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CARSA: A *context-aware reasoning-based service agent* model for AI planning of web service composition

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ABSTRACT

In order to achieve automatic and more intelligent service composition, dynamic description logic (*DDL*) is proposed and utilized as one emerging logic-level solution. However, reasoning optimization and utilization in such *DDL*-related solutions is still an open problem. In this paper, we propose the context-aware reasoning-based service agent model (*CARSA*) which exploits the relationships among different service consumers and providers, together with the corresponding optimization approach to strengthen the effectiveness of Web service composition. Through the model, two reasoning optimization methods are proposed based on the substitute relationship and the dependency relationship, respectively, so irrelevant actions can be filtered out of the reasoning space before the *DDL* reasoning process is carried out. The case study and experimental analysis demonstrates the capability of the proposed approach.

1. Introduction

As an architectural style for building software applications using service components available in a network, services-oriented architecture (*SOA*) (Erl, 2005) has made a major impact on distributed computing research (e.g. *e-science*, *e-business*). *SOA* is usually realized through Web services (Newcomer and Lomow, 2004), which is defined as the self-contained, self-describing, modular application that provides business functionality across the Web. Accordingly, the ability to efficiently and effectively integrate an appropriate set of service components to realize a new service that fulfills the users' request is the essential feature of Web services. In the past decade, substantial research effort has been devoted to automated Web services composition systems. Most existing research work falls into the categories of *cross-enterprise workflow composition* or *AI planning*.

Traditional Web service description languages, such as *WSDL*, can specify the available operations and structure of data in a Web service, but cannot specify semantic meaning or constraints of the data. Similarly, standards such as the *WS-BPEL* can provide a business process model to orchestrate the interaction of service components, but remains weak in the support of semantic inter-operability of Web services. This limitation adds extra complexity to the Web service composition process, and makes it difficult to fully utilize those messages transmitted between Web services. In order to address this problem, recent research has been carried out to incorporate the *Semantic Web* into the *Web services* (such as *WSMO*, Feier et al., 2005, *SESMA*, Peer, 2005, *C-OWL*, Bouquet et al., 2003, *WSDL-S*, Miller et al., 2004, *SAWSDL*, Kopecky et al., 2007). One immediate benefit of this strategy is that the service description can be augmented by rich semantics but with less human assistance or less constraints on the interfaces and protocols. For example, the *POIROT* (Burstein et al., 2009) can learn *workflow* procedures from "observations" of a small number of Semantic Web service traces.

When the user requirement is associated with explicit goal definitions (e.g. *OWL-S*, *SHOP2*, Wu et al., 2003), the *AI planning* approach is more suitable for dynamical synthesis of the required Web services through logical reasoning by *AI planners*. To realize the *Semantic Web services*, the *AI planning*-based methods usually face two issues: one is *how to systematically represent both the static ontology information and the dynamic Web services information* (Calvanese et al., 2007); *the other one is how to achieve the decidable reasoning for determining whether a certain goal can be satisfied after the execution of all component services*.

In one of the recent attempts to address these two issues, Niu et al. (2011) introduced the *dynamic description logic* (*DDL*) into *Semantic Web services*, together with a novel multi-granularity context model which effectively exploits the relationships among different context attributes. With the formal representation in *DDL*, the static information in Web services such as *goal* can be

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