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HANDLING PRODUCT INFORMATION – TOWARDS AN IMPROVED USE OF PRODUCT MODELS IN ENGINEERING DESIGN

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1. Introduction

In the product development process (also referred to as engineering design process), information describing the product is created on the basis of information about the specific tasks, requirements and goals of a project [Lindemann 2007]. As creating information is one of the core elements of the product development process, the correct handling of information – and therefore the handling of data and knowledge as well – is an important factor in product development. Product models – as formal representations of real product properties [Grabowski et al. 1993] – are widely used to represent, analyse, communicate and store information during the product development process [Lindemann 2007]. In product development, different types of product models exists [Pratt 1995] differing in the respective purpose, form, use and their temporal validity. Both product and product development processes tend to be increasingly complex due to different market-, organisational- and technology-based influences [Lindemann et al. 2009]. So, the need for higher sophisticated product information representation increases. This leads to a higher number of different types of product models with increasing complexity [Horvath and Rudas 2008]. As a result, a product developer faces a growing unmanageable number of product model types. We claim that currently no suitable methodology exists for supporting the product developer in choosing the appropriate type of product model for the particular needs in the product development process. Usually, product models are chosen depending on the individual experience and 'accidental' availability of product models. This can lead to the use of possibly inadequate product models as better suited product models are not known or currently not available. The long term goal of our work is to develop a methodology for supporting the process of choosing the right product model for the respective purpose and need of the product developer. This paper provides the basis for the methodology by giving a structured overview of the differences in the current use and scope of product models.

The paper is structured as follows: First, we provide the necessary theoretical background. We start with the general definition and application of models and narrow down to product models used in product development. In the next section, we describe the main goals of the methodology for supporting the developer in choosing and applying the right product model type. Then, an overview of different state-of-the-art possibilities for classifying product models and related approaches is given. In the following three chapters, we detail three criteria used for classification. We identify associated attributes for the classification and discuss their applicability in terms of our objectives. The criteria are then applied for classifying the product models identified in two literature researches. The first literature research considers general literature related to product development without a specific application focus. The second one details the first research exemplarily in the field of electric vehicle development. Finally, we conclude the results and provide an outlook on future work.

2. Theoretical background

Knowledge about the theoretical background is essential for following our approach towards an improved use of product models in engineering design. We will clarify our understanding of the term product model and will emphasise the variety of model application in engineering design.

2.1 Models and their application as product models in engineering design

The term “model” is widely used in numerous domains and its meaning varies in domain-spanning context as well as within a single domain. For example, models are used for describing processes, costs, climatic change or stock-markets – only to mention some [Vajna et al. 2009]. A very good and detailed description of different meanings of the term model in a philosophical, cultural and technical context is given in [Stachowiak 1973]. Stachowiak defined three main features of a model describing the relationship between the model and its original:

- mapping feature (a model is a representation of an original – that could also be a model itself)
- reduction feature (a model only reflects some of the original's attributes)
- pragmatic feature (a model is used in place of the original with respect to some purpose and within a certain time)

As one little part of the current use of models, we focus on models in product development and their specific application for representing product information. We use information as intended by [Aamodt and Nygard 1995] in comparison to data and knowledge: data are syntactic entities, information is interpreted data and knowledge is learned information. Following the definition proposed by [Grabowski et al. 1993], [Lindemann 2007], we define product models in the context of this work in combination with the general model definition from [Stachowiak 1973] as follows:

“A product model is a representation of the product or of a product model. It reflects some of the products properties or characteristics that seem to be relevant for its creation or use. It is used in place of the product with respect to certain users, within a certain time and for a certain purpose.”

Product properties and characteristics in this definition are distinguished as intended by Andreasen ([Vajna et al. 2009], p. 32). They refer to characteristics as the directly determined parameters of the product by the engineer (form, structure, etc.). Properties describe the performance of the product (function, safety, aesthetic, costs, etc.) which is only indirectly determinable by the engineer. As described in the introduction, product models play an increasingly important role in the product development process. Beside “traditional” analogue product models as paper-based sketches or physical prototypes, digital product models are nowadays widely used for example in CAx-systems. In the product development process, different product models are applied. For example, a requirements list is used in early phases to represent the initially intended properties of the product by the marketing division. Later, a relation-oriented function model can be build for identifying possible conflicts by the engineer. Several more examples could be mentioned here but would go beyond the scope of this paper. Product models in the engineering process can be classified according to different schemata that represent similarities between the product models. For example, similarities can occur by the intended use of a product model, the representation form or the content. Types of product models exists that serve as meta-models for the semantics of the contained data. For example, rules exist in relation-oriented function models that determine the way of formulating or drawing the content of the model. For example, “Relation-oriented function models” are a product model type. A single function-oriented product model uses the respective semantic and therefore belongs to this model type.

