Analyzing STEP implementations for automated process planning.

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1. Introduction

The concept of which this manuscript is a small detail of was discussed in different papers on various conferences like the 18th and 19th International DAAAM Symposium (Teich et al., 2007) or recently the German-Russian Logistics Workshop in Moscow (Teich et al., 2008). As a short summary, the goal is the automated generation of offers to a customer in a B2B (Business to Business) environment. Therefore various theoretical and practical concepts have been revised, especially the results of the SFB 457 and resulting doctoral thesis's and habilitation treatise (Teich, 2003). The theoretical model of our approach is picturized in figure one.

[FIGURE 1 OMITTED]

After literature study was conducted, the team developed a theoretical model for generating offers based on a functional description of resources and demand. By linking these two, a generative process planning gets possible. An algorithm for generating these plans was developed. Result is a feasible process plan. Since there are different orders of process steps possible and different machines thinkable per process step, complexity has to be revisited if one is trying to get an automated way of interpreting demand to a detailed offer. Therefore different variants are generated, graded by their costs and delivery time and this result is used for generating new variants. The creation of variants is done by a simple Ant algorithm, the grading by genetic scheduling. In short, this theoretical model will lead to an automated way of planning products, considering the abilities of the companies own resources and the utilization of them. Currently we are working on implementation for single piece parts, which can be planned for turning and milling processes. The research presented in this manuscript deals with the description of the demand in order to be able to plan automatically.

One major problem is the description of the demand in a functional way, which means that the single elements of a single piece part can be identified and related to a meaning, the function of the feature. To tackle this, a study on different CAD systems has been conducted.

The paper is structured into three parts,

* Detailed description of requirements for data model

* Evaluation of implementation of STEP in market-leading CAD/PLM solutions (Autodesk Inventor, CATIA, PARTSolutions)

* Review of the new developed AP 224

* Conclusion derived from results

2. Detailed description of requirements for data model

For the automated preparation of offers, a very detailed demand is required. To accomplish our model, the supplier needs to gain all possible information for matching customer's needs. This results from the requirements determined by the concept:

* Work Scheduling has to be performed automatically as far as possible. Therefore the product has to be decomposed in its intermediate products. Intermediated products can be derived by feature separation. Therefore the product has to be described by features only.

* For determination of the raw material, the description needs to cover information about the initial shape, where all features are subtracted from.

* The description of the features has to be accomplished by a relation to other features (this doesn't apply to the initial shape).

As we talk about an ideal situation, the supplier can take for granted that he will get a 3D-drawing of the demand, enriched with data that enables him to give a detailed answer to the request.

Furthermore, the 3D-drawing has to be accomplished by using features, which is a need for the automated process planning and work scheduling later on (Amaitik & Kilkic, 2005; 2007). Features in this context are defined as an accumulation of information which can be used for process planning. Examples are counter holes, filets etc.

These features need to be enriched by physical properties which are always related to a specific feature or a feature face. Furthermore, tolerances and feature type related attributes have to be added. Features, which include these needed information have a higher level of value according to the advanced reason they are used to.

The method we are using is FBD (Feature based design). We are not realizing Feature Recognition because of the additional complexity this will result in. The authors clearly understand that Feature Recognition and FBD need to be accomplished both to make automated offerings and especially the integration of CAD and CAP resulting from it, feasible.

As a last requirement, the language needs to be producer-independent since dependency will lead to the characteristic interface problem or to technology dependencies for companies which try to adopt our approach.

3. Evaluation of implementation of STEP in market-leading CAD/PLM solutions

In a first face, the most reasonable standards for our model seemed to be IGES and STEP. Since IGES is only for the exchange of data between CAD (Computer Aided Design)--Systems, the second face brought our attention to STEP.

The overall objective of STEP is to provide a mechanism that describes a complete and unambiguous product definition throughout the life cycle of a product, independent of any computer system (SCRA, 2006).

The main implemented Application protocols in industry are AP 203 and 214, which are supported by the main CAD vendors for mechanical engineering industry like CATIA, Solid

Edge, Autodek Inventor or UGS (SCRA, 2006).

For our solution we decided to take a deeper look into the implementation of an independent data standard into proprietary CAD and PLM (Product Lifecycle Management) systems, especially in Autodesk Inventor, CATIA and PartSolutions.

The implementation study can be described as follows:

* All descriptions are done for a prototypical product.

* Different methods are used for describing this product

* The export is tested by interpreting the resulting STEP-file

3.1 The Prototype used

For our research we used the prototype shown in figure two.

[FIGURE 2 OMITTED]

The Prototype can be described by 21 features, belonging to 7 classes of features such as hole, chamfer, thread and so on. To develop this prototype, different CAD systems were used, CATIA, Autodesk Inventor and PartSolutions. To cover differences in output depending on the technique the designer uses, different drawing methods were also applied. For practical implementation, the Prototype was produced to match the features needed for production with the features needed by design. This was necessary, to potentially automatically generate process plans from the output of the design stage.

