21[ST] INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED17
21-25 AUGUST 2017, THE UNIVERSITY OF BRITISH COLUMBIA, VANCOUVER, CANADA

OSLC BASED APPROACH FOR PRODUCT APPEARANCE STRUCTURING

Ebeling, René (1); Eigner, Martin (2)
1: Daimler AG, Germany; 2: Technische Universität Kaiserslautern, Germany

Abstract

Within early phases of a product lifecycle, a lack of process connections between CAD design, product appearance configuration as well as virtual reality and other visualisation scenarios can still be identified. Therefore, the contribution introduces the basic components of a conceptual framework for holistic management of virtual reality and other related visualisation data in order to enhance the current situation within the different product lifecycle stages. The basis of the approach covers the structuring of geometry entities within CAx-authoring tools and the connection to the underlying data backbone. Hence, the ability to structure geometry within CAx-tools and CAx-based open standard formats will be evaluated and discussed. By using the OSLC (Open Standard for Lifecycle Collaboration) specification, these results allow the implementation of a CAD integrated tool to connect product data with configurable linked data entities.

Keywords: Visualisation, Product structuring, Product Lifecycle Management (PLM), Computer Aided Design (CAD)

Contact:
René Ebeling
Daimler AG
IT Group Research
Germany
rene.ebeling@daimler.com

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 21[st] International Conference on Engineering Design (ICED17), Vol. 4: Design Methods and Tools, Vancouver, Canada, 21.-25.08.2017.

1 INTRODUCTION

In the current market situation, globally operating companies have to manage various challenges, which are mainly caused by the increasing complexity of all business areas (Schuh, 2014). This complexity is based on a high number of – usually controllable – internal and – often uncontrollable – external factors (Schömann, 2012). Those internal aspects are arisen by the collaborative and interdisciplinary character of the recent development and overall lifecycle process of a product (Eigner *et al.*, 2014). This, in turn, influences the underlying approaches of modelling, archiving and managing product data and information, which are needed to obtain the required product features and to support the involved stakeholder. As one possibility, model-based systems engineering (MBSE) provides sophisticated approaches to connect different stakeholders along the lifecycle, who are involved in specification, design, service and maintenance processes of single products and overall systems (Eigner *et al.*, 2014). These approaches are still accompanied with the increasing usage of virtual product models used to decrease the deployed resources. Despite the establishment of new methods, approaches and a continuously increased performance of available IT systems, challenges during the collaboration of stakeholders from numerous domains can be observed. One opportunity to support collaboration is based on the usage of virtual product models within virtual, augmented reality (VR/AR) and realistic visualisation scenarios during several stages of a product lifecycle. Another approach is based on the open standard for lifecycle collaboration (OSLC) interface as an open concept for the interoperability of different software tools based on web technologies. By combining aspects of MBSE and currently discussed OSLC approaches, this contribution will provide a method to generate and deliver product data in a required structure for visualisation processes as basis for the automation of VR/AR use cases. Therefore, geometry entities of the underlying design data will be enabled to be used as linked data entities with respect to OSLC concepts. This forms the basis of traceable visualisation items.

2 FRAMEWORK FOR THE MANAGEMENT OF VISUALISATION DATA

Several approaches and methods were implemented in the current process environment of companies to manage product data sufficiently. Therefore, serial process chains or dependencies between different stakeholders were reduced by creating connected product artefacts and networks, for instance to evaluate and control change procedures of data sets. Due to the persistently large variation of the underlying IT systems and by the establishment of VR/AR as a standardised IT tool within the development and usage of products, the implementation of connected artefacts and linked overall management systems are essentials. Despite considerable enhancements, various potentials to minimise time and cost intensive processes can be identified, which basically occur in a strong heterogeneity with respect to interfaces, IT tools and the high amount of manageable product data and properties (Feldhusen and Grote, 2013). Moreover, in the context of realistic visualisation scenarios for VR/AR, the lack of connected processes is also reflected by the inefficient automation over the entire lifecycle of visualisation items, which is affected by time-consuming preparation and the limitations of the current PLM systems (Ma, 2011). Besides efforts during the preparation and modelling, pre-processing is also limited by inconsistent data quality and availability as well as insufficiently defined process chains within the development and lifecycle stages (Seiffert, 2008). Challenges, opportunities and development potentials of current processes to manage visualisation data and fully integrate VR/AR application into the data management could already be identified in previous research activities, as shown in Figure 1 (Ebeling *et al.*, 2016).

