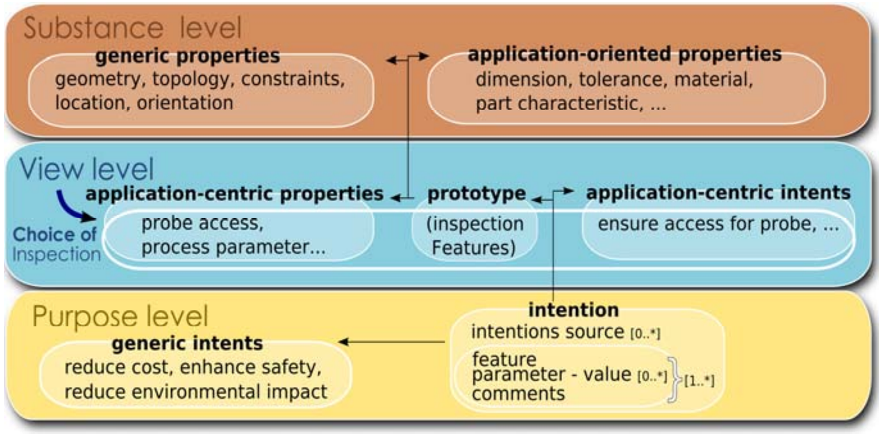

Figure 2 Model overview

3 Definitions in a Three-level Multi-View Semantic Approach

According to the literature study, when geometry is standardized in STEP, a multi-view model is used to describe features from application perspectives, and design intent is poorly communicated. Many generic definitions of feature exist, that describe what "feature" can imply. A feature has a specific meaning within the engineering context, is mappable to a generic shape, and both are related [16]. We thus propose to (1) relate features to a portion of the part geometry, through feature placement and feature recognition by using a pattern matching or trace-based recognition method; (2) describe the engineering context by categorizing features in views, and defining their parameters with application-oriented and application-centric properties; and (3) represent the meaning by intentions[b]. We also propose to categorize feature information in three different levels, namely *substance*, *view* and *purpose*. Figure 2 shows these levels and how they are inter-related. The goal of the design of this three-level model is to provide open semantics and methods to define new views of a feature.

3.1 Substance Level

Features have to be related to some pieces of geometry in a geometric model of a part. Even though the geometry described is not exactly the same for all the related features[c], there is usually some part of the geometry which is shared by the features, by which they could be connected.

All the information that describes the *product* structure, independently of the organization and of the applications is on the substance level. We divide the substance level as follows: **essential properties** that are used to represent a part model, such as geometric and topological elements, dimension, location, orientation, and the location of the material side in the boundary representation; **application-oriented properties** that are essential to some applications, but not all, such as datums, tolerances, dimensions, and material properties [17, 18].

3.2 View Level

We propose to include a meta-model for views so that users can define their own views, according to their perspectives on the product. The view level contains engineering knowledge about the *product*, that is relevant for a particular *application*. As an example, one could define a view for manufacturing [19, 20, 21, 22], with properties like “machine tool” and “tool path,” and features, such as milling and drilling features. The model of view should include **application-centric properties** that are specific to one application, e.g., inspection [23]; and **feature prototype**, which describes how a portion of geometry is interpreted for a particular feature in that application. It thus needs to contain a description of the form of the feature as it should be recognized on the part.

3.3 Purpose Level

On the purpose level, the design intent on a feature and its properties is described. Application experts who participate in the elaboration of the product know the constraints and specificities in their domain. For example, a manufacturing engineer may indicate that some portion of the design is too expensive to manufacture as is. It is often stated that the manufacturing engineer will be interested to know of the designer's intention, but the reciprocal is true as well.

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[b]We distinguish between intent and intention. Intent is a sustained unbroken commitment or purpose. Intention is an intermittent resolution or an initial aim or plan. Source: http://thesaurus.reference.com/

[c]A good example of this can be found in [19], page 116.

The reasoning on why the *product* model is what *it is* results in the purpose of an engineering design. Essential or application-centric intents can be used to describe an intention, which guides the choice of some parameters of feature properties. Intentions must include or be related to the following elements: the source of an intention and feature parameters. For example, a functional intention I_1 can state "*the arm must pivot so that* …." An assembly expert could relate the corresponding features on the two different parts by an assembly-specific view. He could choose the intent "*one-dimension translation,*" and select I_1 as the intention source, with a comment that explains the decision.

