M. Koch, A. Butz & J. Schlichter (Hrsg.): Mensch und Computer 2014 Workshopband,
München: Oldenbourg Wissenschaftsverlag, 2014, S. 297-303.

From Lifecycle Modelling to Lifecycle Analysis - A Framework for Interactive Visualisation of Lifecycle Information

Christian Kaiser[1], Andrea Denger[1], Johannes Fritz[1], Georg Eggenberger[2], Matthias Seidl[1]

Information & Process Management, Virtual Vehicle Research Center[1]
CAMPUS 02 University for Applied Sciences[2]

Abstract

In this paper the proposed framework for a holistic tool-chain from system modelling to interactive visualisations is presented. The novelty of the proposed framework is the first-time interactive visualisation of SysML models by transferring it into an ontology with the intermediate step of XMI transformation and queries via SPARQL for the identification, description and illustration of participating disciplines and aspects in product development. Focusing on the appropriate representation of data and interaction with data, a visualisation should assist users to use different aspects of the data on demand as a basis for communication and collaboration.

1 Introduction

In order to meet the challenges of today's markets and the competitive environment, interdisciplinary development processes across locations have to be designed in an efficient and flexible manner. Systems Engineering (SE) is an interdisciplinary approach developing complex products and systems. System thinking, an important part in SE, allows better understanding and specifying of products and systems. In this case the system has to be considered as a whole through its entire lifecycle, from the definition of the requirements over system design to validation in operations and recycling. (Haberfellner et al., 2012)

The existing knowledge related to both product and production has to be made available in a specific manner. For this purpose, amongst others, tools and methods of the Model-Based Systems Engineering (MBSE) and the Semantic Web can be used (Denger et al., 2013). The traceability of interdependencies offered by linked data structures enables comprehensive analyses and ensures the context-adequate re-use of products and product-related knowledge with the required level of detail. One key aspect of the proposed framework is the possibility of integration of several data sources into an ontology, to be able to query information and information related to it, due to the semantic technology stack in use. One potential data source, as it was used in the proof of concept implementation presented in the following chapters, is a function-oriented and model-based description of products and systems done in a SysML authoring tool. The Systems Modeling Language (SysML) is an application based on the UML standard language for modelling complex systems.

Accompanying to the proposed framework, the evaluation approach and a conclusion are detailed in the following chapters.

2 Proposed Framework

In today's product development processes, one challenging task is to compile information into a proper form to be able to understand the interdependencies between products, product parts, product features, and their applications. Different views with different levels of detail are demanded by related stakeholders. With the increasing usage of the *System Modeling Language* (SysML) for describing systems' interdependencies and stakeholders' views, these challenges can be addressed and assisted. However, SysML as well as its authoring tools are difficult to understand for non-experts.

To give non-experts a chance to use information, the approach is to transform the data of information sources, in this case one or more SysML models, into an user- or task-specific visualisation which assists in view building and uses proper visualisation techniques to represent the demanded structures. To achieve this, an ontology is used to integrate all data sources into one knowledge base. The ontology's structure is based on the business objects and lifecycle aspects in focus of the stakeholders in question.

To integrate data of the SysML model into the ontology, an intermediate step is taken. Firstly, the SysML model is exported in an XMI representation. XMI is a standardized model exchange format, based on XML. In a second step the XMI export is analysed and parsed to create ontology instances by deriving and aggregating the original model's entities as necessary.

To provide the data for the frontend visualisations, the ontology is queried by so called endpoints. For RDF (Resource Description Framework) and OWL (Web Ontology Language) ontologies, SPARQL is the query language of choice. The endpoint answers in structured data formats, e.g. JSON or XML.

In this proposed framework, the SPARQL endpoint is used to retrieve answers for the stakeholder-specific questions from the ontology. The endpoints' answer provides the input for visualisation libraries, which ease the users' perception by proper visualisation of the retrieved data.

To realise this proposed framework, the XMI-to-ontology transformation software has been developed as a first step of the proof of concept tool-chain. Subsequent steps require the implementation, a data retrieval service and a user interface with interactive visualisation and data representation.

