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Semantic Enrichment of 3D Models Based on Ontology Integration

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Abstract. The rise of new technologies has led to a growth in the number of 3D models. They can come from various source, hence they are heterogeneous and complex. The level of 3D data access is often a function of the user's expertise since the 3D data are often registered to different file formats. Some file formats do not show the data tree, as IGES. For using information inside a 3D model, that does not show a data tree, each company adopts his own system that will allow him to access easily to 3D model in order to exploit the hidden knowledge within the models. In this article, we are going to speak about technologies that helps user to exploit and knowledge coming from different file formats. In addition, we are going to present a system named VAQUERO that uses ontology to access, store and share knowledge coming from 3D models.

Keywords: CAD · File format · Semantic representation · Ontology · PLM

1 Introduction

A digital continuity environment, as product data management (PDM) systems or product lifecycle management (PLM) systems have been introduced in recent years to help engineers manage the development of a product throughout its lifecycle, from the design phase to recycling [1]. This environment integrates all the company's departmental functions, structures the produced data and organizes design activities. It allows to manage 3D models information such as geometry, topology, metadata, specifications, analysis and simulation results, etc. [2].

Heterogeneity of 3D models: legacy formats (CATIA, CREO, NX, etc.) and neutral formats (STEP, IGES, JT, DXF, etc.), and their complexities during the development phases create an increasing need for knowledge and expertise derived from the 3D models and their simulation results. Links and dependencies, which appear between heterogeneous 3D models, become increasingly complex in the daily activities [3]. The legacy nature of data, specific to CAD vendors, limits the possibility of open-ended analysis of 3D model, sharing 3D data, modify or revise 3D model, sometimes the retrieval of the 3D model or any information related to the design intent.

One of the main problems faced by users of these systems is the lack of compatibility between systems. As a result, 3D models created using a particular software package may become inaccessible to its creators once that software is obsolete. Incompatibilities of all kinds and at all levels impede the sharing of information and prevent the exchange of services between different systems. And developing interoperability means developing knowledge and solutions to eliminate incompatibilities [3]. Hence, we propose a conceptual system named VAQUERO capable of ensuring a better coverage of the product life cycle phases, by integrating additional information allowing improving and upgrading the low-level file formats such as STL, IGES, etc. in which the data were initially stored.

2 State of the Art: Management of 3D Data

Data and knowledge play an important role in the long-term sustainability and success of organization. The need for processes that facilitate the creation, sharing and leveraging of individual and collective knowledge has emerged for this reason. Knowledge Management has been introduced as one of the major activities for providing efficient and intelligent digital support as well as decision makers, to access any data required, across application borders [4].

2.1 Standards and Tools for Managing 3D Data

It is important for companies to provide one common standard for the integration and sharing of product data between various computer systems. Using a single standard as interoperability solution requires an effort by the users to understand the concepts and the methods of implementation. Therefore, the standards must be adapted to all users in a consensual manner, while, it is not impossible [5].

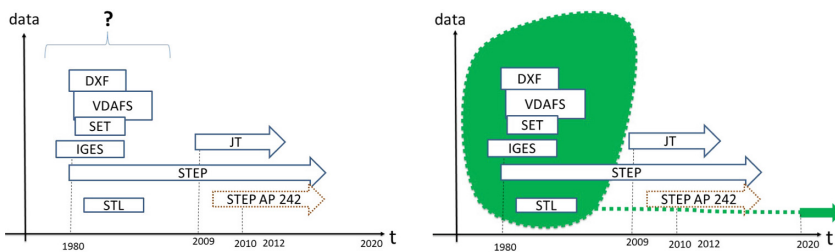


Fig. 1. a) Chronology of neutral file formats b) evolution and use of some formats.

In order to facilitate the flow of information in a heterogeneous digital continuity environment, implementing from several publishers’ solutions, neutral file formats have been developed. Figure 1 shows a chronology of some neutral file formats that exist.

While it is true that 3D models created in a specific CAD system can always be accessed by the same system at different times, as far as data in neutral formats are

concerned, this is still not the case. In a digital continuity environment, some user recommend file formats according to their needs and the CAD system they own. Thus, [6] has produced a work focusing on standards to be used in a PLM system. They highlight the choices to be made in order to determine which standard would be more appropriate or adequate for exchanging and sharing information in different digital continuity systems in order to reuse the data. Hence, [7] thought of using XML to convey information between different PLM systems. The standardization of conceptual and technical gateways between EXPRESS-STEP and UML-XML allowing the generation of efficient execution languages that specify the initial generic model and used in PLM systems. Following the STEP, JT, XML, etc. which are cited by some authors [8], for the extraction of geometric and topological information, attributes or properties, some platforms have been developed to manage the accumulation of data during the product design. We can find 3DEXPERIENCE from Dassault Systèmes, WINDCHILL from PTC and TEAM CENTER from Siemens that bring together some solutions from different companies and enable stakeholders involved in a project to work together without breaking the digital chain. These platforms offer to users intuitive applications to reuse existing parts instead of recreating parts, as they allow users to retrieve 3D models based on a reference part or keyword, make modifications, annotations and share them with other users of the same platform without losing time.

We have noticed based on Fig. 1 above, that the neutral file formats used from year 2009 are quite rich. That is why inside the digital continuity environment, apart from the legacy file format, most of the information needed were extracted from the rich neutral file formats such as STEP AP242, JT. The others file formats such as IGES, DXF, STL, etc. are not used (Fig. 1a). It seems that the data within the file formats produced before year 2009 are not used anymore. While these data can still been useful for starting a new project. It becomes necessary to find a way to use the data within these kind of low-level file formats (Fig. 1b).

