Applicability of Agile Methods for Dynamic Requirements in Smart PSS Development

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Abstract. Smart Product-Service Systems, i.e. solutions consisting of tangible and intangible components interacting with their environment through information and communication technology, are subject to various dynamic influences along the life cycle. Stakeholders to the solution may change, as well as their needs and technological capabilities. This makes the requirements for the solution volatile, uncertain, complex and ambiguous. The system scope and associated requirements are constantly changing. In this paper, it is discussed how agile methods can help to deal with these influences in the development phase. A literature review and an industrial case study are used for analysing the problem of dynamic requirements, and agile methods are identified that can be applied for Smart Product-Service Systems.

Keywords: Product-Service Systems, Smart Products, Smart Services, agile development, VUCA.

1 Introduction and Problem

For manufacturing companies, it becomes more and more relevant to provide additional services to their products and to enlarge the target market through innovative business models. This results in a transition from product- to service-oriented industries, in which the development process is increasingly based on participatory and co-creative design principles and thus makes an integrated products and services development process more relevant [1]. The implementation of Industry 4.0 can be seen as a catalyst and accelerator of this change. The gathering and evaluation of data support processes like design, operation or maintenance and can lead to optimized industrial value chains in the medium and long term [2]. Manufacturing companies can create a unique selling point in an addressed market niche by offering an attractive bundle of Smart Products and Smart Services, using the potential of new technologies for sensors, actuators and data processing.

The combination of Smart Products and Smart Services to an integrated solution can be seen as a “Smart Product-Service Systems” (Smart PSS). During the life cycle of such a system, stakeholders, scope and configuration will change. This means that also the dependencies and interactions between the product and the service elements may vary, and consequently this affects the overall solution design [3]. Therefore, the engineering of Smart PSS is evolving from a temporal development process for individual solutions towards permanent orchestration of distributed product, service and information technology elements adapted to a dynamic environment [4]. This requires that these systems are aligned to the environment of stakeholders, technology and constraints throughout the life cycle, which implies that also the requirements towards the Smart PSS are dynamic.

It is therefore relevant to question the methods used for designing and developing such systems. Conventional approaches aim to generate static requirements documents, which limit the reactivity to unforeseen changes in needs. Tools and methods are required that support the gathering and analysis of dynamic requirements throughout the development phase and (prototypical) operation. In the software domain, similar challenges have led to the introduction of agile methods, which rely on continuous feedback loops to catch instantly new requirements [5]. Thus, our main research question is: *Are methods of agile software development transferable to Smart PSS in order to support agile system development there?* The aim of the paper is to design a procedure model for agile system development of Smart PSS based on an analysis of the applicability of agile methods from software development. More specifically, this paper looks into the suitability of SCRUM and Design Thinking.

The paper is structured as follows: The next section explains the research approach and methodology, followed by an overview of the state-of-the art in the fields of dynamic development environments and agile development methods. Section 4 presents a procedure model for the agile development of Smart PSS, which is applied in a case study for Smart PSS development in automotive plant engineering in Section 5. The following section 6 illustrates the application results for the identified tools and methods in the use case. Finally, in section 7 we discuss next steps and future work.

2 Methodology

The main objective of our work is two-fold, thus we have used a mixed method approach for our research approach: a literature review in combination with action based research, in this instance a case study. A literature review in the field of agile design methods and design of smart PSS was planned, conducted and reported. This analysis showed that there is a research gap in the need for specific application areas of agile methods for Smart PSS. In order to dig deeper into the problems and to shed some light on under which circumstances agile methods can be used in an industrial environment and how they can form the basis for agile development processes, empirical research was carried out in an automotive plant-engineering case study according to Sein, Henfridsson et al. [6].

3 State-of-the-Art

This section summarizes the results of the literature review and describes the current challenges in Smart PSS development originating from an environment characterized by volatility, uncertainty, complexity and ambiguity. Furthermore, agile development methods are introduced as an approach to deal with these influences.

