5 ALGORITHM-BASED TRANSFORMATION OF CUSTOMER REQUIREMENTS INTO PRODUCT PROPERTIES

Youssef Chahadi[a], Martin Wäldele and Herbert Birkhofer

Technische Universität Darmstadt, Department of Product Design and Machine Elements (Pmd)
Magdalenenstr 4, 64289 Darmstadt, Tel.: +49-(0)6151- 16 2555, Fax: +49-(0)6151- 16 3355.
E-mail: [a]chahadi@pmd.tu-darmstadt.de

The procedure described here represents the basis for the development of profile-like structures by the Collaborative Research Center 666 "Integral sheet metal design with higher order bifurcations". The goal is to create an algorithm-based approach for developing optimal profile structures manufactured by the new linear flow splitting technology. The fundamental assumption is that the problem is defined verbally from a customer's point of view and this typically unfocused, incompletely formulated task is fleshed out step by step until the optimal profile can be determined using mathematical optimizing procedures and new CAD modelling technology. The transformation of the customer's requirements into product properties which can be used by the mathematical optimization is an important goal of this research project. The basis for this procedure lies in the systematic separation of the internal and external properties of the profiles being developed.

Keywords: Requirements, Product properties, Optimization, XML, Algorithm-Based.

1. INTRODUCTION

The Collaborative Research Center 666 (CRC666), founded in July 2005, aims to exploit the enormous perspective potential of the new technique of linear flow splitting. This procedure makes it possible to create integral sheet metal products with higher order bifurcations. The key here is a newly developed linear flow splitting technique for cleaving sheet metal, as can be seen in Figure 1. This technology, in combination with metal-cutting and welding processes, opens the ability to define new product categories with completely new features and geometrical properties.[1]

Using this method allows for new and innovative products, producing an even larger spectrum of solutions that have been previously thought of as expensive and complex. One goal of the CRC666 is to develop optimal sheet metal products, which have been difficult to realize using traditional forms of product development methods, or a constructor's intuitive estimations. Together with mathematicians, new algorithmic formulas have been developed for product development. In order to produce these new algorithms, it is necessary, especially for sheet metal design, to standardize the requirement definitions and the product properties. This paper will concentrate on the algorithmization of one aspect in product development. This aspect (see Chapter 2) applies to the requirement request, to the point of translating the customer's requirements into product properties.

2. TRANSFORMING COSTUMER REQUIREMENTS TO PRODUCT PROPERTIES

The starting point for the new algorithm based approach is the vague and verbally formulated customer request, Figure 2.

The process of determining, gathering and transforming the customer's requirements from the written or oral request into product properties is to be automated. The customer has the opportunity to access

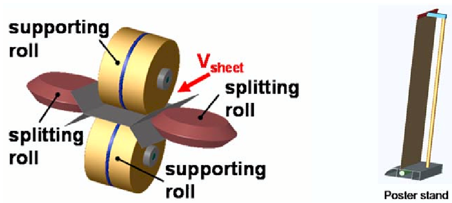

Figure 1. Linear flow splitting.

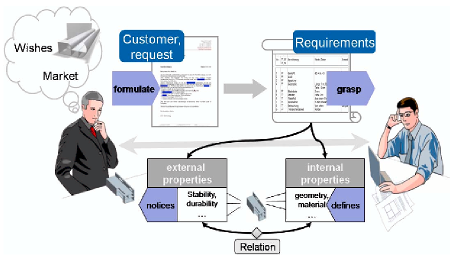

Figure 2. Transforming customer requirements to product properties.

a Requirement Configurator System (RCS), which offers the customer the opportunity to enter his requirements and wishes into the system, so that a complete list of requirements can be generated automatically. To derive standardized requirements, the RCS will be connected to a system of concepts (SoC). By way of the SoC, connections are generated between the general terms used by the customer and the known standardized requirements. The SoC offers a solid foundation and serves as a bridge leading from the vague expressions of the customer to the defined standardized requirement which the product with its properties must fulfill. These product properties are classified into internal and external properties[2] and their relations to one another are shown in the so-called property network.[3] These networks are used for the systematic preparation for a later mathematical optimization of the desired product.