Taking into account the above mentioned Data-Information-Knowledge model by [Aamodt and Nygard 1995], product models can be seen as the enabler for supporting the learning and decision making process in product development: In combination with the semantics of a product model, data about the product gets meaning and can be interpreted as information. Once a product model is built, it provides possibilities to elaborate the contained information in combination with the knowledge of the user. The contained information is interpreted and new information can be derived. This information can then be used for learning and providing support in decision steps in product development.

One approach to combine some of the different product models and types of product models is the so-called integrated product model [Grabowski et al. 1993]. Integrated product models represent product information from different phases of the product life cycle to support data storage and improve information flow. STEP (Standard for the Exchange of Product Model Data) as defined in ISO 10303 is the most famous application of this approach. It enables data exchange between the different systems in design and manufacturing. However, STEP is limited to the later phases of product development after the product has already been designed [Fenves 2002]. It is applied after design decisions have been made. Therefore, [Fenves 2002] proposed the “Core Model for Product Data” (CPM) as a precursor for STEP, which is applicable in the early phases of the product lifecycle. CPM represents an integrated product model in form of a generic information representation core that can contain all relevant information in the early phases.

2.2 Methodology for choosing the appropriate type of product model

As described in the introduction, an absence of methodologies can be stated, which support the product developer when choosing an appropriate type of product model for a specific product modelling need. The methodical support of this selection process is the objective of our research. In contrast to integrated product model approaches (like STEP or CPM), the methodology does not intend combining all product models into one single data model. The existing and applied product models shall not be replaced by one integrated product model. But the methodology shall enable the criteria-based choice and a combination of fitting single product models (digital or analogue) for a certain purpose. So, they are made better available and usable. Requirements and boundary conditions mentioned by the user and the individual application context in product development are considered in our approach. The high implementation effort that comes along with integrated product models is unnecessary.

As depicted in Figure 1, the methodology aims at supporting the product developer in the product development process, when product relevant information needs to be modelled. A knowledge model for existing types of product models builds the basis of the methodology: in the knowledge model, relevant aspects (that have to be defined in further work) are represented, which describe the models and their application. For example, the content, the phases of the product development process, visualisation capabilities, relations and boundary conditions for the applications are possible elements of the knowledge model. The possibilities of data and information transfer between single product models used during the development process and their combination have also to be considered adequately. The knowledge model enables an interface between the product developer and the existing product model types. By applying the methodology (also possibly with tool-support), the product developer is supported in quantifying the specific needs and gets suggestions for possibly fitting product model types and their combination.

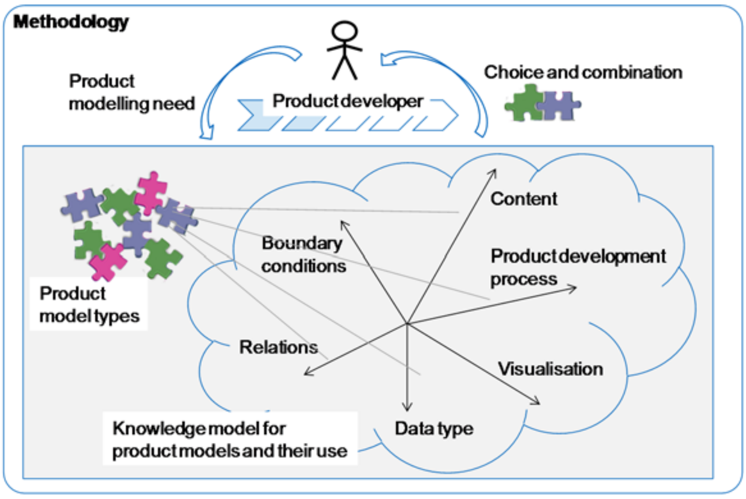

Figure 1. Core elements of the methodology

The following main steps are intended in order to develop this methodology

- Collect and analyse existing product models and identify product model types

- Investigate the possibility to combine different product model types and possible information transfer between them
- Quantify the need of a product developer for a certain type of product model
- Combine the needs and the model types within a knowledge model
- Implement the methodology with necessary tool support

The work presented in this paper focuses on the first step towards this methodology. We provide the necessary overview of the current use and scope of product models by collecting and analysing product models.