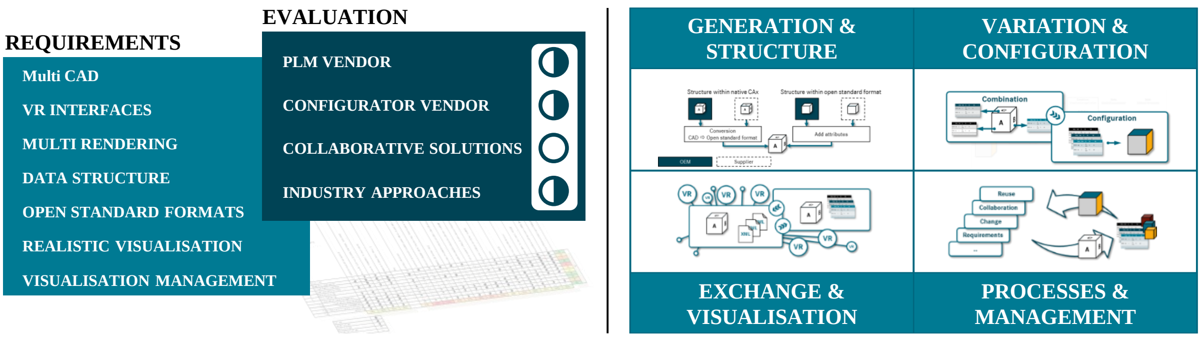

Figure 1: Initial approach to management VR and AR data (Ebeling et al., 2016)

These findings were used to specify requirements regarding a solution to manage realistic visualisation scenarios, which represent a minimum amount for the management of required information and data sets. It can be seen as a guideline for the evaluation and first classification of existing software solution and management systems. The identified weaknesses of established PLM-System and approaches might be used to improve recent IT solutions. Hence, an initial approach for a holistic and traceable management of the required data sets was postulated. This approach comprises a framework including four main areas, which should be implemented to fulfil the suggested data management requirements. These proposed areas are divided into a part of generating and structuring product data with respect to visualisation scenarios and into an area to connect this structured data to a backbone system for the ability to configure all considered data items. Furthermore, the framework is separated into a process and management section, which includes the fundamental processes for handling the structured data items efficiently. The last area specifies a bidirectional data exchange between a data handling central backbone system to authoring and viewing tools. The basis of the framework is determined by linking structured product entities within 3D-data to additional information in an underlying data backbone. Regarding the framework, multiple authoring tools for the data preparation have to be considered to identify and implement a standardised fundament for upcoming lifecycle downstream processes.

3 FUNDAMENTALS FOR TRACEABILITY OF VISUALISATION ARTEFACTS

In order to enable the traceability of artefacts within the context of VR/AR tools, a possibility to connect required data sets in a data backbone with corresponding product entities of CAx objects has to be ensured. Related to MBSE, a number of mechanic focused approaches as RFLP, VDI 2221 or SPES 2020 Modelling Framework consider methods for linking requirements (R), functions (F), logical (L) and physical (P) elements of a product or system to support the traceability within different domains along a system lifecycle (Eigner *et al.*, 2016). Hence, a connection between requirements and artefacts for each use case has to be guaranteed to use the relevant VR/AR and visualisation data as soon as possible. Especially, the non-technical point of view with respect to the definition of requirements and domain-specific elements should be integrated in the consideration as well, as shown in Figure 2.