3. REQUIREMENT DETERMINATION IN THE EARLY PHASES OF PRODUCT DEVELOPMENT

An important intention of our research is the transformation of market and customer wishes into product properties that can be mathematically optimized. The market and customer wishes, in form of a task from the customer's perspective, are usually verbal and unclearly formulated.[4] To remove any obscurities from the goal, and to capture the requirements of the desired product, many iterations would be required, and in the most cases this would result in delays and added costs. Standardizing of the requirements can support the automatization of clarifying the task or ascertaining the exact request.[5] Standardizing helps customer to formulate his requirements in clear and goal-oriented manner and to build common understood language between customer and designer. This would also require a standardized definition of the individually used terms, because most tasks are formulated not only from the developer, but also from the customer's point of view.

Sponsorship for researching the automatic capability of request inquiries has led to the development of RCS, which uses many components and techniques that are similar to Methods. The techniques, such as semantic networks (in the sense of SoC) for the requirement terms, as well as a Text Analyzing Component, and various methods like questioning techniques, checklists, weighting methods, etc. would be used in this RCS. The RCS has two modular, configurable interfaces. One user or customer interface (Front-end), and one administrator interface (Back-end). Therefore, the RCS could be understood as a

Content Management System. The back-end is used for the settings and the definition of the requirements, as well as their relationship with each other. At the same time, placeholders for requirements could be configured in forms of a graphical and user interface such as entry fields, checklists, or tables. A parser system translates the back-end produced graphical interface into a visual configurator, the so-called front-end. In the front-end is a user interface, which gives the customer the possibility to define his or her product requirements. An important component of this RCS is the SoC, which uses various components such as a semantic net or the text analyzer. These work together and hold the standardized requirement terms. The terms in the system are not only connected with the requirement terms, but also relate to the external and internal properties, which also have a relationship with each other. One of the goals of the RCS is the far-reaching automatization of the requests and their transformation into product properties, considering the requirement weighting of the desired requirements.

3.1. Analysis of Relations between Requirement Terms

To analyze the relationship between the terms, two cross examinations would be conducted. The goal is to find a standardized and common term definition of the requirement terms between the customer and the developer. The first examination that would be conducted is a subjective (From Customer → Developer), and the second is an objective (Developer → Customer) examination.

- In the subjective examination, the goal is to define a relationship between two terms. To examine the terms that come from the customer's phrases, most of the terms in the customer questionnaire would be located. Thereby the value of the relationship's strength and the distance between two requirement terms has to be compute, which would be defined and standardized by the intuition of the person who was questioned, after wards a possible relationship could be found between these terms and the product properties. The distance is the opposite of the relationship's strength, that means that when the distance is "small," then the relationship's strength is "large". Computing the values of the relationship's strength and the distance of the examined terms would be ascertained using a Cluster analysis and the Euclidean distance[6] from the poll of Students of Mechanical Engineering. A following step would examine the terms from scientific engineering personnel.
- The objective examination would begin at the end of the first examination. Thus the same terms can be used and the relationship would be partly found from a physical connection in literature. Using this approach, the relationships from the first examination can be confirmed. The relationship between two terms, which is proved by a known physical connection, could correct false relationship choices.

The next section will explain both processes more deeply, using a concrete example (a poster stand).

3.2. Analysis of Relations between Requirement Terms by the example of the Poster Stand

This approach is necessary to make clear how great can be the conceptual difference between the written terms in the customer's query, and how the developer will understand these terms. To be able to form a very precise conclusion about the relationships between the requirements, an example in form of a poster stand will be more deeply explained. Some of the requirements are Dimension, Sheet thickness, Material, Technology, Stiffness, Weight, Load, and Deformation. In the left Figure 3, one can see the calculated distances between the term pairs. The distances are results of calculations based on the survey of the Mechanical Engineering students. On the right is the relationship between the similar terms, which Engineers have intuitively defined. Both processes have the goal of revealing an intuitive association between the terms, as well as to find standardized requirements at the end.