2.3 State of the art: classifications of product models in engineering design

This section gives an overview of existing classifications for product models in engineering design. In literature, different terms appear for artefacts that enable the handling of product information. Some of them are explicitly named "product model", but not all of them. For example, "documents", computer-based "product data management", and "modelling methods" can also be interpreted as product models as intended by our definition. Therefore, classifications of those related artefacts are also taken into account for this overview although they are not explicitly named "product model". Documents like textual descriptions, tables or pictures are either represented paper-based or in form of computer files and are used for documenting product-related information. Product data management is also closely related to product models as one of its main functions is the management of product information. Furthermore, often product models are the result of a (modelling) methodology in engineering design. For example, the House of Quality as one possible product model is the result of applying the well-known quality methodology Quality Function Deployment. Classification criteria for these artefacts can also be important for classifying product models. A literature research has been carried out to illustrate different classification criteria for these applications. The different classifications approaches were reviewed and interpreted according to the respective scope of the classification and the proposed classification criteria. An excerpt of the most important results is shown in the table below.

Table 1. Criteria used for classifying product models and related artefacts

Classification criteria	Scope	Source
completeness	product model	*Dylla, N., „Denk- und Handlungsabläufe beim Konstruieren", 1991.*
degree of abstraction	product model	
specialist discipline	product model	*Dettmering, H., "PDM und Engineering-Informationssysteme", 2005.*
stages of the product life-cycle	product model	
information representation	product model	
stages of the product life-cycle	product data	*Jun, H.-B. et al., "Product Life-Cycle Metadata Modeling and Its Application with RDF, 2007.*
characteristics	product data	
degree of abstraction	product data	
content	modelling method	*Felgen, L., „Systemorientierte Qualitätssicherung für mechatronische Produkte", 2007.*
information representation	modelling method	
principle	modelling method	
purpose	product model	*Ponn, J. et al., „Konzeptentwicklung und Gestaltung technischer Produkte", 2008.*
effort for creation	document	*Lauer, W. et al., "Dynamic Linking and Retrieval of Product Models to Product Development Processes", 2009.*
frequency of use	document	
actuality	document	
creator	document	
effort for usage	document	

As depicted in the table, many different criteria exist that can be used to classify product models. Some of the criteria were used by several authors. However, every author has its own interpretation of these criteria and uses different attributes for describing them: For instance, the product life-cycle can be split up into three stages (start, middle and end of life) or more detailed into design process phases (product planning, design, production planning, manufacturing, distribution, product usage and product recycling). Thus, classification criteria can be subject to interpretation regarding their attributes. For each of the identified classification criteria different levels of detail can be applied to their attributes. This level of detail always depends on the context and the intent for the respective classification. In our case, we will exemplarily focus on three of these classification criteria for analysing the scope and use of product models. Also, we will have a closer look on the different levels of detail for the attributes.

3. Detailing product model classification criteria

Three of the above identified classification criteria were chosen for detailed consideration in the context of our approach. These are the content of product models, the application phase of the development process and the information representation. These three criteria were selected as they show the high variety of product models in application (content and process phase) and scope (content and information representation). We conducted a literature research for each classification criteria, in order to identify and discuss attributes for classifying the product models. Investigations on the criteria will be detailed in the following sections.

3.1 Content of a product model

As described in the definition above, a product model "reflects some of the produce properties or characteristics that seem to be relevant for its creation or use". Thus, the content can be interpreted from the product creator's point of view as well as from the user's point of view. Both points of view have been investigated in two different approaches. Firstly, the content can be classified according to the engineering design theory. Here, the information content is represented by information artefacts, which are required by the designer for developing the product. Secondly, information content can be structured according to the product properties that shall be developed. As product properties are designed based on product requirements, properties and requirements are closely related to each other regarding the content. Therefore, classifications of product requirements can also be used as basis for classifying product properties and also information content of product models.

