Development and Evaluation of a Component-based Context Modelling Method

Hasan Koç[1], Kurt Sandkuhl[1]

Abstract: In very general terms, a method describes a systematic procedure for problem solving including the required aids and resources. This paper is a continuation of our earlier work that reported on the practices and experiences in the development of a component-based context modelling method in the area of information systems development. The contributions of the paper are (1) the detailed development process of the context modelling method, with a particular focus on artefact evaluation by means of the Framework for Evaluation in Design Science Research (FEDS) (2) additional experiences and lessons learned from the method engineering and application process.

Keywords: method component, method engineering, context modelling, method evaluation, FEDS

1   Introduction

Enterprises should easily adapt to the changes in the regulations, customer demands and advances in the technology to secure a competitive advantage and to improve their chances of survival. The shift towards a service-oriented economy makes it even more important for enterprises to be agile to fulfill the changing requirements. A recent EU-FP7 project Capability as a Service in Digital Enterprises (CaaS) addresses these aspects and proposes to design a business service explicitly considering its delivery context. To this end, the project will deliver the Capability Driven Development (CDD) method. An integral part of the CDD is the context modelling method, which allows for eliciting and designing the service application context.

Method engineering is a complex process since methods have to be grounded in solid experiences, elaborated with an adequate level of detail and ideally validated in many application cases in order to reach a sufficient maturity level. This paper is a continuation of our earlier work that reported on the practices and experiences in the development of a component-based context modelling method in the area of information systems development [SK14]. The contributions of the paper are (1) the detailed development process of the context modelling method, with a particular focus on artefact evaluation by means of the Framework for Evaluation in Design Science Research (FEDS) [Jo14] and (2) additional experiences and lessons learned from the method engineering and application process.

---

[1] The University of Rostock, Institute of Computer Science, Chair Business Information Systems, Albert-Einstein-Str. 22, 18059 Rostock, Germany, {hasan.koc, kurt.sandkuhl@uni-rostock.de}

The remaining part of the paper is structured as follows: the background for the work from CDD and previous findings from the earlier work are briefly introduced in section 2. Section 3 presents the overall method development process constituting the frame for this research. Section 4 focuses on the development and evolution of the context modelling method and discusses the different phases of the process with experiences and lessons learned. Conclusions and future work are discussed in section 5.

2   Background

2.1   Capability as a Service (CaaS)

Work in this paper is based on the method development which is a part of the EU-FP7 project "Capability as-a-Service in Digital Enterprises" (CaaS). The main goal of the CaaS project is to facilitate a shift from the service-oriented paradigm to a capability delivery paradigm by applying the CDD approach. Based on the capability meta-model proposed in [Bē15], capability in CaaS is defined as the ability and capacity that enable an enterprise to reach a business goal in a certain context. Context in this case would be any information characterizing the situation of the capability [De01].

The CDD approach includes five top-level method components for capability modelling, a Capability Development Tool (CDT) and a Capability Navigation Application (CNA) to monitor and adjust the service delivery according to the context at runtime. In order to ease adaptation of business services to new delivery contexts, the CDD explicitly defines (a) the potential delivery context of a business service and (b) the potential variants of the business service for the delivery context. This requires development of a new methodical framework supporting business context modelling in the three industrial cases in CaaS, which is the main focus of this work. Method engineering in CaaS was a use case-driven, iterative process. The three use cases contributing to the method development and involved in method evaluation were from e-government, energy industries and insurance. More detailed descriptions of the use cases are available in [Bē15] and [KS15].

2.2   Experience Reports in Method Engineering

Reflecting on the practices of method application and presenting the experiences gained in the projects is a decisive and necessary activity. In the literature, there are only a few publications reporting from the topics of method engineering experiences, such as method application, realized business value, stakeholders of the method as well as the development process of the method itself.

Addressing this gap, our previous work indicated recommendations and lessons learned in method engineering based on the development of the context modelling method

component [SK14]. First, in a distributed team of developers, the previous work strongly recommended to treat the method development task like a project and define clear role and task structures. The roles needed are the overall method development responsible and the responsible actors for different method components, which in project management could be considered as project manager and work package managers. Furthermore, there should be an expert for the selected method conceptualization supporting the method component development and the developers as such. Second, to develop a method documentation template and define it as mandatory for all method component also proved valuable, which should be complemented with additional training for all method developers on the application of the method conceptualization. In this respect, the method conceptualization by Goldkuhl et al [GLS98] proved to be suitable and applicable. Yet, extensions to the method conceptualization had to be done and some concepts were renamed to further operationalize the method use. Third and last, Moody´s principles [Mo09] were used to evaluate the visual notation, whereas they did not help when constructing it, which was rather a creative process. Also, one important missing aspect in the evaluation was the implementability of the visual notation within the modelling environment, which could be crucial for the projects applying the notation in the industrial setting.