In the Figure above it becomes visible, that the intuitive term relationships from the survey are not identical. For example, the term pair "Measurements ⟷ Sheet thickness" and "Measurements ⟷ Material" have the same distance in the first survey, whereas in the second survey, there is no connection between "Measurements ⟷ Material." This is why an Objective examination has to be conducted, with the goal to correct term pairs. This would offer a conclusion about the term relationships. While

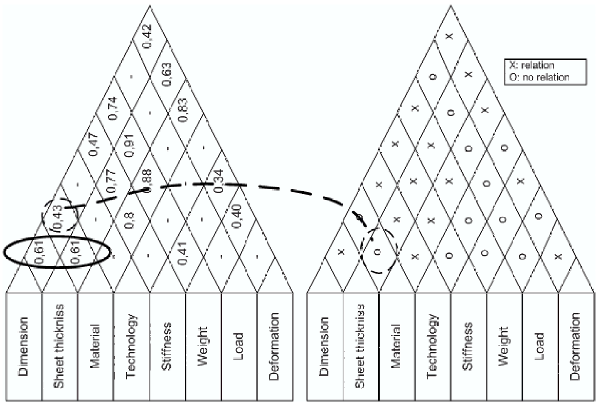

Figure 3. Relations between Requirements Terms.

doing this, the consistent terms as well as the inconsistent term's relationships from both surveys are examined. Most of the objective term relationships are taken from the literature[7] or through the cooperation with.[3] The term relationships play an important role as well, especially for our CRC666, so that a person can force an optimization's direction. This will be closer examined in the section 4.

The results of both examinations have defined these relationships:

HasInfluenceOn: A change of the term A has a direct influence on the term B in the term network.
Determines: A constant target value of term A can determine the value of term B
Limits: Term A sets a constant limit for Term B, however this limit is not set during the product development.
Synonym: Two terms are synonymous, if they have the same meaning.
Antonym: Are concepts with opposite meaning.

Please note that further term examinations could reveal more relationships. The term pairs in the SoC posses these relationships. In the RCS, these relationships would be presented in a comprehendible manner, and provoke thoughts about how the customer can define his requirements in a precise and goal-oriented manner, as well as acting as a reference for the developer.

In the example of a Poster stand, the customer chooses terms that he means to be important for his product. The system visualizes the chosen terms and their relationship in a semantic network (Figure 4).

4. FROM REQUIREMENTS TO PRODUCT PROPERTIES

In comparison to the step-by-step enrichment of product properties over the different phases of the pyramid model[8] a new algorithm-based approach is introduced. Usually, a design process starts with market and customer needs, often articulated vaguely, incompletely and inconsistently. But an algorithm-based approach needs precisely defined parameters and a relationship between them. The first requirement for a successful algorithmization, therefore, should be to develop a well defined vocabulary and terminology, and to analyze technical knowledge like physical models regarding their external and internal properties

4.1. Internal and External Properties

The most important aspect is the fact that products can be completely defined by so-called internal properties, which correspond to a vast set of external properties.[2] The requirements-list describes the "required properties" or feasible areas of properties the customer is looking for (e.g. "reliability" or "steadiness") and the product has to fulfill by its owned properties. The engineer has to choose and specify the products outwarded properties which are related to the demands of the costumer to meet his

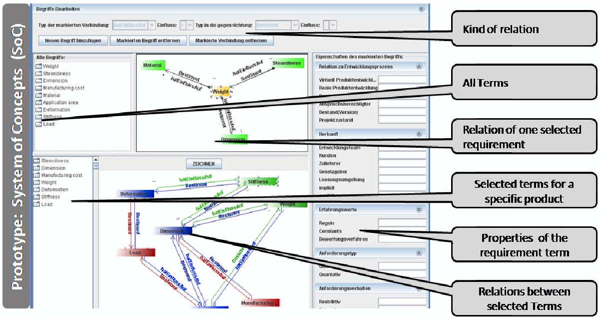

Figure 4. System of Concepts (SoC).

requirements. These outwarded properties are called external properties. They cannot be established in a direct way, they are always determined by the products internal properties (e.g. geometry, material). In short: The designer has to choose internal properties in such a way that the external properties are met.

4.2. Set up Dependencies of Internal and External Properties

The link between internal and external properties is of fundamental importance for the design process and therefore has to be analyzed. This "knowledge" of properties and their relation is often stored in scientific literature (e.g. guidelines, textbooks) and has to be made accessible foran algorithm-based design of CRC 666. These sources of information consist e.g. of texts, formulas, graphs and tables (Figure 5). Even a physical model like the heat resistance model consists of a heat transfer formulas, an explaining text and a picture given more insights to the problem. This model links the heat resistance of a profile's channel to the geometry, as well as to the material properties of the beam itself. This specific knowledge enables one to decide which internal properties to concentrate on in order to create the required external property and meet the requirements. To represent the dependencies of properties and each property chain, coming from external to internal property, a network structure is introduced.[3] In this network structure, called the property-network, the dependencies are clearly defined, coming from external to the internal properties of a product.