3.1.1 Content according to engineering design theory

Different approaches exist for classifying the content of product models according to engineering design theory. For example, [Fenves 2002] developed a core information model (CPM) for product information artefacts in order to enable an improved handling of information in the early phases of engineering design. In his work he compares this core model to four existing information models regarding the content. These information models were primarily developed for application to computer-aided design and to simplify data management in the early phases of product development. In the rows of the following table, the information models are listed. The contained information artefacts are assigned as attributes if they are considered in the respective information model. In addition to the examples given by Fenves, which are marked by the bold and lightly shaded grey box, more up-to-date models are added in the table. For the definition of the attributes, please refer to the original source [Fenves 2002].
This table shows different information content of product models in engineering design theory. In principle, this list of eleven attributes would be suitable for classifying arbitrary product models according to their information content. However, they only provide an abstract description of information content, because these attributes focus on artefacts in early phases of product development. Several application-oriented aspects as ergonomics, usage or costs are not considered in detail or not clearly related to the aspects in this classification. For practical application by engineers, this abstract approach could be misleading as the relation to the product properties (which should result from the design process) may remain unclear. This is why an alternative content structure could be helpful, which has been elaborated as second approach. This approach focuses on information classification more closely related to the product properties, which have to be designed.

Table 2. Attributes and their sources for the classification criteria “information content”

Source / **Attribute**	Artefact	Feature	Function	Form	Material	Behaviour	Flow	Specification	Assembly	Constraints	Requirements
DPPI project; Feng et al., “Incorporating Process Planning into Conceptual Design”, 1999.	x	x	x	x	x	x		x		x	x
NIST project; Szykman et al., “A Web-based System for Design Artifact Modeling”, 2000.	x		x	x	x	x	x	x	x		
DFT project; Sudersan et al.: “Information Models for Design Tolerancing”, 2000.	x		x			x		x	x		
O-O DDE project; according to Fenves, “A core product model for representing design information”, 2002.		x	x	x		x			x		
Ong et al., “Design Reuse in Product Development Modeling, Analysis and Optimization”, 2008.	x	x	x	x	x	x	x	x	x	x	
Horváth & Rudas, “Towards the Information Content Driven Product Model”, 2008.	x	x				x		x	x		
Wang & Wang, “Study on Information Integration for Product Development of Collaborative Design Chain”, 2009.	x	x	x	x		x			x		x
Tama & Reidsema, “Product Knowledge Identification and Modeling for Virtual Collaboration Environment”, 2010.	x	x	x	x	x	x	x	x			
Xie & Rui, “Product Information Model and System Integration based on Generalized CAD”, 2010.	x	x	x	x	x			x	x		

3.1.2 Content according to requirements engineering and product use

Product models represent information about the product. Product properties and characteristics are one important part of product information. As they mostly derive from product requirements, product properties are closely related to product requirements. Therefore product requirements can be used as basis for classifying product information. [Pahl et al. 2006] provide a checklist comprising main features of a product. These features can be applied for determining product requirements holistically. Namely, these main features are geometry, kinematics, forces, energy, material, signal, safety, ergonomics, production, control, assembly, transport, usage, maintenance, recycling, cost and appointed time. These main features and the product properties are not always linked in a one-to-one relationship. In some cases one main feature even affects several properties. For our approach, the main features seem to be suitable as attributes for classifying information content of product models. They describe the product not only from the theoretical – design theory related – point of view, but cover also relevant product properties.

A mapping between content attributes for system development by [Fenves 2002] and the main features of [Pahl et al. 2006] can only partly be realized. For example, the contents form, assembly and material can directly be mapped to the main features geometry, assembly and material in the requirements’ attributes. However, other contents are too abstract (e.g. function and behaviour) and can therefore not be linked to one single feature. The choice between the two proposed approaches depends on the level of detail of product models under consideration.

3.2 Phase of the development process

Product models can be assigned to a point in time or phase of the development process. Development processes can be defined on different levels of abstraction and for different purposes. In our case, two different examples are given. Firstly, standards and procedure models for the product development process are considered. Secondly, we take up a management oriented position on development processes. We reviewed different approaches for classifying product development processes in this area by using the example of standard automotive development processes. In this context, the single process steps are interpreted as the phases of the development process.

3.2.1 Generic product development processes and procedure models

Different generic product development processes exist that intend to provide a guideline for supporting the objectives in product development [Wynn and Clarkson 2005]. Procedure models like the "Munich procedure model" also divide a certain design activity in smaller sub-steps [Lindemann 2007] and therefore provide a reference for the phases in the product development process. The following table provides an overview of the main phases of general product development processes and procedure models.