This paper contributes to this findings by elaborating the method development process, with a particular focus on artefact evaluation by means of the Framework for Evaluation in Design Science Research (FEDS) [Jo14] as well as the gained experiences from the method engineering and application.

3   Overall Method Development Process

The process for development of the top-level CDD method components roughly followed the general phases of an engineering process: scope setting, requirements analysis, design, implementation and test - with several iterations included in these phases. However, all these phases were adapted to the specific needs of the application case and heavily influenced by the method conceptualization used. The produced output is used in the context modelling method development process (cf. section 4).

The process was started with organizational and technical preparations. The organizational preparations included formation of the development team, defining the responsibilities of the team members, agreeing on schedule and clarifying available resources. The technical preparations were directed to identifying and agreeing on frame conditions, such as the purpose of the method as a whole, a set of requirements and the capability meta-model, which were a result of the previously completed requirements work package. The main principles were defined as i) the creation of a component-oriented method to support different ways of working, ii) the update of the meta-model that should serve as a common basis for all method components and iii) development of a ready to use reference methods with links to the proprietary methods.

After these preparations, the actual work on the method started with discussing different method conceptualizations and agreeing on one conceptualization to use. The way methods and method components are applied within CDD is an extension of the method conceptualization proposed by [GLS98]. A method component consists of *concepts, procedures* and a *notation*. The *concepts* specify which aspects of reality are important and what should be captured in a model. The *procedures* describe in concrete terms how to identify the relevant concepts in a method component and the *notation* specifies how the result of the procedure should be documented. The method components are related to each other with *method framework*, i.e. which components are to be used and under what conditions, as well as the sequence of the method components (if any). The *perspective* defines what the procedures should achieve and finally, forms of cooperation represents the necessary skills to apply the method. In line with the project needs, we replaced the terms *framework* and *perspective* by *overview to method components* and *purpose* respectively. Moreover, the procedures are refined with additional elements such as *steps* with certain *inputs*, *outputs* and *tool support*.

The development process for the different method components happened in different parallel activities performed by different groups from the method development team. This paper will focus on the development process for the context modelling component only, which is introduced in the next chapter. Before that, it should be noted that the overall method development process introduced in this chapter was not entirely sequential but rather iterative and incremental (e.g. the change in the frame conditions were also reflected in the resource planning). The overall process worked smoothly for the CaaS project, yet we lack other use cases and projects that might help to generalize the procedure and create good practices.

4   Context Modelling Method: Development Steps

The development of the context modelling method followed the problem explication, requirements elicitation, solution investigation, method design and method evaluation steps. The output created from the overall method development process was integrated after the first iteration of the method design step. The feedback gained in each evaluation cycle triggered the design of a new method version. Moreover, as the use cases and stakeholder goals evolved, changes were observed in the requirements, which were again reflected in the following method versions. This section focuses on this highly iterative context modelling method development process.

4.1   Problem Explication

This step investigated the problems experienced by the enterprises when increasing flexibility of the service delivery in changing environments. The first activity was to define the problem precisely. Based on the overall CDD method objectives, the problem was refined as "the digital enterprises need more support towards offering flexible digital

services, which should be adapted to the changing requirements of the environment". In the second activity, the problem is positioned in the practice, within which it occurs, i.e. surveys and semi-structured interviews with stakeholders from practice were conducted to demonstrate general interest, action research and observation techniques are applied to give depth to the problem. Finally, the last activity analyzed the root causes of the main problem. The output of this step was a precisely explicated problem, with its root causes [JP14].

4.2   Requirements Elicitation and Investigation of Possible Solutions

Different from the main principles produced in the overall development process (cf. section 3), this step elicited additional requirements that should guide the design of the context modelling method. For this purposes, focus groups including the researchers and the practitioners were created. To mitigate the risk that one person dominates such groups, participative approaches were used, upon which the requirements were derived from the enterprise goals regarding a context-aware service delivery. The result was a set of requirements of functional and non-functional nature that the method should fulfill.