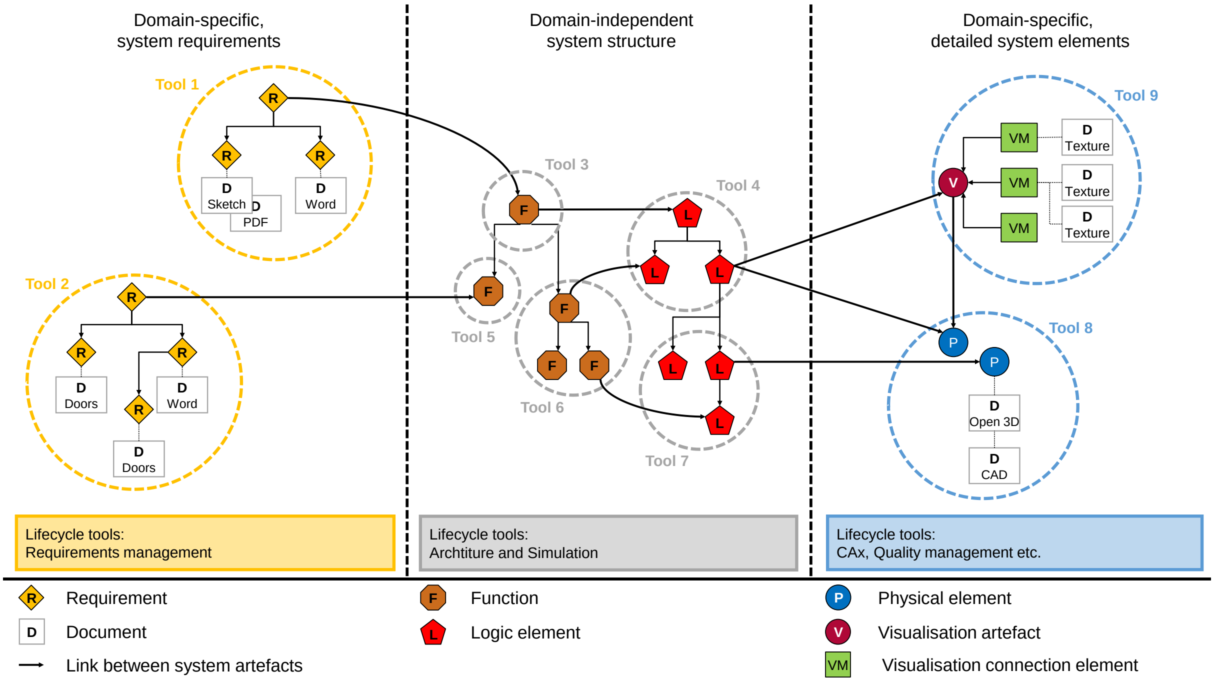

Figure 2: Relations between artefacts of VR/AR and visualisation applications with respect to a RFLP approach, based on (Eigner, 2015) and (OSLC, 2017)

By an integration of domains, which primarily deal with the appearance of a product, it is also necessary to allow the traceability of product defining artefacts and to identify change procedures during the entire lifecycle. For this purpose, a RFLP approach should be chosen, in which the product definition phase has to consider a textual or machine readable domain-specific requirement specification. In this cases, the requirements need to allow a configurable creation of links to associated functions and logical elements of the system structure. Instead of textual transcription, initial sketches and other graphics should also be considered to capture the product appearance within styling related departments. Therefore, this kind of specification has to be digitalised and cross-linked in the manner of MBSE by an open or standardised modelling language or concept. The specification of the OSLC interface provides comprehensive approaches to connect those kind of product lifecycle artefacts in a tool-independent and scalable way beside other web-based solutions as oDATA (Open Data Protocol) or CAMP (Cloud Application Management for Platforms) (OASIS, 2017). The current OSLC specification is mainly focused on the connection of application and product lifecycle tools (ALM and PLM interoperability). Nevertheless, the discussed approaches, which are built on linked data, the REST architectural pattern and other known technologies used in the World Wide Web (WWW), explain the connection of different tools along a system lifecycle (e.g. software or product) under different topics and workgroups. Therefore, it can also be used as an approach to connect other authoring and management tools along a system lifecycle for instance CAD, VR/AR applications (CRYSTAL, 2017).

