Tackling the Granularity Problem in Service Modularization

Full Paper

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Abstract

In the last few years, the principle of modularity has been increasingly applied to services as service providers seek to reduce time and cost of delivering customized services. Theoretically, the modularization process of a complex service system can be divided into three core steps: Analysis, module design, and architecture design. Practically, this process is much more complex and highly influenced by the degree of granularity of the considered service system elements. Depending on this degree, different interdependencies between the elements can be considered resulting in different modules. Therefore, we argue that diverse design decisions across the modularization process have to be made upfront from the end of the overall design process to the beginning of the service system analysis. Following this, we tailor a formerly proposed framework for service modularization by adding a framework calibration phase.

Keywords

Framework, granularity, modularization, service.

Introduction

For a long time, the concepts of product, process, software, and system modularity have been well established in both academic research and practice (Baldwin and Clark 2000; Schilling 2000; Ulrich and Tung 1991). They refer to an approach for organizing complex products and processes efficiently (Baldwin and Clark 1997) by decomposing complex tasks into simpler activities so they can be managed independently (Mikkola and Gassmann 2003). In recent years, the principle of modularity has become more and more important for services as service providers seek to reduce time and cost of delivering customized service offerings (de Blok et al. 2010; Voss and Hsuan 2009; Meyer and DeTore 2001). Numerous papers demonstrate the applicability of modularity to a wide range of services, such as telemedical services (Peters and Leimeister 2013), logistics services (Bask et al. 2011), health care services (de Blok et al. 2010), hospitality services (Voss and Hsuan 2009), and IT services (Böhmann 2004).

From this research, a number of methods have been proposed and applied to services for designing modular service systems. Theoretically, the steps to be undertaken during the modularization process are evident: Analysis of a service system for the identification of elements and their interdependencies, their combination into loosely coupled modules, and the selection of a number of modules to design a modular service architecture (Dörbecker et al. 2015; Böhmann et al. 2009; Peters and Leimeister 2013; and others). Practically, the modularization of real existing complex service systems is much more complicated. Within a field study, we analyzed a real existing complex integrated health care service system (Dörbecker et al. 2015; Dörbecker et al. 2014). The analysis of this service system to identify elements and their independencies was extensive in both time and discussions with experts from different domains. All elements and interdependencies were extensively recorded without knowing which of them could be required in the subsequent modularization process. Afterwards, the combination of elements of high cohesion into loosely coupled modules was highly dependent on the results of the previous analysis and especially possible in numerous ways. The question arose on how to decide for the "most adequate" possibility. Finally, the identification of a number of modules to design a modular service architecture was quite challenging. A system developer decided from a technical point of view and proposed one or more different modularization scenarios. Afterwards, the decision for one specific modularization scenario was forwarded to service system members. In a last step, the benefits achieved through modularization of the service system were assessed.

These comprehensive observations motivated us to argue as follows: The modularization process of complex service systems may not start with the extensive analysis of a service system and end up with the design of a modular service architecture. On the contrary, diverse design decisions across the modularization process have to be made upfront from the end of the overall design process to the beginning. The following questions have to be answered upfront: Who will need which modules? How can these modules be designed? Which interdependencies are needed to design these modules? Which degree of granularity in the elements is needed to design these modules? These questions highlight that the choice of granularity of the elements at the beginning of the process within the analysis phase is highly dependent on the results, i.e. the resulting modules, required at the end in the modular service architecture. Therefore, we argue: Only if the modularization process is calibrated upfront from the end of the process to the beginning, a goal-oriented identification of all required elements and their interdependencies, a goal-oriented combination of these elements into loosely coupled modules and a benefit-oriented design of a modular service architecture are possible.

In an earlier research work, we followed a design-oriented research strategy (Hevner et al. 2004; Peffers et al. 2006) and proposed a framework for the application of matrix-based methods for service modularization (Dörbecker et al. 2015). It consists of three phases: Analysis, module design and architecture design. Every phase consists of several steps. Within this research work, we now tailor this framework by adding a framework calibration phase. This phase has to take place before the analysis phase and aims at calibrating the framework for a goal-oriented modularization. It especially guides the determination of the adequate degree of granularity of the elements and the adequate degree of complexity of their interdependencies required in the subsequent modularization process.