Table 3. Generic product development processes and procedure models

Name / Source	Main Phases
Idealised model for product development *– Andreasen & Hein, "Integrated Product Development", 1987.*	Recognition of need, Investigation of need, Product principle, Product design, Production preparation, Realisation and launch
VDI 2221 - *VDI 2221 "Systematic approach to the development and design of technical systems and products", 1993*	Clarification and specification of task, Identification of functions and their structures, Search for solution principles and their structures, Structuring into realizable modules, Configuration of decisive modules, Configuration of overall product, Elaboration of implementation- and utilization specifications
Generic product development process - *Ulrich & Eppinger, "Product design and development.", 1995*	Planning, Concept development, System-level Design, Detail Design, Integrate and Test, Validation and Ramp-Up
V-Model – *VDI 2206 "Design methodology for mechatronic systems", 2004*	System design, Domain Specific Design, System integration
MVM – „munich procedure model" *Lindemann, "Methodische Entwicklung technischer Produkte", 2007.*	Goal planning, Goal analysis, Task structuring, Generate solution ideas, Properties assessment, Decision making, Ensuring goal achievement

The table makes no claim to completeness but instead intends to show the different interpretations of the main phases. These generic processes and procedure models support the classifications of product models according to the phase. Different interpretations have to be considered when choosing one specific approach or approach combination. In addition, most companies use their own, adapted standard development processes for describing their needs. As an example, we investigated adapted process models in the field of automotive industry.

3.2.2 Process steps in the automotive development process

Different automotive development process were analysed and compared for examining the development processes in the automotive industry. The quality gates and process phases of six different processes were identified and compared. The results are depicted in the following Figure 2. For highlighting the different interpretations, the main quality gates are ordered according to their point of time in the development process; and the single process phases of the different processes are visualised as arrows pointing from left to right.

As can be seen in the Figure 2, the single processes possess sub-processes which differ in number, start- and end-point as well as duration. Similar to the classification of generic product models and procedure models mentioned above, consistent granularity does not exist. The development process by Weber, [2009] (seven phases named A to G) provides insights to the use of product models in the processes. During the *Initial Phase (A)*, a consistent target framework for the vehicle is worked out. This represents a strategic objective and verification of economic feasibility. During the *Concept Phase (B)* the essential vehicle concept design is defined. Characteristic features of the vehicle such as driver ergonomics, aerodynamics, handling, production are determined by using real or virtual 3D models. During the *Component Design (C)* phase, parts and software are constructed on the most detailed level in terms of geometry, material, surface etc. All components are then integrated into a vehicle during the *Complete Vehicle Integration (D)* phase. Prototypes are tested in order to evaluate the intended characteristics. During the phase of *Prototype Build (E)* the planned production process and buildability of the vehicle is evaluated. The phase of *Launch Preparation (F)* lasts from the assembly of the first pre-series car until the final series production capacity is accomplished. During the *Series Support and further Development (G)* phase, problems and defects are solved by changing parts, software or manufacturing equipment.

