Decision-driven Approach for Object Oriented Analysis

Jafet G. Sánchez Ruelas*, Thomas Vietor*

* TU Braunschweig, Institute for Engineering Design (IK), j.sanchez@tu-braunschweig.de

Abstract: A new methodical approach is being developed to support the decision-making process during the design and development of complex products. It builds upon model-based system engineering standards and suggests objects, models, analyses and reports for each stage of the design and development process. The resulting guidelines will help developers to build the right models at the right time. This research uses the development of new electrical vehicle concepts as examples of complex products and uses related ongoing projects as validation platforms.

Key words: Product Complexity, Decision Support, SysML

1. Introduction – Issues and problems addressed by the research

When developing complex products, two typical critical success factors are: how the development team deals with complexity and how to set and achieve requirements. There are several methodologies used to manage complexity; one of them is the use of model-base systems. By abstracting different system pieces as objects, and modeling the relationships between these objects (object-oriented approach), team members can have a better understanding of how the system works and how different objects interact. To achieve customer satisfaction, a product should have the physical and functional characteristics that the costumer requires; these characteristics can be defined as product requirements. Managing requirements with object-oriented models and tools is becoming a common practice known as object-oriented (OO) analysis. Therefore, OO analysis is a way to manage complexity and customer requirements simultaneously.

There are useful standards and guidelines available to model OO systems. However, these guidelines tend to be so general that system modelers with little experience might end-up building unnecessary objects, relations or even sub-systems. A systematic and dedicated object–oriented modeling guideline can help to develop complex products in a more effective and efficient way. The following pages describe ongoing research that aims to define a methodical approach for OO analysis, with a focus on the decision-making process for the design and development of complex products.

2. Objectives – Goals and significance of the research

The design and development process (DDP) of systems and products is well defined; a review of different DDP definitions will be briefly discussed in the next section. The Association of German Engineers, also called VDI for its German acronym, describes in its guideline VDI-2221, VDI-2222 and VDI-2223 the process of creating a product. These guidelines describe the tasks and results expected in the different design phases, and also propose what tools and methods can be used in every step. Yet, these methods and tools do not focus on dealing with system complexity through OO analysis.

Within systems engineering there are several standards for modeling OO systems and system-of-systems. System Modeling Language (SysML) is one commonly used standard. Following standards makes the description and use of model based systems more accessible and allows a better exchangeability of results [4]. Nevertheless, in order to make the most out of SysML, the objects and models syntax and notation must be further specified, which might also require further specifications in semantics.

When dealing with complex products, OO analysis helps the developers' team to specify, analyze and understand this complexity in order to make design decisions. Figure 1 describes an approach to make OO modeling more effective: Depending on the DDP phase, particular decisions and analyses are needed; and to support these decisions, specific objects, relations and diagrams will be suggested. In other words, depending on *when* and *why* an OO approach is needed, it becomes clear *what* (which) models and elements are needed. Subsequently, developers can extract reports that will support them with the decision-making process.



Figure 1 Decision-making approach for object-oriented modeling in the design and development process

This research aims to create a decision-making driven strategy for OO analyses and models. It builds upon SysML standards and suggests objects, models and reports for each stage of the DDP. The resulting guidelines will help developers to build the right models at the right time.

3. State of the art - Overview of existing research and theoretical references

There are different ways to define the DDP and the number of stages in it. Models from different authors have been reviewed and compared [1 and 6]; upon analysis of different models, it can be observed that there are more similarities than differences in these models. Instead of defining a new model, this research adopted standardized models where several experts were already in agreement. Two renowned institutions with such models are the VDI and the International Organization for Standardization (ISO).

ISO published a standard for systems and software engineering lifecycle processes called ISO-15288. The product development phases described in this standard are: requirements definition and analysis, architectural design, implementation and verification. VDI defines in guideline VDI-2221 a similar model structure; complementary VDI-2222 and VDI-2223 describe in more depth the way to proceed in each phase, suggesting the appropriate methods and tools. While the ISO standard and the VDI guidelines have a lot of similarities, the VDI guidelines focus more on the development process stages. Therefore this research takes the DDP model stated in the VDI guidelines, and uses it to define the decision-making stages where this research will recommend adequate

OO models and reports. The flowchart on the left side of figure 1 shows a very simplified model of the DDP that contains the most commonly defined elements.

Managing complexity with the support of model-based systems is becoming common practice in the industry; some of the existing model-based system engineering methodologies have been described [2]. The Institute for Engineering Design (abbreviated IK) analyzed over 60 articles of requirement-driven approaches for product development [7], revealing that the issue of modeling and simultaneously analyzing complex relationships needed further investigation. The implementation of model-assessment tools on OO models increases the confidence of the model itself and consequently the effectiveness of the results [3].