3.1 Integration of 3D-geometry generating tools into visualisation data management

As a rule, most established PDM/PLM systems offer interfaces to connected product elements on the product structure or meta information level. In order to enable an early connection of further product elements with corresponding product particularities, e.g. links between geometry entities, an appropriate method to access these detailed information has to be established, as described for a VRML use case by Jezernik et al. (2002). Similar approaches are already addressed by other publications, for instance as shown within the management of vehicle architecture parameters based on CAD design parameters (Toepfer and Naumann, 2016). Other investigations describe how sketches could be used as a support to define a connection between an abstract solution description of a functional model and a detailed 3D-CAD model. In this case, the preparation of an assembly structure of a CAD model was adopted and used in the early sketching phase to track connections between a simple sketch and a more detailed CAD model (Grundel *et al.*, 2015). In terms of a creative, styling-focused view, a use case scenario in the form of a swim-lane diagram can be adapted for the representation of use cases as an alternative for an abstract functional model (Vajna, 2014). By utilising authoring tools to create and prepare detailed models, these early identified and connected product properties and use case scenarios can be enriched and integrated in a traceable lifecycle process. Thus, a more suitable traceability of decisions will be guaranteed to create formalised knowledge as basis for further development activities (Königs, 2014). The forthcoming method should be considered as a connection of geometry entities with detailed product characteristic of their appearance and as a way to systematically decouple the definition and management of the required product parameters. In conjunction with VR/AR uses cases, structuring of geometry elements has to be focused on visualisation viewpoints. Thus, the inserted information about the visualisation structure should be able to refer to product specifying appearance information and data sets within the data backbone by a visualisation identifier connection point, as shown in Figure 3.

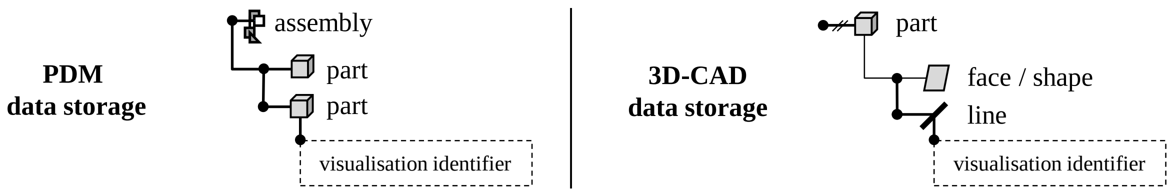

Figure 3: Connecting a logical appearance variant group with parts within an assembly structure and 3D-CAD geometry elements as basis for traceability

The suggested structuring method has to be chosen with respect to an iterative design process, in which the specified visualisation should not be changed during geometry modifications. In the area of CAx tools and their corresponding native file formats, stable update processes must be implemented to avoid errors, e.g. during a modification of features or geometric details. The proposed parametrisation forms the foundation for a connection of trace-links to a data management backbone system (Figge, 2014). Another aspect within the CAx-preparation process is the transfer of the visualisation structure information into an open or standardised exchange format to support all up- and downstream processes, e.g. the integration of suppliers and their utilised tools. This also allows a consistent data management within a data backbone and an effective way to exchange data between data authoring and viewing tools.

3.2 CAx-based options for parameterisation of visualisation artefacts

The development processes of mechanically focused domains is characterised by various data generating authoring tools during the overall design phase, which includes technical as well as creative and aesthetic activities. Thus, a promising solution to parameterise geometry elements with respect to visualisation scenarios should take into account different 3D-data generating authoring tools like M-CAD, CAS- or CAID tools. The representation and access to the required structure have to be enabled with appropriate open interfaces, which will allow software independent workflows and a bidirectional data exchange. The underlying visualisation data management has to be based on open or standardised 3D-exchange formats, which enables a possibility to integrate a wide range of tools. In accordance to the preparation of the 3D-geometry, exchange options of visualisation-specific data formats are essential for the definition of these parameters. An overview is provided in Table 1 and 2, which is related to a benchmark of neutral formats for a process-independent data exchange (Friedewald *et al.*, 2011).