This paper is structured as follows. We firstly introduce our methodology. Then, we provide the theoretical foundations on method tailoring and the benefits of service modularization. Next, we present our framework for service modularization and the extension in terms of a framework calibration phase. Afterwards, we discuss the results and derive further insights for future research. Finally, we conclude the present research work.

Theoretical Foundations

Service Modularization

For a long time, the concepts of product, process, software, and system modularity have been well established in both academic research and practice (Baldwin and Clark 2000; Schilling 2000; Ulrich and Tung 1991). Generally, the concept of modularity is based on the principles of high cohesion and loose coupling (Sanchez and Mahoney 1996): Elements of high cohesion are combined into loosely coupled modules. An *element* is defined as a part of a system that cannot or shall not be decomposed anymore (Balzert 2009). The *interdependencies* between these elements define the structure or hierarchy of the system (Balzert 2009). Finally, *modules* consist of elements with strong interdependencies within the respective modules but only few or weak interdependencies to elements in other modules (Balzert 2009). *Cohesion* describes the extent of intra-module interdependencies and *coupling* the extent of inter-module interdependencies between elements of different modules (Balzert 2009). Modules are connected by *interfaces* which have to be specified appropriately (Peters and Leimeister 2013).

In recent years, the concept of modularity has been extended to services, and more than 60 articles on the topic were published since 2012. Leimeister (2012) defines service modularization as “(a set of) activities being part of interactions between the components of service systems”. The benefits associated with service modularization are manifold (Böhmann and Krcmar 2006), see Table 1.

During the last years, different authors proposed numerous methods for service modularization (Dörbecker et al. 2015; Peters and Leimeister 2013; Böttcher et al. 2011; Böhmann et al. 2008; Corsten and Gössinger 2007; Burr 2002; Hermsen 2000). Basically, all proposed methods contain the following steps: Analysis of a service system for the identification of elements and their interdependencies, their combination into loosely coupled modules, and the selection of a number of modules to design a modular service architecture. Additionally, some methods contain further steps such as testing (Peters and

Leimeister 2013), definition of goals (Böhmann et al. 2008), or implementation (Hermsen 2000). However, to the best of our knowledge, there does not exist any method that focusses on the adequate determination of the degree of granularity of the required elements.

Benefit	Explanation
Cost reduction	... through reuse and further use of modules within different services by realization of economies of scale
Customization, variety	... through reconfiguration of modules for customer-specific requirements
Facilitation of innovations in modules	... through decoupled development within loosely coupled modules
Faster development and implementation	... through parallelization, reuse and further use of modules
Increase in performance and quality in modules	... through complexity reduction as modules only contain a part of the resources and processes of a service
Options for the development of new services	... through standardized interfaces, reuse, further use, reconfiguration, and loosely coupled modules
Structuring of information	... through standardized interfaces and loosely coupled modules

Table 1. Benefits of Service Modularization (Böhmann and Krcmar 2006)

Method Tailoring

Method tailoring respectively *method adaption* is defined as “a process or capability in which human agents through responsive changes in, and dynamic interplays between contexts, intentions, and method fragments determine a system development approach for a specific project situation” (Aydin et al. 2004). The term *context* refers to a collection of relevant conditions and surrounding influences that make a project situation unique and comprehensible (Hasher and Zacks 1984). A *method fragment* is a description of an Information Systems Development Method (ISDM), or any coherent part thereof (Aydin et al. 2004). It is usually prescribed, and structured in terms of fragment properties (Harmsen 1997). *Fragments* can be principles, fundamental concepts, products to be delivered, activities needing to be performed, job aids - techniques, tools, hints, tips - to be used, etc. (Aydin et al. 2004). The *intention* as an indication of what drives the agents while carrying out method adaptation (Aydin et al. 2004).

According to Aydin et al. (2004), two perspectives on method tailoring exist that adopt different levels of abstraction:

- The *engineering perspective* at a conceptual level where the main focus is on models of the “real or empirical world” rather than the “real world” itself, and
- The *socio-organizational perspective* that looks into the empirical world and tries to understand method adaptation in practice, examining real, concrete development processes.

Methodology

We use the Design Science Research Process (DSRP) model given by Peffers et al. (2006) to develop and tailor our framework for the application of matrix-based methods for the modularization of complex service systems (Dörbecker et al. 2015). We choose a “design and development”-centered approach as the proposed framework results from the existence of an artefact (i.e. existence of well-established matrix-based methods in product development) that has not yet been formally thought through as a solution for the explicit problem domain (i.e. complex service systems) in which it will be used.