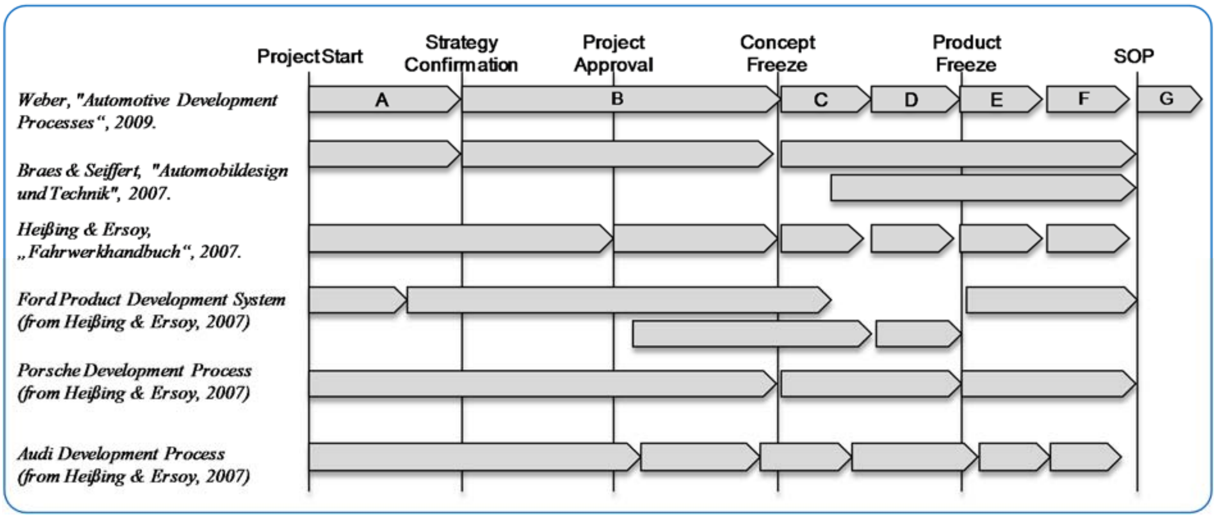

Figure 2. Standard processes in the automotive industry

3.3 Information representation

Information representation is the third classification criteria for application and scope description of product models. In the context of this contribution, information representation comprises the conveyance of product model information to the engineer.
The classification of information representation is split up in two sub-sections. The first section describes the way, information is presented and the second section describes which medium is used for storing information. The different types have been collected by a literature research. The following table shows all determined representation types as attributes for the classification criteria "information representation" with their corresponding literature source.

Table 4. Attributes for the classification criteria "information representation"

	presentation				medium		
Source / **Attributes**	Analytic	Graphical	Tables/Matrices	Textual	Digital	Physical	Immaterial
Dettmering, H., "PDM und Engineering-Informationssysteme", 2005.					x	x	
Lauer, W. et al., "Dynamic Linking and Retrieval of Product Models to Product Development Processes", 2009.		x		x	x		
Ullmann, D., "The Mechanical Design Process", 2002.	x	x		x		x	
Felgen, L., „Systemorientierte Qualitätssicherung für mechatronische Produkte", 2007.	x	x	x	x			
Fuchs, D. K., „Konstruktionsprinzipien für die Problemanalyse in der Produktentwicklung", 2006.		x		x			x

The different sources vary in the classification attributes. The single attributes can be explained as follows: The analytic representation type is needed to display mathematical formula for computations and calculations. Graphical representations are used to illustrate content more vividly. Difficult issues are mostly conveyed graphically, because they are easier to understand than plain text descriptions. Tables or matrices are used to structure information in a compact and clearly arranged way. Textual representations only use text for conveying the information. Of course, mixtures between this attributes are often required. For example, textual descriptions are used additionally within a graphical representation. Considering the storage or conveyance medium, three different attributes are identified: digital, physical and immaterial. Digital information is most likely displayed on monitors, physical information can range from a sheet of paper up to physical prototypes. In addition, models which only exist in one's mind can be classified as immaterial. As mentioned above, this three representation types have to be considered separately from the other four types. For instance, sketches are represented graphically. Furthermore, they can either be drawn on a sheet of paper (physical) or created digitally with CAD software (digital).
It has to be mentioned, that the considered literature only covers a small part of possible attributes of information representation in comparison to model theory approaches. The mentioned literature covers this criterion mostly from a very pragmatic point of view. [Stachowiak 1973] provides further details and more deepen theoretical insights in different types of information representations in model theory.

4. Analysing the scope of product models used in product development

In this chapter product models are analysed according to the three classification criteria. Two literature researches were done for identifying product models. In the first, product model types were identified on a general, abstract level without application to a specific product. General engineering design theory literature served as source for this research. The research resulted in a list of abstract product model types. Based on the first literature research, the second one was focused on a specific use case. Although this second research only covers a small area of application, it goes more into detail and fills some of the identified product model types with more specific product models. Electric vehicle development was chosen for this second use case, as this is an interesting, emerging field of engineering. Within the two researches, the product models were selected on the basis of the above described definition of product models. The distinction between two product models was based on their name and the description of their application. The identified single product models were documented in a spreadsheet with corresponding information and description such as the purpose of the model. The assignment to the classification based on the descriptions of the single product models found in the respective literature and on the experience of the authors. The results are visualised as bar diagrams with the percentage of the respective number of assignments to an attribute. If necessary, several attributes were assigned to one product model.

