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Leveraging 3D geometric knowledge in the product lifecycle based on industrial standards ☆

Alain Pfouga [a], Josip Stjepandić [b,*]

[a] PLM Strategy and Processes, PROSTEP AG, Germany
[b] 3D Product Creation, PROSTEP AG, Germany

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ABSTRACT

With their practical introduction by the 1970s, virtual product data have emerged to a primary technical source of intelligence in manufacturing. Modern organization have since then deployed and continuously improved strategies, methods and tools to feed the individual needs of their business domains, multidisciplinary teams, and supply chain, mastering the growing complexity of virtual product development. As far as product data are concerned, data exchange, 3D visualization, and communication are crucial processes for reusing manufacturing intelligence across lifecycle stages. Research and industry have developed several CAD interoperability, and visualization formats to uphold these product development strategies. Most of them, however, have not yet provided sufficient integration capabilities required for current digital transformation needs, mainly due to their lack of versatility in the multi-domains of the product lifecycle and primary focus on individual product descriptions.

This paper analyses the methods and tools used in virtual product development to leverage 3D CAD data in the entire life cycle based on industrial standards. It presents a set of versatile concepts for mastering exchange, aware and unaware visualization and collaboration from single technical packages fit purposely for various domains and disciplines. It introduces a 3D master document utilizing PDF techniques, which fulfills requirements for electronic discovery and enables multi-domain collaboration and long-term data retention for the digital enterprise.

1. Introduction

The gradual cyberization of physical products and predominantly the introduction of Computer Aided Systems (CAx) have triggered a digital transformation movement in Manufacturing (Andersson & Tuddenham, 2014; Bloching et al., 2015). Applying 3D CAD and Product Lifecycle Management (PLM) strategies has thereby fundamentally led to higher productivity, better quality and a simultaneous reduction of overall development time and costs (Eigner, Roubanov, & Zafirov, 2014; Li, 2015; Stark, 2015).

Meanwhile, product development methods such as Concurrent Design, Simultaneous Engineering and Systems Engineering have widely been adopted (Riascos, Stjepandić, Levy, & Fröhlich, 2015; Stjepandić, Wognum, & Verhagen, 2015). They tend to manage complex development tasks in such a way that independent units can be processed concurrently to build an optimal technical solution designed for a complex issue (Fukuda, Lulić, & Stjepandić, 2013). They ensure inherent behavior of each unit as well as system-wide interactions according to weighted objectives (Kolonay, 2014; Ríos, Morate, Oliva, & Hernández, 2016).

The major advantages provided with aforementioned methods and tools have likewise contributed to growing complexity which needs to be managed (Kluger, 2008). Combined with various domain- and organization-specific software applications available with new product development trends, the pace of changes, the volume of data and the amount of knowledge embedded in virtual product data are now reaching exponential growth in the globally leading manufacturing industries such as automotive, aerospace and shipbuilding (Curran, Xiao, & Verhagen, 2015; Hiekata & Grau, 2015; Katzenbach, 2015).

Attaining better performance and desired accuracy while providing product data to the right party in the context of his current application is essential for greater time-to-market (Figay, Ferreira da Silva, Ghodous, & Jardim-Goncalves, 2015). As the de facto reference of the physical product, from which downstream data are

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* Corresponding author.
E-mail addresses: alain.pfouga@prostep.com (A. Pfouga), josip.stjepandic@prostep.com (J. Stjepandić).

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derived, the 3D product representation deserves a particular interoperability attention (Fischer, Rosche, & Trainer, 2015). Modern organizations thus invest in activities and operations required to achieve seamless experience with 3D data across applications, disciplines and supply chains (Alguezaui & Filieri, 2014; Elgh, 2014; Germani, Mengoni, & Peruzzini, 2012). These main activities and operations are: the exchange of product relevant data across layers as mentioned earlier; the visualization of cyberized products with the purposely disclosure of origin intents and the communication (Chu, Cheng, & Wu, 2006; Huang, Xu, Huang, & Zhang, 2015; Shen, Ong, & Nee, 2008). High transparency and quick access to necessary information have become important metrics of such operations (Chu, Wu, & Hsu, 2006; Li, Xu, & Cha, 2015). Mobile applications promise a wide field of operations (Zhang & Jasimuddin, 2015).

Mastering product specifications, quality, product design, and configurations, bill of materials, changes and releases in a way that they are linked to each other in a readable, unambiguous process chain requires an overall product and process integration along with a versatile collaboration and communication carrier of the digital information (Huang et al., 2015). It must thereby take care of differences in model representations, coordination workflows, engineering domains, methods and tools of the different parties participating at product life while safeguarding all current investments (Cochran, Jafri, Chu, & Bi, 2016).

