Towards an Integrated Service Rating and Ranking Methodology for Quality Based Service Selection in Automatic Service Composition

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***Abstract*—The paradigm shift from purchasing monolithic software solutions to a dynamic composition of individual solutions entails many new possibilities yet great challenges, too. In order to satisfy user requirements, complex services have to be automatically composed of elementary services. Multiple possibilities of composing a complex service inevitably emerge. The problem of selecting the most appropriate services has to be solved by comparing the different service candidates with respect to their quality in terms of inherent non-functional properties while simultaneously taking the user requirements into account. We are aiming for an integrated service rating and ranking methodology in order to support the automation of the underlying decision-making process. The main contribution of this paper is a first decomposition of the quality-based service selection process, while emphasizing major issues and challenges, which we are addressing in the On-The-Fly Computing project.**

Keywords-Service Composition; Service Selection; Quality of Service (QoS); On-The-Fly Computing

I. INTRODUCTION

Nowadays, software engineers have to increasingly face up to the paradigm shift from the 40 years old principle of purchasing software as monolithic and closed standard solutions to the principles of Service Oriented Architectures (SOA) and Service Oriented Computing (SOC) [1], which shall enable purchase and execution of services on demand. Individually requested services may have to be composed of elementary services in order to fulfill the demanded requirements [2]. In this context, the problem of automatic service composition is a major challenge, since appropriate services have to be identified and correctly interconnected. Dependent on the amount of services, different possibilities to compose a complex service inevitably emerge. For that reason, a convenient methodology for choosing between services and composite services, respectively, which provide the same functionality but may differ in their non-functional properties, is required. We refer to this process as *quality-based service selection*.

Different approaches for determining the quality of a service or composite service in order to select the ”best” one out of a set of alternatives can be found in literature (e.g., [3] and [4]). In this context, a wide range of different non-functional properties is considered under the general term of *Quality of Service* (*QoS*) by which service candidates are compared with each other in order to identify and select the most appropriate one.

In contrast, we are aiming for an integrated service rating and ranking methodology, which facilitates the automation of quality based service selection by providing an overall taxonomy that reflects significant sections of the entire process. Each of these sections is investigated on service property level in order to identify and classify the essential challenges. Based on this taxonomy, generic solutions shall be determined and provided in order to enable the automation of the entire process. By doing so, our methodology shall enable the incorporation of arbitrary properties such as non-functional service properties or user requirements. However, we do not want to develop the one and only solution for quality based service selection in automatic service composition. In fact, we want to drive the generalization of this problem forward by developing a holistic representation, instead of providing just another solution for a specific problem setup. For that reason, we first of all identified some major issues that have to be taken into account during our work. Furthermore, a basic taxonomy of the selection process was already determined.

The remainder of this paper is organized as follows. Section II encapsulates the problem from our point of view. Section III lists the relevant major issues we identified so far. Section IV depicts our very basic taxonomy of the entire selection process. Section V describes some existing approaches, which are briefly discussed in Section VI. Finally, the paper concludes with Section VII.

II. PROBLEM DESCRIPTION FROM THE ON-THE-FLY COMPUTING POINT OF VIEW

A major vision of the On-The-Fly (OTF) Computing project is the automated composition of individual services based on services that are freely traded on global markets and that can be flexibly interconnected with each other. In this context, users may formulate a request, which contains information such as user information, preferences, domain-specific information and constraints. A so-called OTF service provider has the task to automatically compose an appropriate complex service, which matches the requested

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functional as well as non-functional properties. Depending on the size and granularity of the available service pool, multiple alternatives will inevitably emerge. Consider, e.g., the following scenario:

A traveling user has to wait at a train station of a large city for changing to another train. Since there is still plenty of time left (e.g. 3 hours), he spontaneously decides to do some sightseeing. He is only interested in specific classes of points of interests. Furthermore, he may walk or use the public means of transport. He uses his mobile device to put a request to an OTF service provider to compose a service, that in turn produces a convenient sightseeing tour by taking all the available information into account. The generation of his personal tour, hence the execution of the composite service, should be as cheap as possible.

The requested composite service could, e.g., consist of a basic trip planning service that in turn requires additional information such as cartographic materials, local points of interest and local public means of transport. Regarding global markets, services that provide the same required information are usually offered by more then one provider. In order to select the most appropriate service out of the set of service candidates, non-functional properties such as performance and cost as well as the specific user requirements have to be incorporated.

III. Issues in Quality Based Service Selection

Until now, we have identified the following major issues with respect to quality based service selection. The list, however, is not exhaustive, since our work is still at the very beginning. It may be modified and extended during our future research.

Implicit and explicit properties: Properties that have to be considered during the selection process can be *implicitly* given, e.g., in terms of non-functional service properties or *explicitly*, e.g., in terms of context-sensitive properties such as user preferences or user information.