2.2 Evolution of the Low-Level File Format

Based on the observation made in the previous section, where the so-called low-level file formats such as IGES or STL are no longer used in digital continuity environments, it appears necessary to identify the entire expert and business information extracted from rich files in order to upgrade and use the low-level files.

As a result, STEP AP 242 seems to be the most up-to-date and semantically rich file format today, allowing us to know what important information to extract and integrate. STEP AP 242 provides all the functionalities covered by the most commonly implemented and used Aps [8]. It additionally defines new structures for 3D parametric and geometric constraints design; geometric dimensioning and tolerance (GD&T); business object model; tessellation; kinematics; etc. The intent of STEP AP 242 is to support a manufacturing enterprise with a range of standardized information models that flow through a long and wide digital thread that makes the manufacturing systems in the enterprise smart.

Hence, the search for the granularity of the information to be integrated and the definition of all the features of the STEP AP242 and to characterize them with those of the low-level formats finally to carry out mappings and to make these files evolve.

Knowing the information to be integrated and the granularity of its information, a standardized ontology could be used to integrate all these information. We can quote for example OntoSTEP or ONTO-PDM [9], which would make it possible to integrate the information and to make evolve the low-level file formats into a STEP standard. For instance, by using ONTO-PDM that is more design oriented, not only ontology can evolve by increasing into other domains such as PMI (tolerance and annotation) etc., but also the semantics of the product by the features of the standard.

3 Semantic Enrichment of 3D Model: Proposal Vaquero

The needs of users for 3D models make it necessary to access and use the information contained within the file formats. However, as we have already said, the heterogeneity of the file formats make it almost impossible to access to all the information we want. The needs to have a rich file format that can contain the information related to geometry, topology, PMI and GD&T could help to process easily some tasks in company. That is why we propose a system named VAQUERO, which can help to integrate all the necessary information related to a 3D model in order to upgrade the file format.

For enriching the 3D model, Vaquero needs to access to the requested low-level file formats by using two types of queries. The queries are formulated based on a geometric descriptor or a semantic descriptor.

The user makes a query based on the geometric descriptor of the part that he would like to retrieve by using its shape. The geometrical descriptor could be one of those quoted in the literature as it can be found in the works of [10]. Once the result of the query is displayed like in Fig. 2a, the user selects the part to retrieve among the possible parts contained in the low-level file format.

After selecting, the enrichment of the file format is characterized by the treatment that the user will make. For instance, by identifying parts, surfaces and give names to any element composing his part. In addition, by characterizing information related to the component, being geometrical or topological information or simulation results. Manufacturing or functional information related to a specific component of the product can be expressed. The link between a PMI and the reference geometrical entity (axis, plane, surface, etc.) of the 3D model can be represented, and the graphical presentation of annotations and tolerance is returned to the user, thus facilitating comprehension (see Fig. 2b).

All the above-mentioned information will be saved in a tree structure in the form of an ontology that will be visible in another window of our system as we can see in Fig. 2b. The used ontology is a standardized one as OntoSTEP or ONTO-PDM that will allow the component to evolve. For example, if the 3D model is represented by IGES standard, by describing it in OntoSTEP, it will use the STEP terminology and will evolve in the STEP standard. The geometric and topological information as well as the graphical PMI will be defined in the ontology in order to provide a structural and semantic definition of each element. The semantic PMIs will allow access to all the information that characterizes it (reference elements, parameters, etc.), and possibly to modify them.

The second input is based on a semantic descriptor. Once some information are stored inside the ontology, he can directly query the system to retrieve a particular information based on the concepts already registered within the ontology.

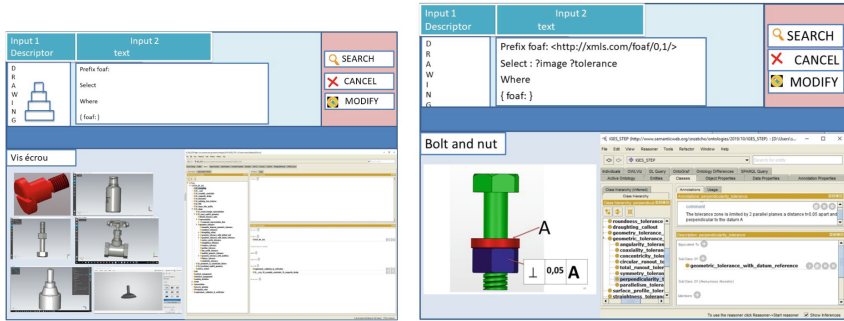


Fig. 2. a) Visualization result of a query; b) semantic annotation of the part.

Ontology, being considered itself as a database and knowledge base, the semantic definition and enrichment of the 3D model will allow an efficient and fast reutilization of the information contained within the enriched file format. The use of the ontology allows a quick annotation and modification of the information stored in the different classes. The fact that the ontology can be written in XML helps the stored information to be share.

4 Conclusion

The proposed system uses an ontology to store the information and semantically enrich 3D model coming from low-level file format such as IGES, STL, etc. with any kind of information. Ontology allows the definition of a domain and serves as bridge between different domains by identifying the different concepts that compose them and the links between them, their properties as well as axioms and rules concerning them. The information stored in a standardized ontology serves as a common and verified source of knowledge, that is used and which will be exploited in downstream processes, such as the realization of dimensional chains, dimensional control, etc. The granularity of the integrated information ensures the continuity through tools and solutions: Sharing information and services to maintain the semantic flow. It ensures the long-term sustainability of the information. We are thinking of interviewing some firms in the automotive industry to find out if there is still a need to look at this type of format in terms of its use.

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