Problem identification: This is described in the introduction of this article.

Objectives of a solution: The tailored framework will contribute to a more structured and more efficient application of matrix-based methods for the goal-oriented modularization of complex service systems in order to maximize as many benefits associated with service modularization as possible. It especially guides the determination of the adequate degree of granularity of the elements and the adequate degree of complexity of their interdependencies required in the subsequent modularization.

Design and development: We proposed a framework for the application of matrix-based methods for service modularization (Dörbecker et al. 2015). We now tailor this framework by adding a framework calibration phase that calibrates the framework for a goal-oriented modularization of a service system.

Demonstration: The demonstration of the application of the tailored framework is planned as a next step. We do this by the help of a real existing complex integrated health care service system (see chapter "Future Research: Demonstration and Evaluation").

Evaluation: The evaluation of the final framework is planned directly after the demonstration. We evaluate the framework by the help of both other types of complex service systems (travel insurance services) and other experts from different domains (see chapter "Future Research: Demonstration and Evaluation").

Communication: For the whole research work around the proposed framework, communication within different publications is already done (Dörbecker et al. 2015; Dörbecker et al. 2014), ongoing (this article), and planned for the next months.

Design and Development: Framework for Service Modularization

Presentation of Framework

We proposed a framework for the application of matrix-based methods for the modularization of complex service systems consisting of three phases: (1) Analysis, (2) module design, and (3) architecture design (Dörbecker et al. 2015). This framework allows for

- The identification of elements and their interdependencies of a service system (phase 1),
- The combination of elements of high cohesion into loosely coupled modules (phase 2), and
- The selection of a number of modules to design a modular service architecture (phase 3).

Generally, the framework is entered at phase 1 and left at phase 3 (Figure 1: Bold arrows). However, the framework has an iterative character: A returning to earlier phases and iterations within phases are possible and necessary (Figure 1: Dashed arrows). This allows for a gradual refinement of the data, continuously increases data quality, and influences both the modularization process and the resulting modular service architecture.

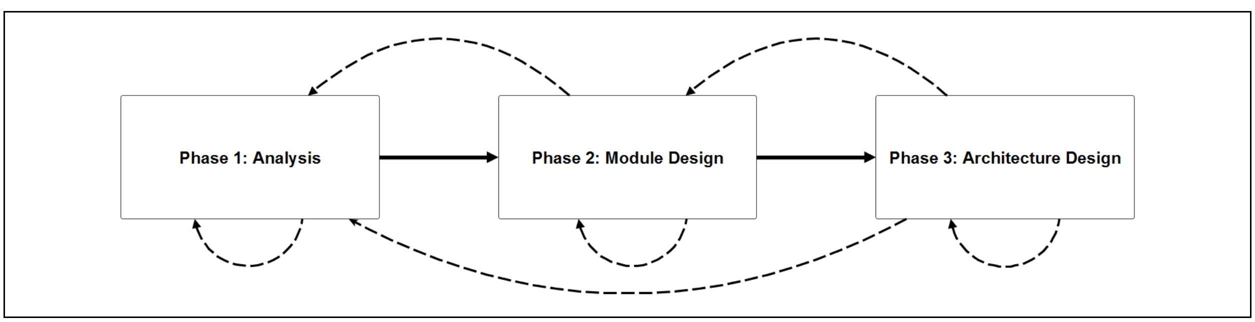

Figure 1. Framework for Service Modularization

Within this framework, the Multiple Domain Matrix (MDM) method is used as an instrument for information transport from one phase to another (Eppinger and Browning 2011). Every phase consists of several steps and every step contains specific tasks, see Table 2.