Table 1. Export options of authoring CAx-tools

	STEP[1]	JT	FBX	VRML	3D-PDF	OBJ	X3D
NX 11	✓	✓	-	✓	-	-	-
CATIA V5 R19	✓	✓	-	✓	-	-	-
Creo 3.0	✓	✓	-	✓	✓	-	-
Solid Edge ST9	✓	✓	-	✓	-	-	-
SolidWorks 2017	✓	-	-	✓	✓	✓	-
Autodesk Inventor 2017	✓	✓	-	✓	✓	✓	-
Alias 2017	✓	✓	✓	✓	-	✓	-
ICEM Surf 2016	-	-	-	✓	-	-	-
Blender 2.77[2]	-	-	✓	✓	-	✓	✓

Table 1 shows currently utilised 3D-data exchange formats, which are typically used within VR and other related visualisation scenarios and frequently used CAx authoring tools from mechanical engineering and styling departments. In this case, these formats also comprise open and standardised as well as proprietary 3D-file formats. Mechanically focused domains and their related processes are still based on standardised formats as STEP, JT and also VRML, as reflected by the higher amount of implemented export options. Nevertheless, the proprietary FBX file format is a common format for the exchange between the majorities of tools related to VR. Due to its large number of transferable visualisation relevant properties like kinematic functionalities, shadow textures or light maps, it is often used to transfer visualisation scenes from one to another viewing tool. While the engineering standard formats are sufficiently implemented inside the technically focused tools, the FBX format is widespread within the area of VR, which is most likely caused by simple API functions of the available SDK.

Table 2. Import options of VR/ AR and other visualisation tools

	STEP	JT	FBX	VRML	3D-PDF	OBJ	X3D
TC Vis Mockup 11.2	✓	✓	-	✓	-	-	-
VRED 2017	✓	✓	✓	✓	-	✓	-
3DEXCITE DeltaGen 2017x	✓	✓	✓	✓	-	✓	-
IC.IDO 10.2	✓	✓	✓	✓	-	-	-
Unreal 4.0	-	-	✓	✓	-	-	-
Unity 5.5.0	-	✓	✓	-	-	-	-
Blender 2.77	-	-	✓	-	-	✓	✓

However, within use cases focused on a technical context – basically oriented toward data generating CAx tools – a visualisation data format should guarantee the greatest possible synergy between engineering and realistic visualisation scenarios. Therefore, STEP, JT and VRML still have to be

1 In this contribution, the word "STEP" exclusively refers to the 3D-geometry formats defined within STEP AP 203 and STEP AP 214

2 The Import and Export options of X3D is based on an open source X3D Blender plugin

considered as the most promising data formats for further investigations with respect to a general automation of product visualisation processes for technical use cases.

4 CAX-BASED PARAMETERISATION OPTIONS AS LINKED DATA SOURCE

4.1 Evaluation of CAx-based parameterisation options for visualisation scenarios

The investigation of CAx-based parameterisation shall verify and value the different options of native data format and the available parameters after a conversion into a standardised exchange format, as discussed in the previous section. For this purpose, the three formats STEP, JT and VRML are examined in more detail with respect to the following three data exchange criteria. At least these three criteria have to be ensured for the stated visualisation scenarios to distinguish between different geometry elements inside a CAx component and to match the corresponding data objects stored within the data backbone.

DATA EXHANGE CRITERIA

- The **TRANSFER** comprises the general possibility to convert CAx native information into a standardised exchange format.
- The **IDENTIFIER** comprises the possibility to create a unique identification within the file structure, which can be automatically assessed with an external interface via an API.
- The **REFERENCE** comprises the possibility to generate and transfer an ID reference to geometry elements into a standardised exchange format, which has to be also assessed via an external API.

For an exchange of the required information, three main features can also be identified, which are already implemented and available within the native and the standardised CAx data formats.

DATA FORMAT FEATURES

- **PMI** (Product Manufacturing Information) forms a class of parameters, in which a PMI-object has the ability to refer to diverse geometry and feature elements of a CAD object. Furthermore, it can be enhanced by a number of additional properties to describe a specification in more detail.
- CAD based **ATTRIBUTES** specifies a property of a CAD object, which typically refers to a single object element. Attributes can also handle an identifier and usually a name property.
- CAD **COLOUR CODES** are used to visualise the geometry in a specific shape colour, which can be also include the identifier and the name of a colour.

The degree of the implementation of the data format features and an initial indicator for the quality of the existing CAD interfaces, can be found in Table 3.