As was already mentioned, external properties can always be traced backed to internal properties. This means that internal and external properties always have a certain relationship to one another. Not only must the designer know which individual parameters influences an external property, he must also know which "setscrews", and therefore internal properties, he must adjust to achieve his desired external properties.[9]

4.3. Steadiness of a Poster Stand

The property-network of a profile structure, the base of a poster stand, described in this paper uses this concept for settling equations, which relates certain standard requirements to product properties. This finally leads to internal and therefore adjustable properties for the designer. By taking just a few customer requirements into account, a complex property-network is generated (Figure 6). Therefore, known physical models, such as the balance of forces and the balance of momentums, have been taken are analyzed. Among other things, the standard requirement steadiness is taken into consideration. The property-network of the base of a poster stand provides insight into the connection and correlation of properties. To improve the steadiness required of the poster stand base, one could either raise the tilting angle of the base or increase the tolerable tilting moment. The tolerable tilting moment is caused by external forces and is just great enough that the resistance points of an edge at the base leave the floor, and the resistance is reduced to zero.

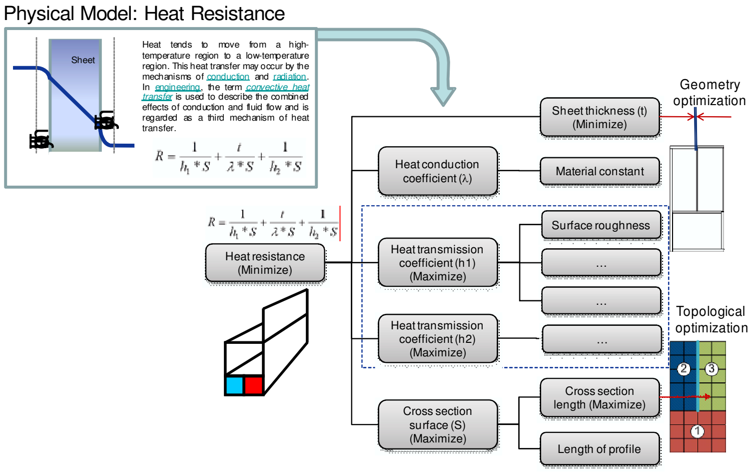

Figure 5. Dependencies of the physical model “heat resistance”.

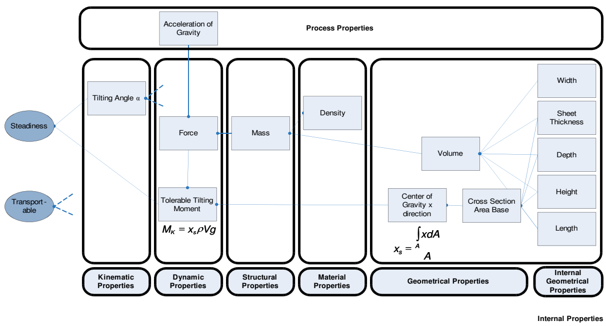

Figure 6. Property-Network “Steadiness”.

Exemplarily, the chain to improve the steadiness of the base and therefore the whole poster stand is illustrated. As shown in this network, the tolerable tilting moment is split up into force which is multiplied by a lever which is equal to the center of gravity in x direction. So, one possible way to increase the tilting moment would be through an extended lever and/or an increase in the force. But these are both properties which cannot be determined by the designer in a direct manner. The force is dependent on the mass of the profile structure and is dependent on the acceleration of gravity on earth, which is a process property and a standard only at the Earth’s surface. The mass is made up of the density of our material and the volume, which is the area of the cross-section multiplied by the length. All these internal properties, e.g. material and geometry, can be modified and chosen and changed directly by the designer. This network can be grasped by humans when just one standard requirement is involved, but it becomes incomprehensible with increasing complexity, i.e. when conflicting requirements occur and customer demands are taken into account. For an algorithm-based transformation and optimization of product properties these property-networks are implemented to XML.