Phase	Step	Task
1. Analysis	1. Identification of elements	Identification of elements that were created or adopted for the service system in order to enable its functioning and to facilitate its effectiveness
	2. Analysis of elements	Determination of number, type and strength of interdependencies between identified elements
	3. Validation of elements and interdependencies	Assessment of the completeness and content validity of the identified elements and their interdependencies
2. Module Design	1. Identification of modules	Combination of highly cohesive elements into loosely coupled modules according to defined modularization parameters (e.g. targeted number and size of modules, selection of interdependencies, etc.)
	2. Analysis of modules	Identification of the strategic topic which is prevalent for each module and generalizes its activities and aims in the service system
	3. Validation of modules	Assessment of the usefulness and meaningfulness of the designed modules
3. Architecture Design	1. Identification of architecture	Design of two or more propositions for a modular service architecture by selecting a number of modules according to defined architecture parameters (e.g. targeted number of modules, etc.)
	2. Analysis of architecture	Selection of one proposition for a modular service architecture
	3. Validation of architecture	Assessment of the selected modular service architecture in terms of achieved benefits through modularization

Table 2. Framework for Service Modularization – Phases, Steps, and Tasks (Dörbecker et al. 2015)

Extension of Framework

We tailor our framework for the application of matrix-based methods for the modularization of complex service systems by taking up the engineering perspective (see chapter "Theoretical Foundations – Method Tailoring"). We add the phase "framework calibration", see Figure 2, which aims at calibrating the framework for the goal-oriented analysis of the service system, the goal-oriented module design and the benefit-oriented architecture design.

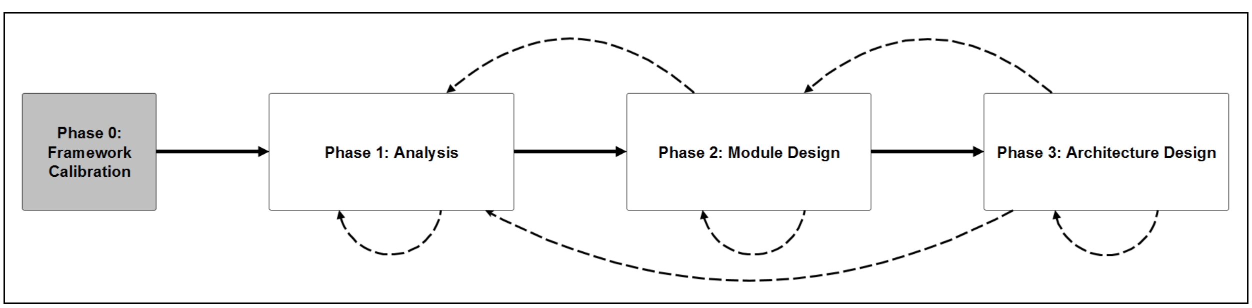

Figure 2. Framework for Service Modularization – Extension

The crucial point is that, contrary to the basic order of the framework, the tasks to be performed within this calibration phase start from the end of the framework and trace back to the beginning of the framework. In other words, it starts with the identification of the results to be achieved through modularization of a service system for different stakeholders, i.e. the modules, in order to draw conclusions about the required analysis of the service system at the beginning, i.e. the required elements and their interdependencies. Only in so doing, a goal-oriented identification of all required elements and their interdependencies, a goal-oriented combination of these elements into loosely coupled modules and a benefit-oriented design of a modular service architecture are possible. Following this argumentation, we propose four main tasks that have to be performed within the calibration phase, see Table 3. These main tasks focus on the three core elements of the modularization process, i.e. the elements, their interdependencies and the modules derived from these elements and interdependencies, and the instrument needed for designing these modules, i.e. the cluster algorithm. Within Table 3, we additionally highlight the phase of the framework the main tasks belong to.

Main Task	Phase
1. Definition of acceptance criteria for modules	3. Architecture design
2. Selection of a cluster algorithm to design modules	2. Module design
3. Determination of interdependencies to design modules	1. Analysis
4. Determination of elements and their degree of granularity	1. Analysis

Table 3. Framework for Service Modularization – Framework Calibration: Main Tasks

In the subsequent subchapters, we will describe these four main tasks in detail. Within every subchapter, we will describe the main task itself, decision points that have to be taken into consideration for defining the main task and possible guiding questions that can assist in the precision of this main task.

We propose to pass through this calibration phase twice. Within the first iteration, all tasks related to the main tasks, all decision points, and all other related issues are collected and documented. This is likely to lead to extensive results. Consequentially, a second iteration is needed that assists in a complexity reduction and prioritization of these extensive results. This can influence the granularity of the required elements, the complexity of their interdependencies, the resulting modules, the number of people involved into the design process, and other aspects. This procedure can lead to a more structured and more efficient application of matrix-based methods for the goal-oriented modularization of complex service systems afterwards.