Table 3. Evaluation of open and standardised formats as basis for the Traceability of Artefacts with respect to visualisation use cases

	Exchange Format	**STEP**		**JT**		**VRML**	
	Native Format	NX	CATIA	NX	CATIA	NX	CATIA
	Native file size (MB)	81,7	85,6	81,7	85,6	81,7	85,6
	exchange file size (MB)	79,8	94,6	21,0	53,3	16,3	20,6
PMI	Transfer	●	○	●	●	○	●
	Identifier	◐	○	●	●	○	◐
	Reference	○	○	●	●	○	○
ATTRIBUTES	Transfer	○	○	●	●	○	○
	Identifier	○	○	●	●	○	○
	Reference	○	○	◐	◐	○	○
COLOUR CODES	Transfer	●	●	●	●	●	●
	Identifier	●	○	○	○	○	○
	Reference	●	●	●	●	●	◐

Fulfilled	●
Partly fulfilled	◐
Not fulfilled	○

This evaluation gives a possibility for the selection of standardised formats and their matching software tools and it provides an examination of the suitability to structure the visualisation data with respect to specific domains. Especially the PMI ability of the JT format provides the most promising solution to structure and indirectly link geometry elements for different visualisation use cases.

4.2 Implementation and usage of CAx-based parameterisation

In the initial implementation, an OSLC specification based interface should be demonstrated by connecting a data management backbone and a CAx-tool. Therefore, the CAD-tool NX will be delivered with data by a GET request to the data backbone. As described by the OSLC specification, a service will be used to provide the data by query capabilities (OSLC, 2017). In this case, the data request delivers a list of the stated visualisation identifiers in a JSON (JavaScript Object Notation) key value format, which can be deserialised and accessed via visualisation identifier objects based on the .NET framework within the software example. The visualisation identifiers are provided in a form of a URI. These URIs are needed to identify and indirectly connect geometry entities with additional information stored within the data backbone.

Figure 4: OSLC specification based request to get visualisation IDs from a data management system

In this implementation, the geometry elements comprises faces and bodies of NX-CAD parts but it could also be extended to diverse elements as splines or other line elements as well as features, e.g. entire chamfers or holes. Therefore, the previously examined PMIs will be used to store the URI information connected to these mentioned geometry entities within the considered CAD models and within the CAD-based open 3D-format like the stated JT by exporting the considered CAD files. Via API functionalities, such as the JT Open Toolkit in case of JT files, the product geometry entities and their related visualisation identifier URIs can be accessed and processed, for instance within a viewing component of a rich-client PLM application, a web-viewer or other visualisation tools.

5 CONCLUSION AND FUTURE WORK

The contribution presented in this paper briefly explains the basic components of a conceptual framework for a model based system engineering approach with respect to VR/AR and realistic visualisation scenarios. This suggested framework can be considered as an initial concept for the implementation of a holistic solution within the data preparation and data management process of the required data sets. Therefore, the need to structure geometry elements during the generation process was discussed, which appears as a fundamental reference to more detailed data description within a connected data management system. The investigation addresses the export and import options of CAx-tools and an evaluation of parametrisation options regarding standardised data formats in order to provide a first recommendation for a selection of an exchange format and corresponding authoring tools. Hence, a first implementation of an OSLC specification based interface of a CAx-system and a data management system was demonstrated.

Further investigation will aim at the definition of a suitable underlying architecture, a detailed specification of the IT system backbone for the management of engineering change processes and an appropriate solution for the interaction with the internal business logic. Moreover, the necessary information have to be handled within a robust and adequate data management system to also realise a smooth bidirectional data exchange of required data sets to VR/AR and order visualisation tools. According to the presented implementation within a CAD-tool, visualisation-focused tools should be also integrated based on OSLC concepts and web technologies in order to enhance supplier collaborations and the exchange between different tools and software version.

REFERENCES

CRYSTAL (2017), “CRYSTAL - Critical System Engineering Acceleration”. www.crystal-artemis.eu/ (accessed 16 April 2017).

Ebeling, R., Specht, R. and Eigner, M. (2016), “An initial approach of a standard based framework to manage realistic product representations”. *In: DS 84: Proceedings of the DESIGN 2016 14th International Design Conference*, Dubrovnik 2016, pp. 601–610.