3.2 Used Drawing methods

To design models of products, different methods can be used. It can be distinguished between 2D-, 3D- and Feature-models. It can be stated, that 3Dcontains 2D- models, Feature- contain 3D-modells. For example, a hole can be described by 2D circles, swept on a 2D path to build the volume of a hole. Also volumes are enriched by semantic data to Feature-models. For our approach we tried to model our prototype by features only, mainly by subtractive Feature Based design. We wanted to find out, if we are able in current CAD-systems to do so. Also the output was tested since it is an requirement for further developments. The three modelling techniques can be described as follows:

1) Subtractive Feature Based Design: Starting from a Base_shape, which encloses the final part, features are applied by subtracting their volume from this shape till the final product has been described.

2) Additive Feature Based Design: Features are merged together and subtracted from each other till the final shape has been described.

3) Translation of a shape and subtractive design: A shape is rotated around a axis. The final shape is reached then by subtraction of features like vertical holes for example

3.3 Test- Export

As stated above, the export to STEP was tested in different CAD systems. Figure three shows an example for visualisation and representation in Autodesk and the related STEP-File.

[FIGURE 3 OMITTED]

These exports were also imported in the same CAD-System and the other two which were available to the team.

3.4 Results

The analysis shows the main disadvantages of STEP as it is implemented today. The evaluation is demonstrating the effect of different drawing methods (only subtractive from the raw material feature, additive with defined features only and rotation of a base shape) and compares the output in STEP-Files afterwards.

An Overview of the research work done, is shown in figure four. As stated in the requirements in chapter two, the subtractive feature drawing method is preferred by the authors. Since we also wanted to see the consequences for the output depending on the method a designer is drawing his part, we tested this output also.

Results can be summarized shortly. The translator of each program produces boundary representation models only. Here are the elements needed for our approach, which get lost:

* material properties

* tolerances

* Feature based design history.

[FIGURE 4 OMITTED]

Especially the features used for drawing while using the subtractive drawing approach are very important for the automated process planning. Also tolerances need to be in the model of the demand to determine the resource to accomplish a process step.

It can be stated that the existing implementations are not useful for our approach. Reasons for not using the possibilities of AP 203 and 214 can be seen in the company principles of these CAD-solutions. We assume that they are not really interested in giving the drawing history in a neutral format to the outside of the system.

As a result of this, our team needed to look ahead and search for a more convenient solution, which was found by STEP AP 224.

4. Review of ISO 10303 AP 224

The ISO 10303 standard provides for the exchange during the whole product lifecycle a neutral and computer-interpretable representation of product model data and includes mechanisms relating to the exchange. Mainly interesting parts for the practical use are the domain-specific application protocols (AP). This separation in several context-sensitive protocols enables a targeted using of STEP and keeps the comprehensive suite manageable.

STEP is a solution for the exchange of product model data in a neutral format between extremely differing platforms and computer systems. This is fundamental for the collaboration of different industries within a common project and a requirement for our approach. The standard is divided into various parts each published separately. Hence you just have to purchase only parts of interest.

In short the architecture can be described with five main categories of documents. The essential part is defined by the description and implementation methods which specify elementary fundamentals required to understand the definitions of the application protocols. Furthermore there are integrated resources including building blocks for the definition of application protocols. Another specialty of the standard are the included conformance tests and abstract test suites. Figure 5 illustrates the architecture of STEP (Nell, 2003).

[FIGURE 5 OMITTED]

The STEP AP we decided to go for is AP 224. It is called "Mechanical product definition for process planning using machining feature". A detailed analysis of the AP brought us to this decision, leaded by the following points:

* The determination of the raw material gets possible by the definition of so called base shapes. They can be a block, a cylinder or a polygon with any number of sides. The base shape can also be defined explicit by declaring a boundary represented volume.

* The features which then can be removed by the designer are separated into machining features (for example a hole or a pocket), transition features (such as chamfers or filets) or compound features, which are machining features taken together by a path, on which the same features in terms of size and sort are arranged on the final product.

* Tolerances can be assigned to measurements (based on ISO 1101 and ANSI Y14.5M (SCRA, 2006)).

One disadvantage can be seen in the description of dependent features, which is realized by appointing shapes which are not used to describe the features they lie inside. This disadvantage can be eliminated by generating the shapes of all features and then determine the location of the shapes described explicit by such a definition. This AP is an ISO-Standard since late 2007. Therefore implementations can only be found in some tools. Mainly Universities (Amaitik & Kilic, 2005; Amaitik & Kilic, 2007; Liu et al., 2004; Sharma et al., 2002) and some companies have a solution based on STEP AP 224 in place (LOCAM, STEP Tools, SCRA (SCRA, 2006)).

Since we don't have access to these solutions, we developed a workaround to have testing data for process planning in place. Basically we take the EXPRESS (which is the language of STEP) -schema of AP 224 and derive our instances. Therefore a schema interpreter was developed. This provides the AIM (Application Interpreted Model) which enables us to use the ARM (Application Reference Model) of the Standard. We are currently developing the visualization- part of our program to be for this data in 3D, which can then be used to be able to design products by FBD.

5. Conclusion

The results from analyzing the existing implementation of STEP were not promising. Developing our own design guide and extracting information using proprietary API (Application Programming Interface) would be the result. However, using STEP AP 224 enables our approach to be realistic and achievable for the machine building branch. For other sectors the application seems easier, the definition of features not so complex (for example textile industry).

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