Main Task 1: Definition of Acceptance Criteria for Modules

The first main task aims at the definition of acceptance criteria for modules that could be implemented into a modular service architecture. This is needed as not every module that is designed during the modularization process must be implemented afterwards into the envisaged modular architecture. It is possible that only those modules are implemented that are particularly promising for certain groups of service system members or for the achievement of specific benefits associated with service modularization. Therefore, these groups of service system members as well as the prioritized benefits have to be identified upfront and to be involved into this main task. In sum, this main task assists in answering the question: Who will need which modules?

Within Table 4, the decision points and guiding questions according to the first main task are defined.

Decision points	Guiding questions
Acceptance criteria for modules in terms of • Usage of modules • Benefits of modules	Who will use these modules? Who will select the modules? Who will design the modules? Who can assess the resulting modules? For what are the modules used? When are the modules used? How often are the modules used? Where are the modules used? Which benefits are associated with the modules?

Table 4. Decision Points and Guiding Questions – Calibration of Architecture Design

Main Task 2: Selection of a Cluster Algorithm to design Modules

After having successfully defined the acceptance criteria for the modules, the second main task aims at the selection of an adequate cluster algorithm that can assist in the design of the required modules. Depending on the size of the service system, either a manual clustering or an automated cluster algorithm can be performed. Additionally, different types of cluster algorithms exist. Depending on the decisions for the first main task, the choice of cluster algorithms can be restricted to a smaller number. Finally, the decision for a cluster algorithm can influence both the resulting modules and the extent of clustering. In sum, this main task assists in answering the question: How can these modules be designed?

Within Table 5, the decision points and guiding questions according to the second main tasks are defined.

Decision points	Guiding questions
Selection of cluster algorithm in terms of • Type of clustering • Selection of algorithm for clustering • Extent of clustering	Which information is needed for clustering? Which results are aimed to be achieved? How will be clustered? How expensive is the clustering? Who will do the clustering? Who can assess the clustering results?

Table 5. Decision Points and Guiding Questions – Calibration of Module Design

Main Task 3: Determination of Interdependencies to design Modules

The third main task aims at the determination of those interdependencies that are required to design the required modules identified in the first main task by using the required cluster algorithm identified in the second main task. The aim is explicitly not to identify all interdependencies within the service system of interest. Due to the intangible nature of many services, interdependencies have to be rendered visible and given a name. This may lead to a higher effort in the determination of the interdependencies as opposed to other technical systems. In sum, this main task assists in answering the question: Which interdependencies are needed to design these modules?

Within Table 6, the decision points and guiding questions according to the third main task are defined.

Decision points	Guiding questions
Determination of interdependencies in terms of • Number of interdependencies • Type of interdependencies (binary or weighted) • Strength of interdependencies (weak or strong) • Prioritization of interdependencies • Hierarchy of interdependencies	How many interdependencies are required? Which types of interdependencies are required? Are the interdependencies interdependent? Are interdependencies of different importance? Who will determine the interdependencies? Who can assess the resulting interdependencies? Where can these interdependencies be found?

Table 6. Decision Points and Guiding Questions – Calibration of Analysis (Part 1)

Main Task 4: Determination of Elements and their Degree of Granularity

The fourth main task aims at the determination of those elements that are required to design the required modules identified in the first main task by using the required cluster algorithm identified in the second main task and depending on the required interdependencies identified in the third main task. The aim is explicitly not to identify all elements within the service system of interest. This main task highly influences the granularity of the resulting modular service architecture. The more elements are identified, the more fine-granular the resulting modular service architecture can be. This step can additionally assist in the increase in transparency and the reduction of complexity of the service system. The more elements are identified, the more elements can be checked in terms of redundancy and reuse. However, the more elements are aimed to be identified, the more extensive their determination can be. In sum, this main task assists in answering the question: Which degree of granularity in the elements is needed to design these modules?

Within Table 7, the decision points and guiding questions according to the fourth main task are defined.

Decision points	Guiding questions
Determination of elements in terms of • Granularity of elements (size and number) • Type of elements (processes, resources, ...) • Prioritization of elements	Which types of elements are required? What is the necessary granularity of elements? Are elements of different importance? Who will determine the elements? Who decides for the degree of granularity? Who can assess the resulting elements? Where can these elements be found?

