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ScienceDirect

Procedia Computer Science 28 (2014) 497 – 504

Procedia
Computer Science

Conference on Systems Engineering Research (CSER 2014)

Eds.: Azad M. Madni, University of Southern California; Barry Boehm, University of Southern California;
Michael Sievers, Jet Propulsion Laboratory; Marilee Wheaton, The Aerospace Corporation
Redondo Beach, CA, March 21-22, 2014

Verifying the Abstraction Level of Structural Models

Michael Roth[a], Daniel Kasperek[a], Udo Lindemann[a]*

aTechnische Universität München, Institute of Product Development, Boltzmannstr. 15, 85748 Garching, Germany

Abstract

Structural modeling is one of the concepts in systems engineering to handle the complexity of technical products. In the process of modeling the choice of the abstraction level and the grade of detail are afflicted with uncertainties. Current methods support in identifying wrong elements or dependencies but support during the verification of the abstraction level is missing. This paper presents an approach to identify errors and not adequately chosen levels of abstraction. Using domain mapping matrices and matrix-multiplication, the approach supports the identification of elements, whose definition should be reconsidered. The approach is applied within an industrial case study.

Keywords: information acquisition; domain mapping matrix; uncertainty; level of abstraction; complexity management;

1. Introduction

In engineering markets the customers' expectations and requirements, as well as their variance grow. This is one of the reasons, why the complexity of products is steadily increasing.[1] Moreover the number of variants and thus the size of the product portfolio are increased to satisfy the individual customer expectations. As a result we observe a hardly manageable amount of variants and evolutionary grown complex systems in the industry.[2] It is associated with a huge

* Michael Roth. Tel.: +49-89-289-15129; fax: +49-89-258-15144.
E-mail address: michael.roth@pe.mw.tum.de

doi:10.1016/j.procs.2014.03.061

amount of information, which represents the system and its behavior. To handle this amount of information and to understand and to improve these complex systems, methodologies and techniques of systems engineering, such as the decomposition of the systems into elements and their interactions are used.[3,4]

For the system decomposition several matrix-based models have been developed, as they provide a simple and compact representation of complex systems.[4] The methodology of Structural Complexity Management (StCM) is one approach, which uses these models in order to deal with the challenge of complexity.[1] Based on the modeling of the system by its underlying structure, this methodology supports systems engineers during all necessary steps from modeling to structural analysis. Thereby a structural model is the result of the system decomposition, representing it by its elements and their interactions. However, the capability of StCM and thus the quality of its analyses and results is strongly influenced by uncertainties.[5] Failures in the definition of the elements and interactions reduce the quality of subsequent analyses' results. Though, the proper choice of the grade of detail and the adequate level of abstraction are crucial. Considering the previously mentioned huge amount of information associated to the complex systems, the choice of the grade of detail and level of abstraction are critical tasks.

In this paper we present an approach to identify not adequately defined elements of structural models within the StCM methodology. The approach uses matrix multiplication and the deduction of indirect dependencies to systematically obviate errors in the calculation steps of the approach itself, as well as to analyze the level of abstraction. Moreover conclusions for the refinement of the level of abstraction can be drawn.

In the following we first provide the necessary background of our approach. This includes a brief overview on the structural modeling of complex products. We present uncertainties and their influence on the modeling process. Then we provide an overview on the StCM methodology, associated principles and the state of the art. We point out the challenges during the information acquisition as well as resulting advantages of reduced uncertainties in this phase. In this context we introduce our approach consisting of three steps. We define the necessary input data, preconditions and based on this develop each of the three steps in detail. We validate our approach within an industrial case study, where we use it in order to find the adequate level of abstraction for the structural modeling of an evolutionary grown mechatronic product. Finally, we discuss the results and conclude with an outlook on future work.

2. State of the Art

2.1. Structural modeling of complex products

Boardman and Sauser[6] state that every system, which consists of at least two parts, possesses an underlying structure, which is determined by elements and links. Especially in complex technical products, the underlying structure is built up by multiple components, which are linked by various dependencies with high diversity.[7] The analysis of this structure is one approach to handle the system's complexity.[8] In the context of systems engineering it is necessary to identify the internal dependencies between the elements of the system. For example before changing a component of the system, the impact of this adaption onto other elements has to be considered. Thus the knowledge of a system's structural dependencies improves the developer's capability to manage complexity.[1]

To support the decomposition and modeling of complex systems, Felgen et al.[7] identified fundamental principles for complexity management within systems engineering. In the context of our paper, we point out the two principles of "abstraction" and "selectivity". The principle of "abstraction" implies the concentration on the essential, while un-essential aspects of a system are omitted. In this process the "selectivity" is one partial step. However it implies a risk of neglecting essential entities and vice versa, which is a source of uncertainty. Fig. 1 illustrates these principles in the process of structural modeling together with possible uncertainties. Hence we identify the proper choice of the grade of detail and the level of abstraction as key factors determining the model's quality.