3.1 Smart PSS Development in a dynamic Environment

Smart PSS are complex systems that have to be aligned to an environment of stakeholders, technology and constraints. This environment is dynamic and changes have an impact on the requirements for the solution. Its characteristics influencing Smart PSS development can be described with the elements of volatility, uncertainty, complexity and ambiguity (VUCA). *Volatility* denotes strong fluctuations of a state over a relatively short period, making it hardly predictable. *Uncertainty* means that causal relationships of the system under consideration are known, but not their probability of occurrence to forecast future developments. *Complexity* describes the unpredictability of system behavior due to the abundance of elements and connections. *Ambiguity* refers to the obscurity of causal relationships, when an event cannot be clearly assigned to a potential effect, leading to false assumptions. [7, 8]

Developing Smart PSS poses particular difficulties under these conditions. Influences from the volatile system environment have a direct impact through technological interfaces, e.g. the real time processing of Big Data. As future operation scenarios are often vague and can only be described by probabilities, there is uncertainty about the requirements for the Smart PSS. Furthermore, they are complex systems with a large number of different elements and connections, making it impossible to predict precisely the behavior of the system. As Smart PSS are by nature one-of-a-kind solutions, there is no pattern to derive requirements, leading to ambiguous specifications.

In order to cope with a VUCA environment in Smart PSS development, an approach has to be able to handle these conditions. It has to be agile enough to react to volatile changes and unlock additional information sources to reduce uncertainty. Furthermore, processes should be restructured to match system complexity and involve experimentation with prototypes to reduce ambiguity. Such methods and tools have been introduced in computer science as agile software development. [7]

3.2 Agile Development Methods

Agile development methods address the challenges of VUCA-influenced development environments with an iterative and incremental way of working [9]. They start as quickly as possible with value-creating development tasks in order to achieve a so-called Minimal Viable Product (MVP), which is repeatedly subjected to customer feedback, leading to a participatory design approach. Compared to plan-driven product developments there is no need to draw up specifications, but new requirements are continuously added. An agile approach is consequently suitable for Smart PSS developments, in which the complete specification of requirements at the beginning of the project is impossible. Based on reviews of agile development approaches in industry [10–13], two methods with a high relevance for physical product development are examined more closely – Scrum and Design Thinking.

Scrum is the most widespread agile approach [10], with a focus on small, highly efficient teams. As shown in Fig. 1, product development is orchestrated in the form of events that are held at fixed intervals and with fixed durations. An iteration in the development is called "Sprint" and is timed between 1 and 4 weeks, depending on the project. The Development Team plans the development activities and scope of the Sprint with the Product Owner and discusses the progress in a Daily Scrum meeting up to a maximum of 15 minutes. Each iteration ends with the Sprint Review, where the implemented functions are presented by the Development Team and accepted by the Product Owner. A reflection on the methodical work is carried out in the team within the Sprint Retrospective. [14]

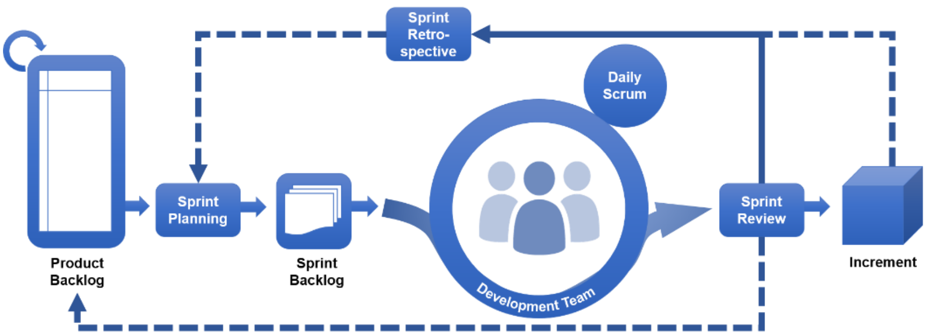

Fig. 1. Scrum Framework, following [14]

Design Thinking is an agile method to promote innovation focused on the intuitive thinking processes of interdisciplinary developers by approaching the problem from several perspectives [15]. The Design Thinking process combines empathy for the problem context with creative problem solving and rational analysis of proposed solutions, as illustrated below.