4. Enquiries and approach – Research questions and research methods

For centuries, the development of vehicles was based on the experienced gathered from the development of previous models. The scenario for electrical vehicles beyond 2020 gives a perfect design platform to develop complex products where experience in interdisciplinary knowledge fields is required. When replacing the classic combustion engine for an electric motor, these centuries of experience need to be reassessed. Thus, this research uses the development of electrical vehicles for 2020+ as an example and for validation purposes.

Based on the hypothesis that OO analysis can support the decision-making process in complex products, this research analyzes existing model-based system engineering methodologies and selects SysML as a standard for its own OO models. Then, by taking the design and development stages as defined in VDI-2221 and focusing on those where decisions need to be made, this research asks the following questions:

- How to create a consistent path (guideline) to make the use of OO analysis with SysML more effective in design and development?
- How to know/discern whether the effort and time required for building OO models are worth?
- Which existing methods (e.g. QFD, TRIZ, Critical path analysis, etc.) can take advantage of modelbased systems engineering to assist with the decision making process?
- Which visualization diagrams, semantic, and reports are most appropriate to facilitate the interpretation of results coming from OO analyses?

Aiming to address these issues, this research categorizes existing model based system engineering methodologies by their applicability and effectiveness in the decision-making phases of the DDP, proposes appropriate existing and/or new OO models and analyses, and finally suggests the best way to visualize the results to facilitate the reporting. It is clear that not all decisions need an OO approach; therefore a proper discerning strategy is being conceived.

5. Preliminary results and pending outcomes – Preliminary research outcomes and expected contributions to the field

Previous worked in IK extended SysML to cope with the needs of holistic requirements management and early identification of goal-conflicts [7 and 8].

Through a European funded project, this research took the previous in-house work and extended it to support the evaluation and selection of optimal electrical vehicle architectures by the following means: simplifying the modeling of vehicle components and requirements in SysML, documenting experts' knowledge in the model,

finding conflicting goals among areas of expertise, analyzing uncertainty of different technologies available in the future based on 4 extreme scenarios, and lastly delivering vehicle-concept assessment reports and prognoses in multidimensional diagrams [5]. The collaboration with the industry partners in this project served to validate the effectives of the OO models and results. Nevertheless, these results are just a few of the missing OO analyses and reports needed to support the complete DDP in the decision-making stages. The main search and categorization of commercial and published OO models is planned to conclude in three months.

Besides, an investigation on reporting diagrams and tables to visualize information and results remains pending, in some cases the OO models are alone the report needed to clarify complex relationship, nevertheless the syntax and notation from SysML is limited; for this, a study to improve the representation of OO models has just started.

6. Conclusions and next steps - Plan for the completion of the research

A methodical approach for OO analysis in the decision-making stages for the DDP is being developed in this research. A summary on the status of the literature review was briefly presented. In Figure 1, the approach taken by this research was shown. Some models and reports that are already developed were briefly mentioned, and the pending SysML models and reporting diagrams will be developed by the end of this year. A study on system diagrams with improved data representation has started and the first proposals of improvement can be presented in the Doctoral Colloquium.

The Doctoral Colloquium at IASDR 2013 will be a great opportunity to share ideas and put the abovementioned approach in question, and so find optimization opportunities and/or missing spots. It is also a great chance to find out how useful (or effective) these results could be for researches in other parts of the world, and to realize possible adaptations that must be done to achieve this effectiveness.

7. References and Citations

[1] Bishop, G. L., and Magleby, S. P. (2004) A review of technology push product development models and processes, In Proceeding of IDETC and CIE Conference 2004, ASME.

[2] Estefan, J.A., (2008) *Survey of Model-Based Systems Engineering (MBSE) Methodologies*, Rev. B, INCOSE MBSE Initiative, Jet Propulsion Laboratory, California Institute of Technology.

[3] Gausemeier, J., Frank, U., Donoth, J., Kahl, S. (2008) Specification Technique for the Description of the Principle Solution of Self-optimizing Systems in Mechanical Engineering (Part 1), Konstruktion, Springer-VDI

[4] Object Management Group (2012) Systems Modeling Language, www.omgsysml.org, [Acc. Dec. 2012].

[5] Sánchez Ruelas, J.G., Stechert, C., Vietor, T., Schindler, T. (2012) *Requirements Management and Uncertainty Analysis for Future Vehicle Architectures*, In e- Proceedings of FISITA, paper ID: F2012-E02-006.

[6] Sharafi, A., Wolfenstetter, T., Wolf, P., Krcmar, H. (2010) *Comparing Product Development Models to Identify Process Coverage and Current Gaps: A Literature Review*, IEEE.

[7] Stechert, C. (2010) Modellierung komplexer Anforderungen, Publisher Dr Hut, Munich.

[8] Stechert, C., Hagner, M., Vietor, T., Goltz, U. (2011) *Requirements Management from an Interdisciplinary Point of View*, In Proceedings of IASDR 2011.