The proposed framework for a holistic tool-chain consists of the following components: Authoring tools to describe for example products and their interdependencies, a software tool for the transformation of the single data sources into one single ontology, an ontology editor tool for the possibility of evaluation and a server tool which is able to host the data of the ontology and provide it for web frontends.

Figure 1 shows the logical steps of the proposed tool-chain. Business objects like target definitions, requirements, functional behaviour, product structures, and dependencies are input for the SysML modelling. For the transformation into the domain-specific ontology the SysML model is exported as XMI file and is transformed to an OWL ontology file. The ontology is verified and validated out of specific stakeholders' questions manually. The resulting findings can be used to adopt the transformation code. Finally, SPARQL queries sent to the SPARQL endpoint lead to a response which can be used as input data for visualisations. Each single step is described in detail in the following subsections from the tool-chain's workflow viewpoint.

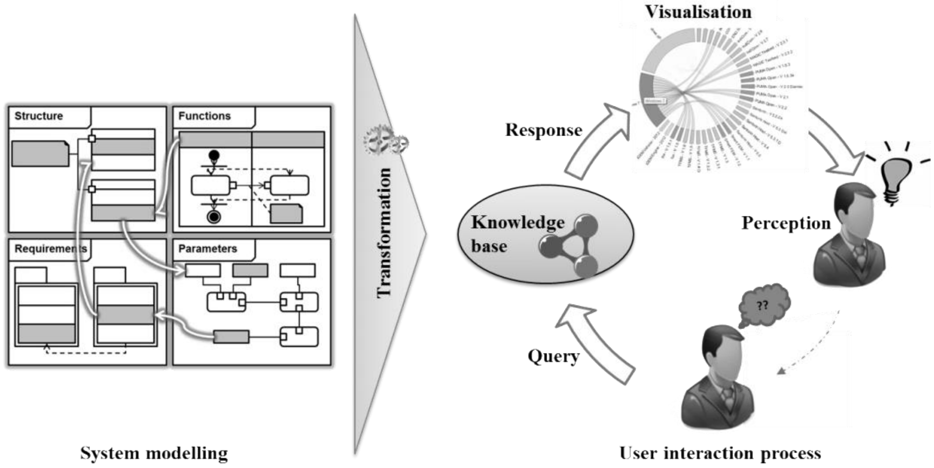

Figure 1: The proposed framework, based on (Denger et al., 2013).

2.1 System Model

The input information, for example product requirements, is captured in SysML models. The SysML model represents the knowledge base, which provides the foundation for information exchange. In order to answer stakeholders' questions, the knowledge base created in SysML is exported to a machine-readable form first. One widely spread export format in SysML authoring tools is XMI.

2.2 Ontology Transformation

Several steps are necessary to convert the XMI export of the SysML model into OWL. The first step of the developed transformation software is reading the XMI. The next step is to parse the data and assign correct data types. The objects then are sent to the builder. The third step is to perform various operations on the gathered data, for example to create a list of all objects and enrich the objects with additional information from the XMI model. The builder first initialises the ontology and then fills the ontology with data instances. In the final step the ontology is written to the file system.

2.3 Ontology Evaluation

The proposed ontology can be designed in many different ways. According to the concept, the design possibilities are decided during development of the transformation program. It is important to understand relations and dependencies of the business domain correctly. The approach is to analyse given stakeholder business questions and compare them to the created ontology (Fritz et al., 2013). According to Grueninger et al., (1995) competency questions - in this case business questions in the engineering context - are used to test the ontology. Each question is modelled as a single graph and then consolidated to a common ontology (Guebitz et al., 2012). The designed ontology created in the ontology transformation step must be able to answer those questions. The stakeholders' feedback can be used to redesign the program.