Eigner, M. (2015), “System Lifecycle Management im Kontext von Industrial Internet mit Industrie 4.0 und Internet der Dinge und Dienste”. https://vpe.mv.uni-kl.de/fileadmin/vpe/Downloads/PLM_Future_2015/_2__PLM_Future_Tagung_2015_-_Eigner_SysLM.pdf (accessed 7 December 2016).

Eigner, M., Dickopf, T. and Huwig, C. (2016), “An interdisciplinary model-based design approach for developing cybertronic systems”. *In: DS 84: Proceedings of the DESIGN 2016 14th International Design Conference*, Dubrovnik 2016, pp. 1647–1656.

Eigner, M., Roubanov, D. and Zafirov, R. (2014), *Modellbasierte virtuelle Produktentwicklung*, Springer, Berlin, Heidelberg. http://dx.doi.org/10.1007/978-3-662-43816-9

Feldhusen, J. and Grote, K.-H. (2013), *Pahl/Beitz Konstruktionslehre*, Springer, Berlin, Heidelberg. http://dx.doi.org/10.1007/978-3-642-29569-0

Figge, A. (2014), *Effiziente Erfassung und Pflege von Traceability-Modellen zur Entwicklung technischer Systeme*, Technische Universität Berlin. http://dx.doi.org/

Friedewald, A., Lödding, H., Freiherr von Lukas, U., Mesing, B., Roth, M., Schleusener, S. and Titov, F. (2011), *Benchmark neutraler Formate für den prozessübergreifenden Datenaustausch im Schiffbau*, Rostock. http://publica.fraunhofer.de/documents/N-194622.html

Grundel, M., Abulawi, J. and Loewner, J. (2015), “Skizzen mit formalisierten Informationen anreichern”, in Schulze, S.-O., Muggeo, C. and Abulawi, J. (Eds.), *Tag des Systems Engineering, Ulm*, Hanser, München, pp. 99–108.

Jezernik, A., Hren, G. and Golob, B. (2002), “Assembly configuration and appearance changes in VRML environment”. *In: DS 30: Proceedings of DESIGN 2002, the 7th International Design Conference*, Dubrovnik 2002, pp. 503–508.

Königs, S.F. (2014), *Konzeption und Realisierung einer Methode zur templategestützten Systementwicklung, Berichte aus dem Produktionstechnischen Zentrum Berlin*, Fraunhofer Verlag, Stuttgart

Ma, D. (Ed.) (2011), *Virtual reality & augmented reality in industry: The 2nd Sino-German workshop*, Springer, Heidelberg. http://dx.doi.org/10.1007/978-3-642-17376-9

OASIS (2017), “Organization for the Advancement of Structured Information Standards”. https://www.oasis-open.org (accessed 3 April 2017).

OSLC (2017), “Open Services for Lifecycle Collaboration”. http://open-services.net/wiki (accessed 3 April 2017).

Schömann, S.O. (2012), *Produktentwicklung in der Automobilindustrie: Managementkonzepte vor dem Hintergrund gewandelter Herausforderungen*, Gabler Verlag / Springer, Wiesbaden. http://dx.doi.org/10.1007/978-3-8349-6673-5

Schuh, G. (2014), *Produktkomplexität managen: Strategien; Methoden; Tools,* Vol. 1, Carl Hanser, München, Wien. http://dx.doi.org/10.3139/9783446443549

Seiffert, U. (Ed.) (2008), *Virtuelle Produktentstehung für Fahrzeug und Antrieb im Kfz: Prozesse, Komponenten, Beispiele aus der Praxis,* Vol. 1, Vieweg + Teubner, Wiesbaden

Toepfer, F. and Naumann, T. (2016), “Management of vehicle architecture parameters”. *In: DS 84: Proceedings of the DESIGN 2016 14th International Design Conference*, Dubrovnik 2016, pp. 1679–1688.

Vajna, S. (2014), *Integrated Design Engineering*, Springer, Berlin, Heidelberg. http://dx.doi.org/10.1007/978-3-642-41104-5