Based on the requirements, systematic literature analyses in the areas of context modelling and capability modelling with a particular focus on method engineering were conducted. The state of the art analysis showed that context modelling and context-based systems are a popular topic in contemporary research with a lot of different context definitions and application examples existing. Most work focused on the conceptualization of context and a method for context modelling, showing what steps to take and how to identify relevant context elements, has not been proposed yet. The gained knowledge during the analysis was applied in the next step, when designing the method. To exemplify, the six parameters of the context proposed in [BB05] was used as an inspiration, namely constraint, influence, behavior, nature, structure and system. Moreover, amongst the categories, we selected "situational context" as the most relevant classification for CaaS, since developments in this category focus on information characterizing the state or situation of a person, object or location. Regarding the capability modelling methods, we observed that the term "method" is used synonymously with "process, procedure" or "step". Also, it was not possible to identify an off-the-shelf method related to enterprise models and stakeholder goals or an approach consisting of actors, notations, important concepts and activities to be executed when modelling capabilities.

4.3   Design of the 1st Method Version

This step presents the first iteration of the context modelling method development. The requirements enriched in the prior step are used here to express the purpose of the method, which were formulated as questions that the method should be able to answer. Following that, important concepts derived both from the literature work and the

industrial use cases were selected to find a right balance between the theory and practice. Based on these concepts, generic procedures are created that help to identify them. During the first design iteration, the overall method development process introduced in chapter 3 were still being executed. In particular, there was no agreement on the method framework to be used, hence the documentation template could not be created. Yet, solely from the context modelling method point of view, the problem explication, requirements analysis and solution investigation steps could be carried out, which established the foundations of the context modelling method.

The first iteration resulted in a fairly immature artefact, which had to be further developed in accordance with the output from the overall development process and the evaluation results. Specifically, the evaluation cycles provided the most important input for designing the next method version, leading to a close relation between the design and evaluation steps. The following section details the interplay between these two steps.

4.4   Selecting the Right Strategy for the Evaluation

The design process of the context modelling method is iterative, i.e. the design of the artefact produces method versions, which is then evaluated in different settings. For evaluating the method version(s), Framework for Evaluation in Design Science Research (FEDS) proposed by Venable and colleagues [Jo14] is applied. Each evaluation result feeds the loop back to the design method step, i.e. the evaluation activities executed after each method version contributed to the refinement of the procedures, concepts and notation of the following method versions.

Following the FEDS approach, first an evaluation strategy should be selected that is based on the resources and the evaluation criteria. Here we explicated the main goals as ensuring the efficacy (*the positive outcome is due to the artefact*) and effectiveness (*the method works in real settings*) of the artefact. Furthermore, since we develop a socio-technical artefact, we aimed to minimize the social/ user oriented design risks related to whether the design fulfils a need or solves a problem. The evaluation of an artefact in its natural context is a resource-consuming task, hence existing research projects that the method engineers work in as well as the student assignments should be used to minimize the costs. As identified in the previous steps, there was a general lack of proposals about the context modelling methods. Thus, the development would be of exploratory nature and the initial design described in section 4.3 could have minor flaws, which had to be taken into account in the strategy selection.

Consequently, we selected the "Human Risk & Effectiveness" evaluation strategy, i.e. evaluation methods that produce empirically-based interpretations to improve the characteristics of the artefact (*formative evaluation*) should be applied in artificial settings, which allows for a few false starts. Then, the evaluation should be scaled up rather fast to the more realistic settings (*naturalistic evaluation*) in the upcoming method versions to create shared meanings of the artefact in different contexts (*summative evaluation*) [Jo14]. To obtain the utility of the artefact, four main properties derived

from the non-functional requirements should be evaluated, namely "perceived usefulness, perceived ease of use, fit with the organization and ease of learning". Finally, the individual episodes required to evaluate the artefact were planned, which are elaborated in the following section.