2.4 Ontology Data Querying Interface

The ontology generated in subchapter 2.3 can be hosted on a SPARQL endpoint and made accessible for queries, for example using HTTP. The W3C recommended query language is SPARQL. "SPARQL can be used to express queries across diverse data sources, whether the data is stored natively as RDF or viewed as RDF via middleware." (World Wide Web Consortium, 2013b) A query leads to a response, amongst others for example JSON formatted.

2.5 Context Based Interactive Visualisation

Interactive visualisations, with filter or highlighting, assist people to clear their view on the data. In this concept interactive visualisations will be used to answer business questions.

One provided business question is: *Which product version belongs to which package*? The mock-up in Figure 2 shows a possible interactive visualisation to answer the question.

It represents a Gantt-chart; the original library is called *EmberTimetree* (Crowdstrike, 2013). The Gantt-chart can provide information on milestones of products, product releases and to which Release a product belongs. For example, as seen in the mock-up, the *Package_2014*, a combination of products, has several releases, *R3* and *R2* can be seen. In release *R3*, several products will be included, for example *Product H* in version *2.x*. A possibility to focus on a particular timeslot is planned with the overview area beneath the bar-trees. The interactive visualisation is encapsulated in a web-page.

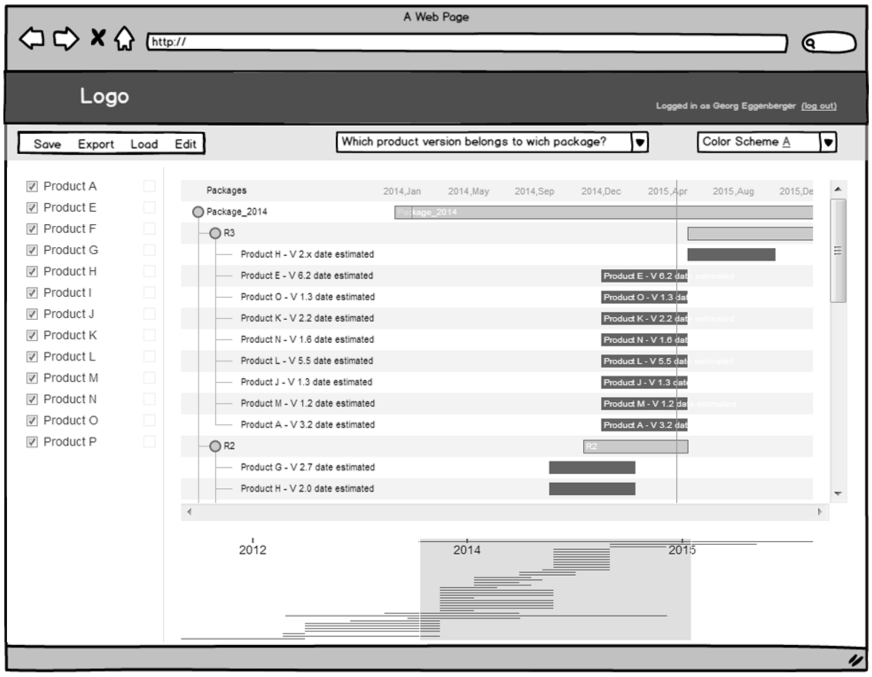

Figure 2: A mock-up of the web page including an interactive visualisation.

The concept of the web-page disposes a login possibility for security aspects. As SPARQL queries should be sent to an endpoint, the possibility to filter is included on the very left side of the mock-up. As several business questions may be included, a dropdown box should let the user choose which query to answer. As colour-blindness and personal colour preferences should always be taken into account, a dropdown box to choose one out of several colour schemas is provided on the upper right corner.

3 Evaluation Approach

The data and the system can be evaluated in each state of the tool-chain, when it is modelled in SysML, when it is stored in an ontology and when it is visualised. Data modelled with SysML has to fulfil certain language conformity, defined in the OMG standard for SysML v1.3 (Object Management Group, 2013). The language conformity and the modelling method can be proved for consistency.

The ontology has to fulfil an OWL consistency (World Wide Web Consortium, 2013a). The ontology can be tested with reference queries to measure the consistency and the completeness by comparing the data to the SysML model.

