Composition of Optimal Service Workflows with Quality-of-Service Enabled Multi-Criteria Uniform Cost Search Algorithm

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ABSTRACT

This paper proposes a search-based method to partly automate the workflow composition, including the planning and execution stages, with web services in a service-oriented architecture. The proposed methodology models the workflow composition problem as a directed and weighted graph, henceforth called the service-oriented architecture graph, where vertices are associated with the degree of completion of the overall task at hand and edges represent service executions. Edge weights are formulated based on the quality of services as defined by the user. A uniform cost search algorithm is adapted and applied to identify the optimal path based on user input, which constitutes an ordered sequence of service executions, from a given initial state to a user-defined goal state. The proposed approach for service oriented workflow composition was applied to an information-technology domain problem to demonstrate its utility through a simulation study. Simulation results indicated that the proposed methodology is feasible and optimal solutions can be computed within reasonable computational cost bounds.

Keywords: Automation, Optimal Workflow Composition, Quality of Service, Service-Oriented Architecture, Uniform Cost Search

INTRODUCTION

Workflow composition in service-oriented architecture (SOA) of software involves highly-skilled experts, such as software engineers, developers, and architects to create the software architecture and integrate services for even the simplest applications through mainly hands-on and manual processes (Agarwal et al., 2008; Papazoglu et al, 2007; Newcomer et al., 2005; Rao et al., 2004; Sristava et al., 2003). Expert-level skills are also required to create innovative and competitive services (Agarwal et al., 2005). There is a need for more effective methods to be able to create the architecture and compose workflows with services. Furthermore

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and perhaps no less importantly, any degree of increased efficiency for the creation of SOA workflows will also allow experts more time, focus and effort to concentrate on the innovation of creating a variety of performance-enhanced and reusable services, rather than the manual, prolonged, and error-prone tasks of composing the workflow.

Automation of the composition process is the apparent choice for improving the efficiency in this regard. However, the automation of service workflow composition is still at its early stages and needed to bring the service-oriented architecture methodology to a state of wider applicability and realization. An algorithmic methodology is essential to enhance the level and degree of automation for the service workflow composition process. Any such algorithmic methodology should be able to search for an optimal solution of this problem under multiple cost criteria specific to the problem domain. The algorithm should be able to incorporate multiple quality-of-services (QoS) in service oriented workflow composition through a multi-criteria cost measure. The functional and non-functional properties of services should also be taken into account. Functional properties describe the input, output, and the activities conducted by the service. Non-functional properties are the costs borne as a result of execution of each service. Non-functional properties, also known as quality of services (QoSs), of a service include aspects of services such as time to execute, resources required for execution, monetary cost of the service, and several other properties that might be of interest. Therefore, a generic problem solution methodology in the service composition domain is desirable.

RELATED WORK

There have been a number of recent attempts for the automation of workflow composition process with logical workflow composition, semantic workflow composition, abstract process model, and artificial intelligence (AI) approaches. Some of these works have been attempted for prototype implementation, and yet at the present time, there appears to be very little evidence of testing and validation particularly through field deployment.

As described by Hafner (2009), the manual service workflow architecture has five layers, which include applications layer, web services workflow composition or publication and discovery layer, service description layer, XML messaging layer, and transport layer. Today’s frameworks automate portions of this layered-architecture to ease the pain for developers. For example, the .NET framework automates the service description layer, XML messaging layer, and the transport layer. However, there are still tedious manual tasks that the service developer is expected to complete, including the composition of the services into workflows, and their integration with applications. The following subsections present a literature survey on the attempts for automation of the workflow composition problem. The focus is given to the integration of AI planning techniques with service workflow composition since it appears to have attracted considerable attention from the researchers.

Savarimuthu (2005) employed the rapid development of service-based system approach, which is based on alpha-logic and alpha-calculus to automate the composition of service workflows. A developer creates the service workflow using alpha-logic, the workflow is first converted into alpha-calculus, and then into executable format. Savarimuthu asserts that the alpha-logic notation is simpler than programming languages. However, comprehension and creation of workflows with the alpha-logic notations requires advanced level mathematical knowledge. The service workflow composition is not automatic. A software expert’s time and effort are required to develop and implement service workflows through this methodology. The logic-based workflow composition method is a step ahead of the manual method, but it requires specialized and advanced mathematical knowledge on the part of the software professional.
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