4.1 Literature research 1: General product model types

The first literature research was focused on product model types on general level without application to a specific product. 63 different types of product models were identified from 49 references. The identified product model types are assigned to the aspects of the three classification criteria. For detailing the phase of the development process, the generic classification attributes are applied according to VDI 2221. For the content, the information artefacts are chosen as described by [Fenves 2002]. The results are depicted in the following Figure 3. These two classifications are chosen because of their suitability for classifying general product model types.
The three charts in Figure 3 visualise the results of the classification. Looking at the process phases, it can be seen that the majority of the models are used in the first half of the development process. This observation corresponds to the interpretation of the V-model. The level of integration first decreases and then increases over the course of the development. With the decrease of the integration level, the amount of different product models increases. Subsequently, the product models are integrated to form the final product and the number of used product models decreases. The identified product models contain information about the function, the form and the artefacts of the product (meaning the component, product, subassembly or assembly). Concerning information representation, most of the

identified product model types use graphical information representation. As most product model types allow digital as well as analogue interaction, the percentage stands for “never analogue” and “never digital”. Here, only a small number of all products is assigned (e.g. physical prototypes can never be applied digitally and a FEM simulation model can never be applied by analogue interaction).

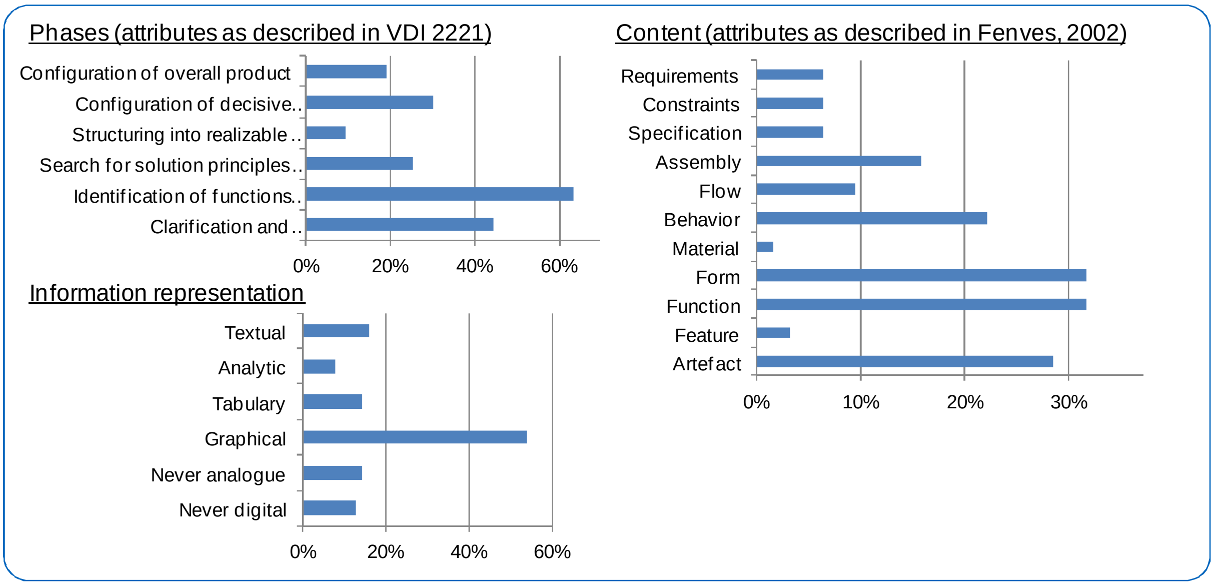

Figure 3. Classification of general product models

4.2 Literature research 2: Specific use of product models in electric vehicle development

The electric vehicle development was chosen as an exemplary use case for analysing the application of more detailed product models in specific context. For this research on product models used in electric vehicle development, 151 detailed product models were extracted from 41 references. Most literature sources covered topics related to electric vehicles. Some additional references focus on conventional cars and contain product models that can be used for both, electric and conventional cars. The 151 product models are distributed over 34 product model types, which have been identified in the first research. For example, a FEM model was identified as a product model type in the first research. In addition, FEM models in electric vehicle development were detailed in the second research considering the specific problems (for example for dynamic load or fluid dynamics).

The product models in the development of electric vehicles were analysed with regard to the three classification criteria. Here, the detailed process steps from the automotive industry and the user-oriented content classification were applied according to [Pahl et al. 2006]. The three charts in Figure 4 show the results of the classification.

Again, most product models were applied in the early phases of the product development process. Energy was the feature, which was mostly addressed concerning the content. This corresponds to the focus of the regarded field of application. In contrast to that the transport of material was only addressed in 10 percent of all product models. The evenly distributed number of product models that refer to the context of signal and the context of kinematics and forces show the interdisciplinary character of electric vehicle development. Considering information representation, most product models were assigned to digital representation. Graphical, textual and analytic representations outnumbered the use of tabular information representation.