Level of information: In many of the current approaches (cf. Section V), service properties are assumed to inherit the same *level of information* (e.g. quantitative values). However, different service provider may describe the same non-functional properties based on different levels of measurement (different scales). Furthermore, service properties may not be only described on different levels of measurement, but can also be non-existent for particular services.

Different hierarchical levels: Considering a global market, composite services and elementary services may match the same functional properties. In order to decide for the most suitable one, services have to be compared on *different levels of hierarchy*. The topmost level corresponds to the individual service that has to be composed, while the lowest level is defined by the granularity of the available elementary services in the service pool. In general, the number of levels in between cannot be defined in advance.

Local selection vs. global selection: While *local selection* of service candidates may not appropriately consider the overall quality of the final composite service, it is computational very efficient. On the other hand, *global selection* may identify the best overall solution, but ends up in a combinational problem, which is proven to be NP-hard. Either way, the point of time of decision-making has to be taken into account, since it essentially affects the rating and ranking strategy.

IV. Significant Sections of the Quality Based Service Selection Process

The intended methodology for quality based service selection has to provide generic solutions for the issues mentioned in Section III. The very first step towards such a methodology is the investigation of the entire service selection process on service property level by systematically disassembling the entire process in order to identify sections that depend on inherent service properties as well as scenario specific user requirements. In this context, we identified the following taxonomy, which reflects significant sections during the selection process.

A. Acquisition:

For the acquisition of property values, different techniques can be used. Single values may be accurately acquired by measuring. Other property values in turn have to be acquired from a series of measurements, in which the measured values vary from each other. Still others are not based on any metric at all, but have to be estimated from previous observations or are arbitrarily defined. Independently, service properties may also change over time.

B. Representation:

After acquisition, a property value has to be appropriately represented, while the representation in turn depends on the type of acquisition. In this context, descriptive statistics provide convenient methods for describing data. Single values can be classified with respect to their level of measurement (qualitative vs. quantitative values) or with respect to their scale, namely nominal, ordinal and metrical scale. Series of measurements are usually accumulated and represented as a distribution, which in turn can be approximated by means of statistical quantities (e.g., measure of central tendency and measure of dispersion) or fuzzy sets. Furthermore, methods of multivariate statistics such as cluster analysis enable a reduction of acquired data by means of abstraction and generalization, respectively, if required.

C. Utility Functions:

A utility function usually assigns a single value to an elementary or composite service. This value expresses the service's quality with respect to the explicitly and implicitly given properties. Service candidates can be compared with

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each other and consequently ranked in order to support the decision-making process. However, utility functions may be based on different sets of service properties (e.g., due to incomplete service descriptions) or have to incorporate different hierarchical layers.

D. Aggregation and Decomposition:

In order to rate and rank a composite service, the property values of the underlying elementary services have to be aggregated, e.g. by means of addition or multiplication, while the aggregation functions generally depend on the composition structure (parallel, sequence, loop etc.). On the other hand, a decomposition of property values is also of interest, when breaking down the global selection problem to a set of local ones or when services have to be compared on different hierarchy levels. However, aggregation may not only take place on service property level, but also on utility value level.

E. Objective Functions and Optimization Objectives:

Service rating heavily depends on the particular optimization problems, that are usually defined in advance. User preferences preset objective functions such as costs and availability and a specific optimization objective like minimizing and maximizing, respectively. Apart from this, a user may also desire a specific range of satisfaction by defining relative boundaries. In this context, homeostatic approaches provide convenient methods to deal with these types of optimization goals. However, service properties may also depend on each other. For that reason, multiple goals have to be simultaneously considered since they can negatively affect each other, leading to multi-objective optimization.

V. Related Work

Zeng et al. [5] introduced an approach that bases on a multi-dimensional quality model for elementary services as well as composite services. In their work, five generic quality criteria (service attributes) are considered: execution price and duration, reputation, reliability and availability. Each attribute is assigned a specific aggregation function in order to determine the quality vector of a composite service. Based on this quality model, the selection of services is then formulated as a global optimization problem, which is solved by means of linear programming methods.

Alrifai and Risse [6] proposed a combination of global optimization and local selection in order to increase the efficiency of quality driven service composition. To combine local decision making strategies with global optimization, global QoS constraints are firstly decomposed into local ones. These local constraints are then used as upper bounds for the quality values of elementary services, so that services that violate the constraints can directly be discarded. The quality values of composite services are computed by means of pre-defined aggregation functions. A utility function finally maps the quality values of an elementary or composite service onto a single real value.

In [7], not only non-functional service properties (QoS attributes) but also behavioral service properties (transactional attributes) are considered. A local optimization with respect to common QoS attributes is combined with a global consideration of transactional attributes (e.g., compensability) in order to ensure a reliable execution of composite services. A set of non-functional properties such as execution price or execution duration is defined for elementary services and transfered to composite services by means of pre-defined aggregation functions. Furthermore, user preferences are expressed as weights over the non-functional attributes.