4 A Scenario and Example

As features are described relatively to their geometry and topology in views, a feature recognizer may be applied to the part file, or users may manually choose the features in the geometry of the part. Users will thus get the application-specific features in which they are interested.

Users can edit the values for any parameter of the feature recognized, and associate an intention to the modification. If this generates a conflict with another application, the intention is mandatory. While modifying a feature parameter values, users have an immediate visual access to the intents associated with the current value, and to their views, which can help avoid or solve conflicts.

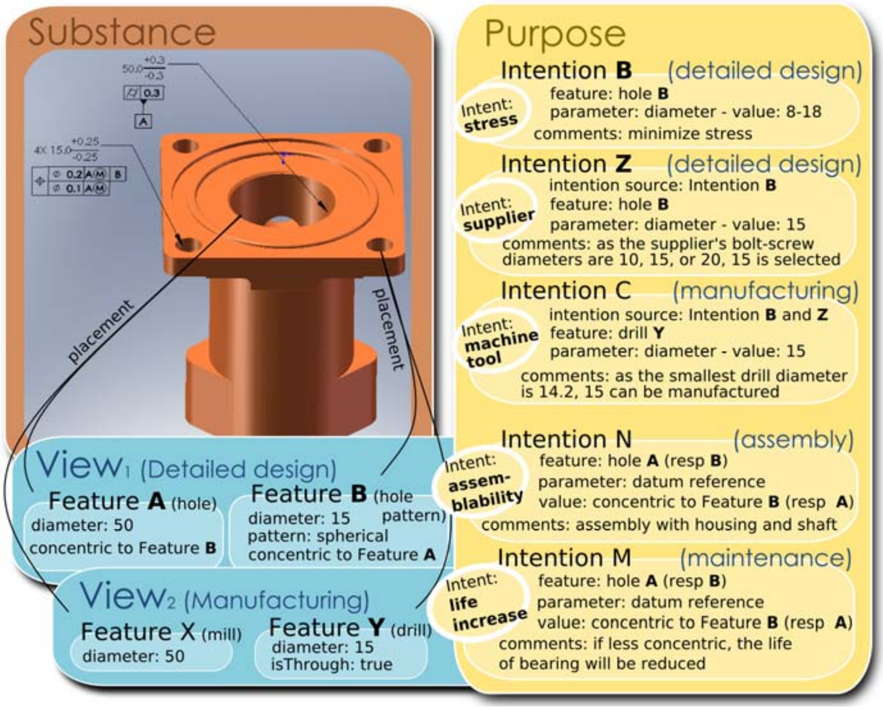

Figure 3 Example use of the model

Figure 3 illustrates the methodology of the model with an example. A part with a toleranced pattern of feature and a datum (*substance level*) is presented along with two views of detailed design and manufacturing (*view level*). The datum hole and the pattern hole and some of their parameters are included in both views as design and manufacturing features. On the right of the figure, intentions for detailed design, manufacturing, assembly and maintenance describe how features are inter-related (*purpose level*). In intention **B**, the designer expresses that the diameter of the pattern hole needs to be in the range 8-18 mm, to minimize the stress on the part. The supplier can supply only bolt-screws of diameters 10, 15 or 20mm (intention **Z**). As the manufacturer's machine-tool cannot drill holes with a diameter less than 14.2mm, the diameter of hole should be 15mm (intention **C**). The reason why the datum hole and the pattern hole should be concentric is expressed in the intentions **N** and **M** from the assembly and maintenance views.

5 Conclusion

An initial work has shown some analyzed characteristics which will be used to develop a novel multi-view semantic model that should support meaningful exchange across the product lifecycle. The model relates features to the STEP definitions for the geometry, and to other standards for tolerancing, dimensioning, and process planning. It also integrates views to support feature descriptions in different applications. We proposed to note the intent explicitly and relate it to an enginneering design, to better preserve it.

We plan to further develop the model based on the three-level conceptualization. We will specify views, based on the NIST models for (a) assembly [1], (b) process planning [21], (c) manufacturing [20, 22], and (d) inspection [18, 23]. Future work should also include an in-depth review of all constraints needed to connect features.

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Acknowledgements

The authors gratefully acknowledge helpful discussions with and comments from Thomas Kramer and Xenia Fiorentini. Funding for this work was provided by the NIST Sustainable and Lifecycle Information-based Manufacturing Program.

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