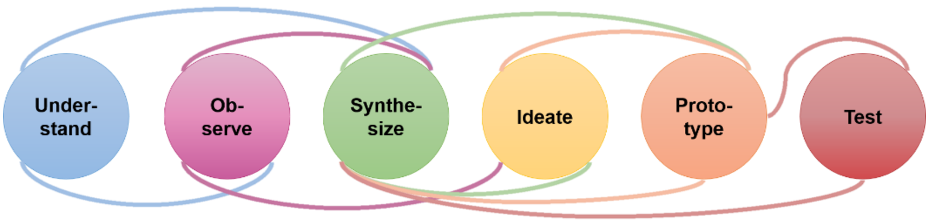

Fig. 2. Design Thinking Process, based on [15]

In the first phase, the development team builds understanding for the problem. In the second phase, the developers acquire the user perspective by recording their needs in direct interactive exchange as well as indirectly through observations. The synthesis defines the team-wide view of the problem from the findings. Based on this common view, ideas are then generated and finally implemented in prototypes. From then on, the prototypes offer the possibility to test the functions and thus to recognize false assumptions at an early stage. Based on the test results, the development team generates a new, deeper understanding of the problem and starts the design thinking cycle again. By repeating this process, the problem and ultimately the solution space are narrowed down. [15]

4 Procedure Model for agile Smart PSS Development

According to [11], the application of Scrum is suitable in the early steps of product development in automotive plant engineering due to the availability of detailed descriptions how to perform the method. Scrum is also the method most widely used in an industrial context, so that benchmarking would be possible [10]. A high user acceptance is also probable. A disadvantage of the exclusive application of Scrum is the absence of a methodical development of an initial product vision [14].

In contrast, the use of Design Thinking methods in the early steps of product development make it possible to develop an initial product vision [15]. In plant-engineering, consistent usage of Design Thinking in the development phase could have an effect on the modernization of the service portfolio and organizational structures. The integration of the Scrum method into the Design Thinking process is thus proposed as a concept for the realization of the procedure model for agile development of Smart PSS and is illustrated in Fig. 4 below.

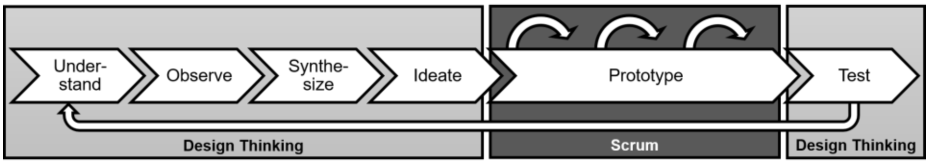

Fig. 3. Phases of the Procedure Model for agile Smart PSS Development

5 Case Study

The thyssenkrupp System Engineering subsidiary of thyssenkrupp AG manufactures systems for automotive body and engine assembly, as well as the associated test stations. The change to electric drive and shorter product cycles make the automotive plant-engineering environment extremely volatile, while the preference for different power and energy storage technologies remains uncertain. While the complexity of automotive production lines is increasing, their bespoke design causes ambiguous requirements.

Therefore, a training system was developed to examine whether future employees could be familiarized with their work processes already in the design phase. The standard training method so far has been to introduce employees to the basic welding process in the welding school in order to train aluminum welding, and then receive practical training in production on the real work piece. This procedure repeatedly led to high training effort and consumption of the training components during the learning phases. In order to get better learning results at lower costs with fewer resources, a virtual training environment has been implemented as a part of the Scrum phase (prototyping). This integrated virtual training environment as an integrated part of the prototyping phase can be seen as a Smart PSS.

The virtual training project was set up to check whether the use of Virtual Reality (VR) technology and the CAD models of the assemblies would make it possible to familiarize the trainees with complex work processes. A concept was developed to simulate the station and work processes using VR. The objective of the project was to review firstly the concept for internal purposes. After this, the system can be offered to external customers.

