Structured Model-based Engineering of Long-living Embedded Systems: The SPES Methodological Building Blocks Framework

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Abstract In industrial practice, development processes, even when framed by laws and standards, such as those applicable to the automotive industry, for example, are unique not only to each application domain but furthermore to each manufacturer. While the engineering process often focuses on the development of the different engineering artifacts, no structured process is defined to create these artifacts. In consequence, reuse of solution concepts from one domain to another, or even from one company to another is impeded. In particular, for long-living systems, there is a strong need for the application of common re-engineering and maintenance solutions. To address this need, solution concepts must be customizable and combinable with one another. This allows for the applicability of common solution techniques to different companies and fosters the application of solution techniques from other domains. In this paper, we introduce the SPES Methodology Building Blocks Framework to support the adaptation and integration of methodological solution components.

1 Introduction

In the embedded industry, a number of domains and even the companies within a domain have different requirements and constraints on the development processes. As a consequence, in many cases the concrete development processes and the applied concepts, tools, and techniques used in one company vary considerably from those used in another company. Hence, the SPES[1] Modeling Framework was designed to focus on the development of artifacts which need to be created and processed, without giving much consideration to the industrial engineering processes that create them (cf. [BV13]). While this has shown to be an effective way to allow for inter-domain and inter-company problem estimation and solution development, it also showed that such artifact-oriented engineering has shortcomings regarding the real-world applicability of the developed solutions. The proposed solution approaches and techniques must, in practice, not only be designed to be compatible with respect to input and output artifacts, but must also fit into the companies' current engineering processes. In particular for long-living systems, there is a specific need to establish common re-engineering and maintenance processes. Highly interacting embedded systems depend on each other and replacement of one system necessitates the re-engineering of its neighboring systems. Since these systems might be property of another supplier, a common re-engineering process must be instantiated for multiple individual companies.

Hence, this paper proposes the SPES Methodological Building Blocks Framework. Its main purpose is to allow for the integration of existing, company neutral solution concepts into individual development processes. Thus enabling companies to tailor their use of development artifacts to their specific needs. Therefore, the framework allows for defining individual engineering steps in individual engineering processes. In doing so, fine-grained artifact-oriented technical solutions are used as detailed implementation of the reusable generic engineering steps.

2 SPES Modeling Framework

The SPES Modeling Framework aids in seamless, continuous model-based engineering of embedded systems. For that purpose, it defines four viewpoints and various abstraction layers that serve as guidelines for creating certain artifacts which support the development of embedded systems (cf. [BD+12]).

The different viewpoints facilitate the separation of concerns in the development of engineering artifacts. Figure 1 illustrates the four viewpoints: The requirements viewpoints supports the elicitation, documentation, negotiation, validation, and management of requirements. The functional viewpoint focuses on the functionality of the system under development and describes the system's behavior, as it is observable from outside the system boundary. The logical viewpoint defines the decomposition of functions into logical components and the technical viewpoint deals with the deployment of software to hardware components.

[1] The SPES (Software Platform Embedded Systems) approach was developed by a national innovation alliance consisting of several joint research projects and aims at continuous model-based engineering of embedded systems. See [PH+12] for more details.

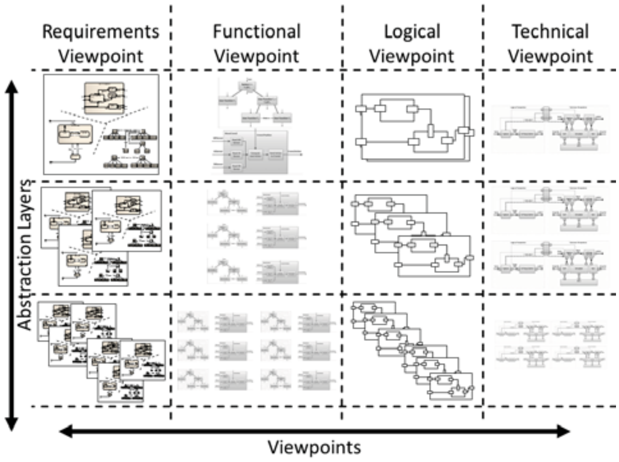

Figure 1: Structure of the SPES Modeling Framework

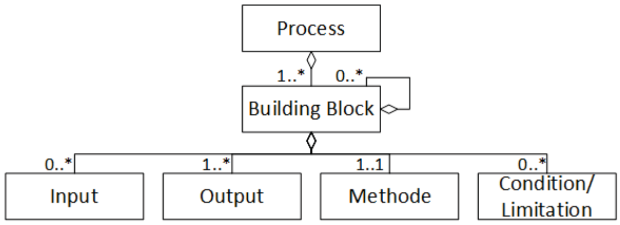

Figure 2: SPES Methodological Building Blocks Framework

In addition, application domain specific abstraction layers can be defined to address domain specific needs and to allow for complexity reduction by means of abstraction.