Ben Mabrouk [8] proposed an efficient service selection algorithm which is formed as a guided heuristic. First of all, a set of service candidates for each activity in a composite service is identified based on advertised QoS of services in order to perform a preliminary filtering. In a second step, a selection phase refines this first filtering and ensures the global compliance of user preferences. Services are grouped with respect to their QoS values into a set of so-called QoS levels, which in turn are used to determine the utility of the service candidates. Dependent on the type of composition (i.e. sequence, AND, XOR and loop) aggregation functions determine the quality of a composite service.

In [9], attributes (QoS properties) such as cost or response time of elementary as well as composite services are considered. In order to calculate the values for composite services, aggregation functions for each QoS property are defined in advance, dependent on user QoS constraints and the type of composition (parallel, sequence and combinations of both). Furthermore, a utility value models the user's priority with respect to QoS criteria. The utility value of an elementary service property is created from normalized QoS values and from weights, which reflect the priority of a QoS property. The overall utility value of an elementary service is obtained by summarizing the values of all particular QoS properties, while the overall utility value of composite services correspond to the sum of the utility values of all contained elementary services.

In many cases, the value of a service attribute may be difficult to be precisely defined. To overcome this problem, fuzzy sets and fuzzy logic [10] can be integrated to allow the representation of imprecise and vague information, respectively. Fuzzy sets can be interpreted as a generalization of crisp sets. The characteristic function of a crisp set assigns a value of either 1 or 0 to each element in the universal set, meaning nothing but an element either belongs to the crisp set under consideration or not. By generalizing this characteristic function such that the values assigned to an element fall within a specific interval, e.g. $[0, 1]$, the membership of these elements can be indicated in a more fine-grained way.

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In [11], the selection of a single service is formulated as constraint satisfaction problem in the fuzzy domain. The user's preference to a specific service attribute (QoS criterion) is denoted by a fuzzy expression, which is composed of a group of fuzzy sets connected by the logical *and* operator. The user's overall preference to a service is subsequently formulated by connecting the fuzzy expressions of all service attributes with the logical *or* operator. After mapping the service composition problem into a fuzzy constraint satisfaction problem (FCSP), a depth-first branch-and-bound method is applied in order to find a solution.

Another approach that makes use of fuzzy logic was introduced in [12]. In comparison to [11], not only attributes of elementary services are considered, but also those of composite ones. For this purpose, the same non-functional properties of composite services (e.g., price or security) are aggregated according to the type of the composition. In this context, four different types of compositions are differentiated: sequence, parallel, choice and loop. Each combination of non-functional property and composition type is assigned a specific aggregation function. Furthermore, the user's preferences are modeled in the fuzzy domain in terms of fuzzy IF-THEN rules, which facilitates an efficient evaluation of good approximations of service attribute values [13]. The quantitative ranking of candidate services is finally achieved by an inferencing step for all n rules and a subsequent aggregation step of all inferred n values.

Pfeffer et al. [14] also proposed a fuzzy based approach for representing and evaluating service attributes. In their work, the values of service attributes may additionally change over time based on monitoring data of executed services. For that purpose, the monitored values for a particular service attribute are accumulated over time. The resulting distribution is approximated by fuzzy triangle functions and modified, whenever a new value was acquired. User preferences are likewise formulated in the fuzzy domain for each particular service attribute and superimposed with the associated service attribute value by multiplication. The ratio between the multiplication area and the original area is then interpreted as a service's fitness.

VI. Discussion

Apart from the inconsistent terminology, each of the approaches in Section V deals with some of the identified issues of ours mentioned in Section III, while covering parts of the taxonomy briefly described in Section IV.

All approaches are assuming a pre-defined set of non-functional properties, which are either precisely represented in terms of quantitative values or imprecisely represented in terms of fuzzy sets. However, none of the described approaches attends to the acquisition of property values and the resultant influences, except for Pfeffer et al. [14], who additionally consider monitored data for elementary services. Composite services, in turn, are not covered by the work of Pfeffer et al., while all other mentioned approaches incorporate at least an aggregation mechanism for determining non-functional attributes of composite services.

Furthermore, although not explicitly mentioned as such, different objective functions (e.g., costs or availability) are minimized or maximized with respect to specific user constraints. In this context, only single and independent optimization goals are considered, while the optimization problem itself is either solved locally, globally or by some sophisticated combination of both. However, neither ranges of satisfaction (homeostatic methods) nor dependencies between non-functional properties are currently considered in any of these approaches.

The application of utility functions (utility values, fitness values) is indeed a common principle. It can be found in all described papers, except for the work of Lin et al. [11]. However, the usage of utility functions differ among the approaches. For that reason, a clear definition and classification within the service composition context is still missing.

VII. Outlook

Our next step will be to assemble a detailed survey of important existing approaches with respect to the issues pointed out in Section III and to the taxonomy briefly sketched in Section IV. In this context, the taxonomy itself will be elaborated in more detail, and extended, if necessary. Finally, a concrete example for demonstrating our approach will be developed. By doing so, we want to establish a basis for investigating quality based service selection algorithms based on our rating and ranking methodology.

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