4.5   Evaluation Cycles and Method Versions

The evaluation of the 1st method version (1st evaluation) has a formative-artificial character and adopts the criteria-based method. The enterprise modelling experts discussed the 1st method version and checked whether it fulfils the requirements. In line with the 1st evaluation, the context modelling method is updated (see Fig. 1). The important concepts that the method user needs to be acquainted with had to be aligned with the capability meta-model to have an ontological commitment to the terms. Based on the classes in the capability meta-model important concepts in the procedures are highlighted and explained. Here we also used the results of the literature reviews to use additional concepts such as "variation aspect" or "variation point", which were then added to the meta-model. In order to represent such concepts, a notation was developed and then evaluated based on Moody´s principles [Mo09]. To define the relationship between the concepts, the associations in the meta-model were used. Moreover, the tools are introduced, which the method user needs to model the context. The generic procedures are refined as *steps*, which comprise of the activities, input(s), objective(s) and output(s), tool support required to execute the steps is added to the method.
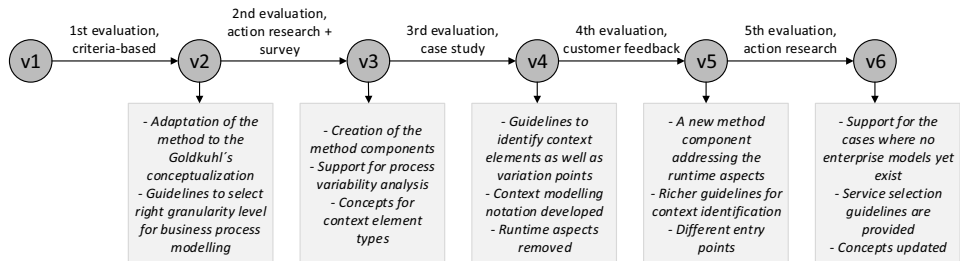

Fig. 1: Evaluation Cycles and Contributions to the Method Versions

The activities to update the method to v2 included two researchers, an enterprise architect and a knowledge worker. This helped to clarify the concepts that the method uses and to identify initial skills required when applying the method. Also, by observing the modelling activities of the business stakeholders in the participatory modelling sessions, the researchers could propose guidelines on how to develop enterprise models. Examples of this were the produced goal models, mostly with ambiguous and hardly measurable objectives and business process models with various granularity levels.

The 2nd evaluation used both formative-naturalistic and summative-naturalistic methods. The former included the practitioners and the enterprise modelling experts. To gather

feedback concerning how the method works in real settings, we applied action research, where the real user (practitioners) also participated to the formative design. The summative evaluation phase focused on the properties of the method by conducting an online survey. The 3rd method version incorporated the gained feedback, which mainly addressed a clear separation between scope setting, variability analysis and operationalization of the context model. Based on this finding, three method components were defined appropriately.

In the 3rd evaluation, single case study approach was adopted to gather the feedback from the method application in an industrial setting. During the method application, we observed that the client identified all possible gateways as variation points and all sub-processes as process variants. This caused confusion in the identification of the contextual factors, i.e. *everything related to the resolution of the gateways* were elicited as context elements, without considering its effect on capability delivery. Thus the 4th method version provided guidelines to identify i) what constitutes a context element and how to distinguish it from other information objects and ii) variability and variation points in business process models. Moreover, the context modelling notation is specified, i.e. pictograms for developing context models are provided to the method user. Now that the method user can model the context, the need for implementing it grew. However, the *operationalization* method component proved to be insufficient for this purposes, i.e. the clients did not know how to represent the business rules and how to model the adjustments in line with the application context. As a result, the 4th method version focused only on the early design phases and removed the runtime related aspects, which should be addressed in the further versions.

The 4th evaluation was formative-naturalistic and basically collected client feedback and requirements for the runtime aspects. The results were incorporated into the 5th version of the context modelling method. In particular, the new component described the way of adding part of the specifications such as preconditions and rules for using the context model during operations. Also, the guidelines regarding to context identification are enriched based on the experiences with the clients and use cases. We observed that the industrial partners had different enterprise models that had been developed before the application of the method. For instance, one partner offered business services in utilities industry and has already modelled business processes that are implemented to offer such services, whereas the other partner had established goal models. To support the investigation of the contextual factors based on existing enterprise models, the 5th version provided two different starting points, namely "goals-based" and "process-based" strategies.

The 5th and last evaluation to date focused on the effectiveness of the latest method version by conducting an action research cycle with one client. The cycle was applied in the course of a student project with the client. The group included a researcher, an enterprise architect and four students over a timeframe of three months. During the investigation it became clear that the context modelling method lacked support for the situations, where the business services are only described as textual specifications and no

formal models are adopted for their implementation. Last but not least, additional guidelines are provided to the method user on how to select the service(s) that should be implemented context-aware and concepts are updated and aligned with the procedures.