This paper provides an introduction to the challenges and current approaches for the interoperability of 3D geometric shape information based on industrial standards in Section 2. In Section 3, concepts are discussed to leverage the focused use of 3D standard formats in multi-disciplinary collaboration chains. Section 4 introduces an approach and use cases based on a document format to achieve better integration of 3D with diverse linked parcels of product defining data to effectively support the collaboration experience.

2. The challenge with interoperability formats

Following the unstoppable trend to 3D visualization, several interoperability data formats have emerged in the past and became industrial standard (Fröhlich, 2013; Pfalzgraf, Pfouga, & Trautmann, 2013; Tian, Zhang, Chen, Zhou, & Chen, 2014). There are two primary types of formats: Proprietary and Open formats.

Proprietary formats are vendor-specific. They are used to describe product data in the majority of authoring tools in the marketplace. Descriptions of these formats are regarded as intellectual property by the software vendors and are protected appropriately. Nevertheless, few third-party software vendors have decrypted such formats and offer the corresponding libraries as a tool-kit (Katzenbach, Handschuh, & Vettermann, 2013). Due to their lack of openness, they are essentially less suitable for collaboration in the extended enterprise (Emmer, Fröhlich, & Stjepandic, 2013). They will no longer be considered in the context of this paper.

Open formats, on the other hand, are often developed to enable interoperability between applications. They provide definitions which are openly specified and accessible to third-parties (e.g. application vendors and customers), who wish to make data available from and to their applications. Open formats and particularly standards ratified by a recognized international organization are stable by nature and may slowly evolve (ISO 14306, 2012). Open standards, however, enable the reduction of total cost of ownership and ensure independence from specific vendors by making sure that the data they encapsulate is always capable of being leveraged downstream and recoverable from an archive repository (Opsahl, 2012).

It now goes without saying that formats (Fig. 1) such as IGES (Section 2.1), DXF, STEP (Section 2.2), 3D XML or JT (Section 2.3) are being widely adopted and have contributed to greater momentum in product development (Katzenbach, Handschuh, Dotzauer, & Fröhlich, 2015).

This paper is focused on the formats which are broadly adopted in the manufacturing industry. Established 3D file formats used in downstream processes for visualization such as Autodesk FBX, OBJ from Wavefront Technologies or VRML – Virtual Reality Modeling Language and its derivates are regarded as being an output by conversion from the 3D formats used as the backbone in the enterprise. They typically are then used alongside game engines or within more modern mixed reality hardware such as tablets and head-mounted displays, and will no longer be considered in the paper.

2.1. IGES – initial graphics exchange specification

IGES is a file format, which defines a vendor-neutral data format establishing information structures for the digital representation and exchange of product definition data. It was initially published in 1980 by the U.S. National Bureau of Standards (NBS) as NBSIR 80-1978. It supports exchanging geometric, topological, and non-geometric product definition among Computer Aided Design and Computer Aided Manufacturing (CAD/CAM) Systems such as administrative identifications, design or analysis idealized models, shapes including their physical characteristics, processing, and presentation information (Eigner et al., 2014). Applications supported by IGES thus include traditional engineering drawings and design, models for simulation analysis and other manufacturing functions.

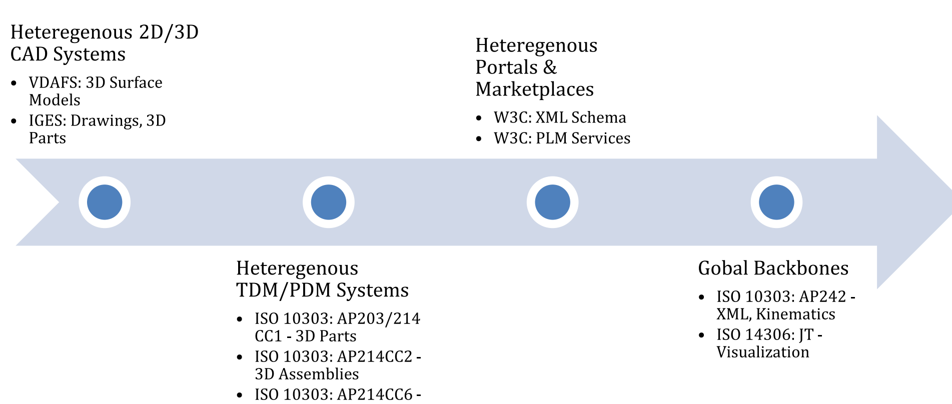

Fig. 1. Continuous development of collaboration standards (Katzenbach et al., 2015).