Table 7. Decision Points and Guiding Questions – Calibration of Analysis (Part 2)

Framework Calibration – The Granularity Problem

Finally, we highlight the golden thread on how the different decision points contribute to solve the granularity problem in service modularization. Therefore, we designed Figure 3 that we will describe in the following. This figure contains all four phases of the framework. On the x-axis, the phases of analysis, module design and architecture design are plotted. On the y-axis, the phase of framework calibration is plotted. The body of the figure contains all decision points derived within the four main tasks of the calibration phase. The figure contains black and red arrows. The black arrows indicate the basic order of the framework which is from left to right. The red arrows indicate the reverse order of the calibration phase which is from right to left. We restricted the number of red arrows within the figure to three as we argue that these three decision points ("benefits of modules", "selection of cluster algorithm" and "type of interdependencies") could mostly influence the decision point "granularity of elements".

First, the benefits aimed to be achieved through specific modules could highly influence the granularity of the elements. Depending on the prioritization of the benefits, elements of different granularity could be required to achieve these benefits. Secondly, the selection of the cluster algorithm could highly influence the granularity of the elements as different cluster algorithms may require different inputs in order to design modules that assist in the achievement of the prioritized benefits. Thirdly, the type of interdependencies could highly influence the granularity of the elements as not every interdependency might exist between two different elements.

For example, to achieve reuse, machine-based service systems may require a greater precision in the identification of elements than service systems that are predominantly human-based. Human-based service systems might be more flexible in handling a certain degree of vagueness in the specification of the elements than machine-based service systems. Similarly, the selection of the cluster algorithm may influence the number of elements that can be reliably dealt with and thus influence the granularity of a useful modelling of the service system.

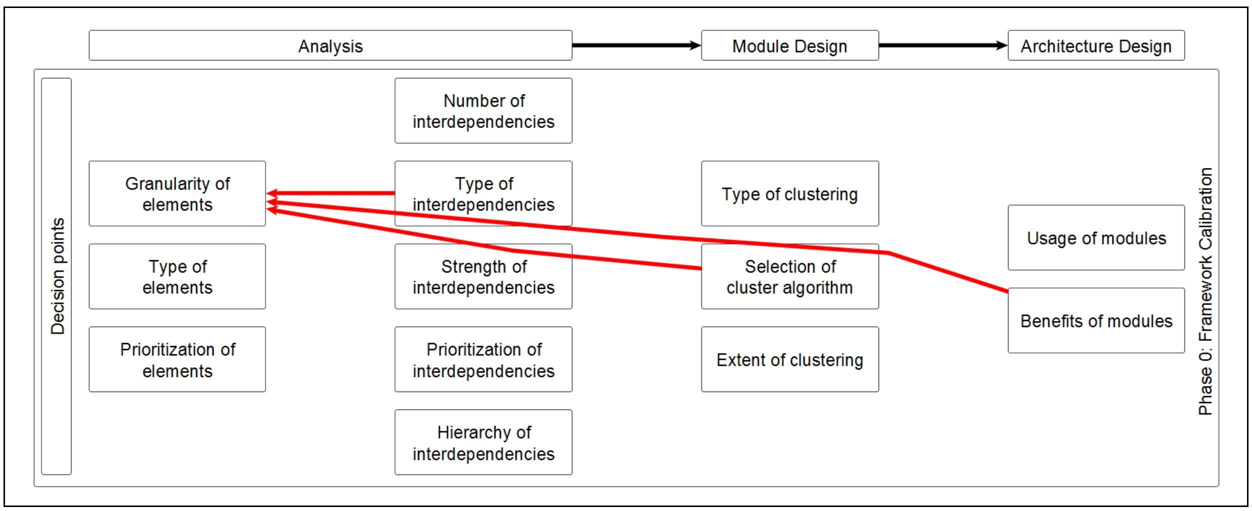

Figure 3. Framework Calibration – The Granularity Problem

Discussion

In the following, we will discuss four aspects: (1) The calibration phase in general, (2) the definition of the four main tasks, (3) the definition of the guiding questions, and (4) the extent of the initially proposed framework in relation to the tailored framework.

The origin of the tailoring of the framework proposed in Dörbecker et al. (2015) was the unknown degree of granularity of the elements required for the subsequent module and architecture design. Theoretically, a certain number of elements was required to combine them into a certain number of modules according to a certain number of interdependencies. Practically, all elements that could be identified were collected and extensively documented. Then, some interdependencies were determined and assessed for all identified elements. Depending on these results, a number of modules was designed. During module and architecture design, missing elements could be identified that led to costly loops in returning to the analysis phase in order to determine and document these missing elements. Once again, the interdependencies were examined and assessed for the new elements. Finally, the module design was adopted. In sum, the (almost) completeness of the elements and their interdependencies was accomplished by an extensive proceeding within an unknown number of iterations.