5   Experiences and Future Work

This paper extended our earlier work that reported on the practices and experiences in the development of a component-based context modelling method. The extension concerned the elaboration of the method development process, with a particular focus on artefact evaluation by means of the FEDS framework [Jo14] as well as the gained experiences from the method engineering and application.

During the method design, we benefited from the capability meta-model, which was developed before the project started. The advantage of a such meta-model was twofold. First, the concepts that the method components refer to were to a great extent represented there and they have been reused. Second, to define the relationship between the concepts in notation development, used applied the associations in the meta-model. According to the use case needs, the concepts and the meta-model were updated. In this respect, the evaluation cycles adopting action research was helpful, i.e. the practitioners involved in the method application raised their concerns whenever clarifications were needed. This created the basis for the discussions, where the researcher could intervene and help the client with the understandability issues. The symbiosis as such resulted in an improved context modelling method and will most likely influence the non-functional requirements listed in section 4.4 positively.

Application of the FEDS framework proved to be suitable for the evaluation. The evaluation activities executed after each method version contributed to the refinement of the procedures, concepts and notation of the following method versions. Unfortunately, mitigation of the researcher in such projects might be a problem, especially in the evaluation of the artefact. Although the bias of the method engineers, who also played a role in evaluation, cannot be completely eliminated, we minimized this threat by involving other researchers without expectations, as well as industry practitioners.

The CaaS project takes a use case-driven approach. The use cases defined in the beginning of the projects matured over time. Accordingly, the requirements that the context modelling method fulfill evolved. Also, after the artefact evaluation, new requirements emerged that had to be taken into account in the upcoming versions. In a such highly iterative process, the component-oriented method conceptualization provided a holistic view and allowed for an easy maintainability of the method.

In line with the principles introduced in section 3, the method should not be a monolithic block. The artefact should allow for a situational use, thus we classified the outcomes of the design method step into different method components. Here, two options were feasible. First, each purpose defined earlier in the method design process could be

addressed by a respective method component. This option is preferable, when the method user has a complete overview on the industrial setting, in which the method is going to be practiced and is aware of the enterprise goals that should be fulfilled. The alternative way was the creation of method components depending on the procedures and the produced outputs. We opted for the latter one since we did not have any experiences with the industrial use cases defined in the project.

Future research needs to investigate the interaction with a complete CDD environment, which includes a Context Platform that provides information, a Capability Navigation Application that monitors context indicators and applies adjustments, and a Capability Delivery Application that supports the organizational work practice. Last but not least, to assure rigor of the method as well as its application in the practice, a final and summative-naturalistic evaluation is going to be conducted.

References

[BB05]   Bazire, M.; Brézillon, P.: Understanding Context Before Using It. In: Modeling and Using Context. Springer 2005; pp. 29–40.

[Bē15]   Bērziša, S. et al.: Capability Driven Development. An Approach to Designing Digital Enterprises. In Business & Information Systems Engineering, 2015, 57; pp. 15–25.

[De01]   Dey, A. K.: Understanding and using context. In Personal and ubiquitous computing, 2001, 5; pp. 4–7.

[GLS98]   Goldkuhl, G.; Lind, M.; Seigerroth, U.: Method integration: the need for a learning perspective. In Software, IEE Proceedings -, 1998, 145; pp. 113–118.

[Jo14]   John Venable, Jan Pries-Heje, Richard Baskerville: FEDS: a Framework for Evaluation in Design Science Research. In European Journal of Information Systems, 2014.

[JP14]   Johannesson, P.; Perjons, E.: An introduction to design science. Springer, Cham, 2014.

[KS15]   Koç, H.; Sandkuhl, K.: A Business Process Based Method for Capability Modelling. In: Perspectives in business informatics research. 14th International Conference, BIR 2015, Springer, 2015.

[Mo09]   Moody, D. L.: The Physics of Notations: Toward a Scientific Basis for Constructing Visual Notations in Software Engineering. In Software Engineering, IEEE Transactions on, 2009, 35; pp. 756–779.

[SK14]   Sandkuhl, K.; Koç, H.: Component-Based Method Development: An Experience Report. In: The Practice of Enterprise Modeling. Springer Berlin Heidelberg, 2014; pp. 164–178.