5. XML-STANDARD TO EXAMINE THE TRANSFORMATION FROM REQUIREMENTS INTO PRODUCT PROPERTIES

Data exchange in the CRC666 is based on a distributive Information management system. This system consistently administers the data of various subprojects of the CRC666. One important function of the consistent data distribution is the actualization and the allocation of the data, which allows for

Optimization of the data, as well as generating 3D models.[10] One future main objective is a complete algorithmization and automation of the Virtual Product Development, which starts with the customer query and ends with a finished product. For a consistent distribution and uniform exchange of data, it is necessary to define standardized interfaces between the subprojects. With XML, various data types can be defined either in a hierarchy (Tree-Structure) or a non-hierarchy (Network structure) structure. XML offers a powerful Schema-Language to define and structure complex connections; this Schema is called XML-Schemas. Complex connections, such as relationships between requirement terms and relationships between product properties (internal and external), can be defined. Even relationships between requirements and product properties fit into this category. A parser system was developed to filter the product-specific requirements, as well as the link to the necessary product properties. The parser also formats the data in an exchangeable form with the Information management system. The administration of the terms occurs in the concept system.

Figure 7 A Customer will have a Poster stand that is tip resistant. Using the RCS, the customer can compose his or her wishes. The Requirement of the Tip resistance is standardized in the concept system, and in this system it is defined as having a connection to physical properties called "Tilting-Momentum".

The system suggests a simplified term relationship that is associated with Tip Resistance. In this case, it depends on (Dimension, Weight, Load). The visualization of this relationship is important to show to the customer, why the desired requirements are not possible, even without optimization of the related requirements and properties. For example, the customer wants an inexpensive, Tip-resistant poster board, which has a Weight = 7kg, which would greatly limit the optimization of this product. If the customer had completed his entries and also his weight entry, the data would be processed and sent to the developer, ready for further development. The weighting entry helps the developer choose an optimization direction. The developer receives the data in a detailed form, such as the XML depiction to the right. Detailed relationships will be displayed, e.g. what kind of relationship relationship between the external properties of "Tilting Momentum" and internal properties exists.

6. CONCLUSION

Through a subjective and an objective examination of possible request terms in customer's queries, an approach has been developed to standardize these terms and their relationships. The goal of this approach is to develop an excessively detailed, consolidated, and uniform understanding of terms used between the customer and the developer. The structuring and classification of these terms and their relationship with each other create the main portion in the development of this SoC used by the developed RCS and the term which could be understood as product properties, and/or are product

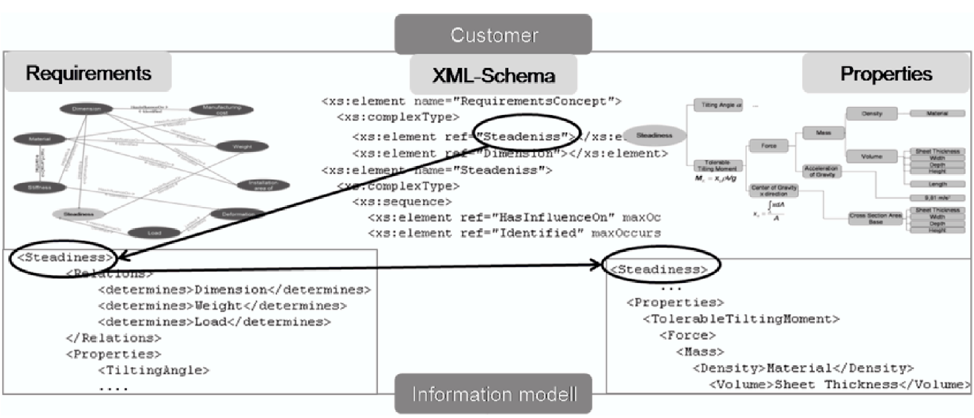

Figure 7. XML-Interface.

properties. The structuring and systematization of these terms is important to ensure an algorithmic comparison to property-networks. The more comprehensive in the standardization of terms in this system, the more significant the process automatization of determining the request or the assignment will be. As a result, the algorithmic transformation of the request into product properties will be greatly aided. This means that more research into the request terms, as well as researching more into the property-based model (such as a physical model) will be required. Due to the complexity of the connection between the data, an automated transformation of the requests into product properties via an interchangeable format between other systems is not possible without the use of appropriate computers. To solve this, an XML-requirement and properties schema will be developed, which can still be arbitrarily expanded.

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