Therefore, we tailored the proposed framework by adding a calibration phase that takes into account these weaknesses in the overall modularization process. This phase enables the gradual determination of the degree of granularity of the required elements by stepping through the overall process from the end to the beginning. It focusses on the three core products of the modularization process, i.e. the elements, their interdependencies and the resulting modules, as well as the instrument for designing these modules, i.e. the clustering algorithm. All four items provide numerous parameters to influence the design of the resulting modular service architecture and are highly dependent on each other. Therefore, we argue to start with analyzing the required modules, then selecting an adequate cluster algorithm, afterwards identifying the required interdependencies and finally identifying the required elements with an adequate degree of granularity. This can lead to the fact that not all elements and all interdependencies of a service system are identified. However, it can lead to a reduction in the effort needed to identify all required elements and their interdependencies for the targeted modules.

Consequentially, we defined four main tasks within the framework calibration phase that focus on these four core items. For a more precise definition of these four main tasks within a service system of interest, we defined decision points for every main task. These decision points have to be mandatorily taken into consideration before entering the design process. The crucial point is that these design points describe "what" is to do. After having defined all main tasks, experts from different domains (such as service system developers, service system users, and service system managers) have to decide on "how" to do. During this operationalization of the decision points, their adaption can be necessary. This has to be brought into agreement with all people involved.

Afterwards, we defined guiding questions that can assist in the precision of the four main tasks as well. These guiding questions should be formulated as precise as possible and additionally as many questions as possible should be defined in order to understand all properties of the present service system. These specific properties highly influence the resulting modules, and consequentially the elements and their interdependencies.

Coming to the extent of the initially proposed framework in relation to the tailored framework. Certainly, the extent of the framework calibration phase within the tailored framework may not be disregarded. We propose to pass through this framework calibration phase twice. The first iteration is extensive and aims at identifying all available information. The second iteration is less extensive and aims at reducing the complexity of the results gained during the first iteration. Once this is accomplished, we expect a reduction in effort and complexity during the subsequent analysis, module design and architecture design. Nevertheless, this has to be assessed during a demonstration by the help of a real existing complex service system. Even if the extent might be the same, just distributed differently, the crucial point is that the goal-orientation within the tailored framework has increased.

Future Research: Demonstration and Evaluation

The demonstration of the framework application is divided into two parts: The demonstration of the general framework and the demonstration of the tailored framework. The first part was accomplished at the end of 2014 (Dörbecker et al. 2015) and led to the development of the tailored framework. The demonstration of the tailored framework is planned as a next step. For both demonstrations, one and the same real existing integrated health care service system is used. This system is a real life innovative project which was launched in a large German city several years ago. The aims of the system are diverse, but all of them are oriented at improving the prevention and treatment of mental health disorders. The complexity of the integrated mental health care arises from the nature of mental disorders which are often accompanied by other illnesses and require a treatment by multiple actors and organizations.

The evaluation of the final framework is planned directly after the demonstration. The framework will be evaluated in the context of insurance services. The considered insurance company is located in Hamburg, Germany, and provides a number of different insurance services, such as travel insurance services, health insurance services, and private pension services. The evaluation will focus on travel insurance services. Between four and six semi-structured interviews with experts from different domains within the present company will be conducted in order to assess the completeness and generalizability of the framework as well as the benefits and effects achieved through service modularization for the present service system.

Conclusion

We tailored our framework for the application of matrix-based methods for the modularization of complex service systems by adding a framework calibration phase. This phase aims at calibrating the framework for

- The goal-oriented identification of elements and their interdependencies of a service system (phase 1),
- The goal-oriented combination of highly cohesive elements into loosely coupled modules (phase 2), and
- The benefit-oriented selection of a number of modules to design a modular service architecture (phase 3).

This phase consists of four main tasks that focus on the three core elements of the modularization process, i.e. the elements, their interdependencies and the modules derived from these elements and interdependencies, and the instrument needed for designing these modules, i.e. the cluster algorithm. For every main task, decision points and guiding questions were defined that assist in the precision of these tasks.

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