The usability of the visualisation is another aspect to validate, e.g. using a Thinking Aloud test. Colours, the overall impression and the significance of the webpage are influencing the usage and furthermore the rating of usefulness a user would give the system (Hartmann, 2007).

In order to understand user needs correctly an iterative approach of prototyping for design (Alavi, 1984) and agile development methods in general are used. Three major business questions of the stakeholders have been identified and supported with proper visualisation techniques. The used visualisation techniques were a Gantt visualisation, a Chord diagram and a Collapsible Tree layout.

4 Outlook and Conclusion

In this paper the framework for a tool-chain from system modelling to interactive visualisations is presented. Hereby specific demands with regard to a future workplace scenario have to be considered. Focusing on a concept evaluation, a lightweight solution for exactly and only the stakeholders' use cases is planned. Three major business questions of the stakeholders have been identified upfront and supported with proper visualisation techniques. Future work includes more visualised business questions and the implementation in an industrialised tool environment, e.g. the IBM Rational Jazz platform.

Acknowledgement

The authors would like to acknowledge the financial support of the "COMET - Competence Centers for Excellent Technologies Programme" of the Austrian Federal Ministry for Transport, Innovation and Technology (bmvit), the Austrian Federal Ministry of Science, Research and Economy (bmwfw), the Austrian Research Promotion Agency (FFG), the Province of Styria and the Styrian Business Promotion Agency (SFG).

We would furthermore like to express our thanks to our supporting industrial and scientific project partners, namely AVL List GmbH, BMW AG, Karlsruhe Institute of Technology, Munich University of Technology, and to the Graz University of Technology.

Literature

Alavi, M. 1984. An Assessment of the Prototyping Approach to Information Systems Development. *Commun. ACM*, 556-563.

Crowdstrike Inc. 2013. *Ember Timetree by Crowdstrike*, http://crowdstrike.github.io/ember-timetree/. Retrieved 2013-11-14.

Denger, A., Fritz, J., Denger, D., Zingel, C., Ölmez M. & Kissel, M. 2013. Model-based approach for function-oriented steering of products. *ProduktDaten Journal 20 (1)*, 53-57.

Fritz, J. & Denger, A. 2013. Best-Practice-Ansatz zur Erfassung und Modellierung von Stakeholder-Sichten, In *Tag des Systems Engineering: The Value of Systems Engineering - Der Weg zu den technischen Systemen von morgen*: Carl Hanser Verlag München, 135-144.

Grueninger, M. & Fox, M. S. 1995. In IJCAI'95 workshop on basic ontological issues in knowledge sharing: *Methodology for the design and evaluation of ontologies*.

Guebitz, B., Schnedl, H. & Khinast, J.G. 2012. *A risk management ontology for Quality-by-Design based on a new development approach according GAMP 5.0*. In Elsevier Science B.V.: Expert Systems with Applications. 7291-7301.

Haberfellner, R., de Weck, O., Fricke, E. & Vössner S. 2012. *Systems Engineering: Grundlagen und Anwendung*. Zürich: Orell Füssli Verlag.

Hartmann, J., Sutcliffe A. & De Angeli A. 2007. Investigating Attractiveness in Web User Interfaces. In ACM San Jose California: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 387-396.

Object Management Group 2013. *SysML 1.3*, http://www.omg.org/spec/SysML/1.3/. Retrieved 2013-11-27.

World Wide Web Consortium (W3C) 2013a. *OWL 2 Web Ontology Language Document Overview (Second Edition)*, http://www.w3.org/TR/owl2-overview/. Retrieved 2013-11-27.

World Wide Web Consortium (W3C) 2013b. *SPARQL Query Language for RDF*. http://www.w3.org/TR/rdf-sparql-query/. Retrieved 2013-11-15.

Contact Information

Christian Kaiser
Virtual Vehicle Research Center
Department information- & process management
Inffeldgasse 21a
8010 Graz
christian.kaiser@v2c2.at
http://www.v2c2.at