3 SPES Methodological Building Blocks Framework

While the SPES Modeling Framework suggests the creation and documentation of certain artifacts, the SPES methodology does not define a process for their creation or analysis. The SPES Methodological Building Blocks Framework is not only meant to aid the use of the SPES Modeling Framework and to structure the developed methods into one consistent description, but furthermore, to allow industrial partners the use of the multitude of proposed methods and artifact types within their individual development processes. In contrast to other related approaches, the SPES Methodological Building Blocks Framework only uses terms for defining building blocks, which are not already used for artifacts in the SPES modeling framework. This is done to minimize confusion among industrial partners.

A methodological building block is the low level unit for method process construction (see Figure 2). A methodological building block comprises a specific methodological solution, which can be, for example, a technique, a guideline, or a tool. A methodological building block can have some inputs (e.g., an engineering artifact of a specific artifact type) and has at least one output (e.g., an engineering artifact or an analysis result). Furthermore, there might be limitations and conditions associated with a methodological building block. Conditions can be further differentiated into pre-conditions and post-conditions.

The methodological building blocks framework defines two major types of methodological building blocks:

- Construction building block have outputs that are artifacts to be documented in the SPES Modeling Framework. For example, the synthesis of the functional design from requirements would create the functional design which belongs to the functional viewpoint. A construction building block may have some input (e.g., requirements artifacts). However, not all construction building blocks need input (e.g., the creation of a context diagram may be done from scratch).
- Analysis building blocks are used to analyze existing artifacts. This could be, for example, a consistency check between two artifacts. An analysis building block takes one or more artifact as input and their output is an analysis result, which is typically not documented in the SPES Modeling Framework, even though it might be a diagram.

Methodological building blocks can be combined to form coarse-grained building blocks in order to solve a specific engineering challenge. This building block concept, on the one hand, provides flexibility, as it does not impose a rigid process, and, on the other hand, allows for reusing building blocks within the same process as well as in other processes. Like a jigsaw consisting of different puzzle pieces which fit into another, the methodological building blocks are appropriately combined in to define a process that solves a specific problem in the engineering of embedded systems. Within this process, construction building blocks as well as analysis building blocks can be combined by compatible inputs, outputs, as well as compatible pre-, and post-conditions. One building block's output can be another building block's input. Furthermore, one building block's post-condition might ensure that another building block's pre-condition is met. Not only single building blocks themselves, but also sequences of building blocks can be reused in other engineering processes.

4 Industrial Application

We applied the framework in the context of industrial engineering challenges and to different application domains (i.e. automation, automotive, avionics). Figure 3 illustrates the application of the SPES Methodological Building Blocks Framework to define a process for creating a dedicated review model for the purpose of validating behavioral requirements and functional