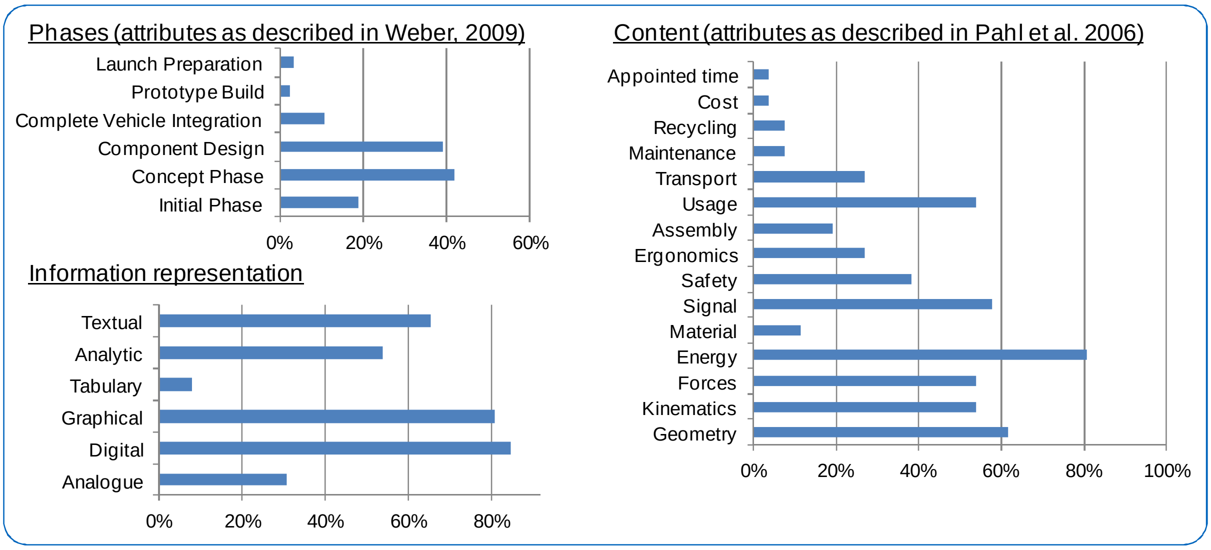

Figure 4. Classification of product models in electric vehicle development

5. Conclusion, discussion and outlook

The scientific research presented in this contribution focuses on the analysis of the use and scope of product models in engineering design. This builds the first step towards a methodology that is intended to support the product developer in choosing and combining single product models. For analysing the actual use and scope of product models, general classifications for product models were analysed concerning their classification criteria. Three of the most important classification criteria were selected exemplarily for detailing the classification attributes. The information content, the phase of the development process and the information representation were analysed in detail and possible attributes for the classifications were identified. On the basis of two literature researches (one general and one specific), general product model types and more specifically applied product models were identified and classified according to the three classification criteria. The results of the analysis show the large variety of product models both regarding content, their use in the product development process and their different representation types. The high number of varying classifications leads to the challenge for identifying a suitable classification for the development of the intended knowledge model. Questions like “How granular has the development process to be for classifying product models?” or “Which content is most relevant for the engineer?” will have to be answered in further research.

Some other engineering methodologies (e.g. set-based-engineering [Sobek et al. 1999]) also consider the importance of product models in engineering design. However, they do not focus on the application of product models in particular as intended in our work. Other areas of research in product development are related to product models and therefore also possibly influence this work. Information and knowledge management, product lifecycle management, simulation and modelling, computer aided design, prototype building and computational optimization – only to mention some of them. Due to these many different fields, the work presented here cannot claim to be complete although a lot of different literature has been considered. Nevertheless, this contribution helps gaining a sense of the large number of product models and the challenges that lie in their classification. Similar challenges occurred in the work presented by [Browning 2010] considering process models. In several papers in the last years, Browning et al. did a lot of work for identifying, analysing and categorising process models in product development (for an overview and further interesting details please refer to [Browning 2010]). Some of the challenges he faced in his attempts for classifying process models also occurred here.

In a further step, the methodology described above will be implemented step by step. Studies in industry will narrow down the focus on a specific scope and serve as further information source and validation scenario. Key issues will be the identification and quantification of the individual modelling needs of the product developer during the product development process. Also, the level of detail and the quantification of the classification criteria attributes have to be investigated. Furthermore, the combination of product models and the information transformation between different types of product models will be subject to further investigation. Based on the combination of the product developers' needs, the possibilities for combining product models and their classification, the methodology will be implemented.

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