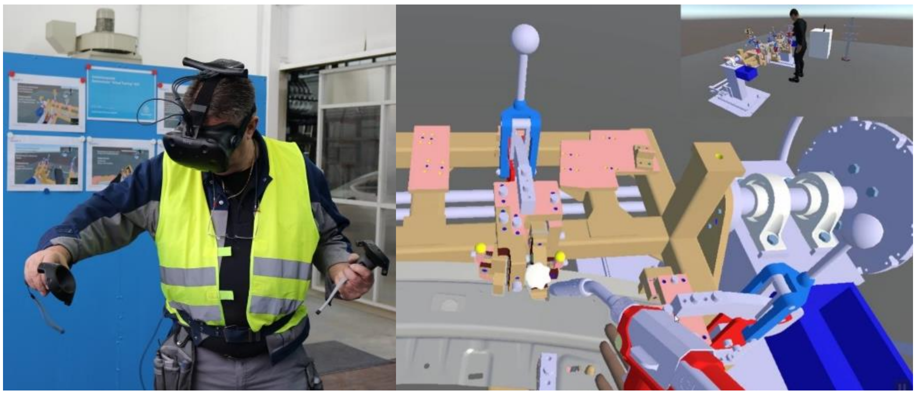

Fig. 4. Virtual Reality Application and virtual Workstation

During the introduction of agile development, the team and the project manager were introduced to the basics of the Scrum framework. The differences between the roles of a classical project manager and the Product Owner were explicitly addressed. The Scrum methodology was applied in the development phase. Two sprints of three weeks each were run through. Additional techniques such as testing and the virtual task board were integrated in the course of development.

The sprint length of 3 weeks at thyssenkrupp System Engineering is commonly used across all industries. In contrast to the cross-industry practice of daily scrums, in the case study scrum meetings were held every two days. This deviation was due to the sector-specific organizational structure of a weak matrix organization and the resulting design of the Scrum process. In the context of the final retrospective, the work with the Scrum methodology was evaluated. At thyssenkrupp System Engineering, 15 of the Scrum users answered an online questionnaire, which is partly based on the questions of the study Status Quo Agile 2017 [10].

6 Results

At thyssenkrupp System Engineering, 15 of the employees with Scrum experience answered an anonymous online questionnaire, derived from the questions of the Status Quo Agile 2017 study [10]. The resulting feedback was compared with the statements of the cross-industry study in order to enable conclusions about the applicability especially for automotive Smart PSS. The overall performance of Scrum was assessed positively, with 80% of the users rating the performance as good or very good. This is close to the cross-industry ratings with 86% positive feedback. The thyssenkrupp System Engineering Scrum users rated the development method in each criterion (transparency, innovation potential and speed) better than the participants in the comparative study did. It could be proven that cross-industry studies and the application in the case study show similar tendencies. The survey shows that the Scrum development method is accepted by thyssenkrupp System Engineering developers. Through the exemplary application and the feedback of the Scrum users, the applicability of Scrum in the case study development project could be demonstrated. The applicability of Scrum in the early product development of an internal Smart PSS R&D project could be shown.

7 Conclusions and Future Work

The pre-selection and evaluation of the agile methods was carried out based on industry-independent literature. The theoretical applicability of Scrum and Design Thinking was derived, which was used to build a procedure model for agile product development in automotive Smart PSS. The investigation of the applicability of agile methods for the development of Smart PSS in automotive plant engineering was conducted as a pioneering activity. The resulting procedure model supports agile system development by applying two agile methods, Scrum and Design Thinking. The Scrum part of the model could be implemented exemplarily in a case study. The evaluation of the Scrum method exceeded those of a cross-industry comparative study. In the test phase of the procedure model, a high result quality could be confirmed and the need as well as the readiness for user integration into the development process was validated. The procedure model developed represents an approach for the industry-specific application of agile methods for Smart PSS. In future research, the process model will be validated including the ideation phase with the application of Design Thinking activities. Based on the results from the case study and literature review, better results can be expected for the early development phase. In addition, it is necessary to examine the applicability in the medium and long-term, as well as the transferability to other Smart PSS developments with a high ratio of physical components.

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