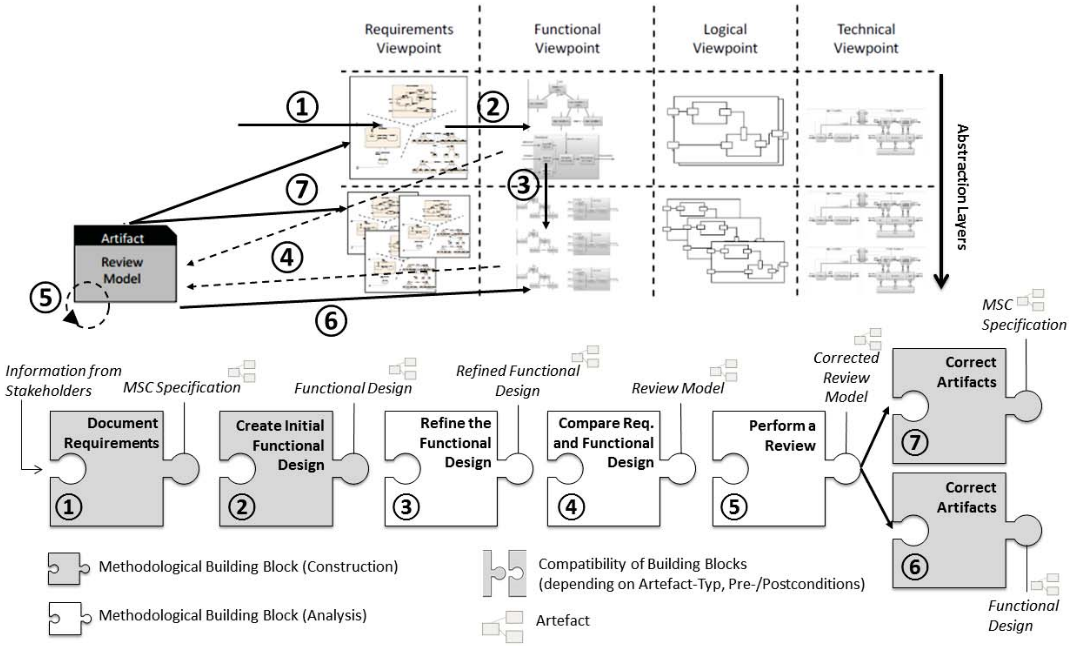

Figure 3: Example for the application of the SPES Methodological Building Blocks Framework

design (see [DWP15] for details). The figure describes the process of creating a Message Sequence Chart (MSC)-based requirements specification (1 in Figure 3), a corresponding functional design (2 in Figure 3), a refinement of the functional design (3 in Figure 3), the creation (4 in Figure 3) and use (5 in Figure 3) of a review model, and the correction of the functional design (6 in Figure 3) and MSC-specification on the chosen level of abstraction (7 in Figure 3). Construction building blocks are indicated by solid arrows and analysis building blocks by dashed arrows.

The usefulness of the resulting combined process was evaluated by the use of controlled experiments and can be considered as highly effective, efficient, and supportive (cf. [DS+15]).

Beside this particular application, the Building Blocks Framework was applied to several further industrial case studies. For example, methodological building blocks were used to create a realistic, model-based specification of an automotive adaptive exterior lighting system (cf. [FH+15]). In addition, we validated the Building Blocks Framework through interviews and questionnaires among industry experts (cf. [DHW14]). In summary, we are confident that the proposed SPES Methodological Building Blocks Framework is applicable to supplier and integrator companies. In particular, we experienced technology transfer between the automotive and the avionics domain.

5 Related Work

The discipline of method engineering in general deals with the construction of methods [Br96]. To instantiate methods in particular situations (e.g., for a certain industrial development process) approaches from the field of situational method engineering aid in constructing adapted methods suitable for particular needs and intended workflows (see [He03], or [RSM95]). Method engineering approaches build upon different concepts to define atomic parts of a method (e.g., method fragments [HBO94], method chunks, [RB+06]], or process chunks [RP93]). In addition, approaches exist that integrate product-focused fragments and process-focused fragments (e.g., [RB+06]). Furthermore, situational method engineering frameworks are proposed [MR06], for example, combines an assembly-based approach for situational method construction and a road map-driven approach for engineer-specific method configuration. For more approaches dealing with situational method engineering we refer to the state of the art review provided by [HR10]. It is to note, that to the current date, the community of method engineering has achieved a notable level of maturity, but the focus on solving individual issues is suspected to hinder the spreading of method engineering solutions in practice (cf. [Ro09]).

6 Conclusion

In this paper, we introduced the SPES Methodological Building Blocks Framework. The framework aims at aiding in process definition for artifact-oriented engineering methodologies. Hence, the SPES Methodological Building Blocks Framework aids in the use of generic solution approaches in different engineering processes and fosters interoperability of solution knowledge between different companies and domains, such as automotive, avionics, etc. The framework is based upon several approaches from the field of situational method engineering. To allow for easy use by industry professionals, the methodology building block descriptions make use of a very common and easy to understand template definition format. In addition, to avoid confusion among practitioners, we carefully defined the framework using only terminology not used in model-based artifact-oriented frameworks, such as the SPES Modeling Framework. We gave a short insight into the application of the SPES Modeling Framework for one concrete methodological approach, which has been applied in close collaboration between academia and industry for the avionic and the automotive domain. Beside others, we also used methodological building blocks to integrate methods for context modeling and context analysis (cf. [DB+14]).

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