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# Artificial intelligence in service-oriented software design

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ABSTRACT

Service-Oriented Architecture (SOA) has gained considerable popularity for the development of distributed enterprise-wide applications within the software industry. The SOA paradigm promotes the reusability and integrability of software in heterogeneous environments by means of open standards. Most software companies capitalize on SOA by discovering and composing services already accessible over the Internet, whereas other organizations need internal control of applications and develop new services with quality-attribute properties tailored to their particular environment. Therefore, based on architectural and business requirements, developers can elaborate different alternatives within a SOA framework to design their software applications. Each of these alternatives will imply trade-offs among quality attributes, such as performance, dependability and availability, among others. In this context, Artificial Intelligence (AI) can assist developers in dealing with service-oriented design with the positive impact on scalability and management of generic quality attributes. In this paper, we offer a detailed, conceptualized and synthesized analysis of AI research works that have aimed at discovering, composing, or developing services. We also identify open research issues and challenges in the aforementioned research areas. The results of the characterization of 69 contemporary approaches and potential research directions for the areas are also shown. It is concluded that AI has aimed at exploiting the semantic resources and achieving quality-attribute properties so as to produce flexible and adaptive-to-change service discovery, composition, and development.



## 1. Introduction

Service-Oriented Architecture (SOA) has been chosen by the software industry for building distributed and enterprise-wide software applications, which should be both high-quality and adaptable to market changes (Erickson and Siau, 2008). Moreover, SOA creates opportunities to improve agility and speed in aligning business needs with information technology infrastructure (Hassanzadeh et al., 2011). In this context, SOA promotes service reuse to rapidly build applications by assembling already-implemented and Internet-accessible software pieces, called services.

Both the amount of Web Services available on the Internet and the need to satisfy multiple user requirements and Quality-of-Service (QoS) concerns create a niche for the application of Artificial Intelligence (AI). The main advantage of the use of AI stems from its efficient performance in dynamic, distributed, non-deterministic and uncertain environments; reducing the search space. Further, AI seems to be promising when high scalability and management of generic quality attributes are required, and when verification and validation of service composition (deadlock freedom and safety properties) are demanded.

Those services can be accessed, matched and integrated by discovery and composition applications. Service discovery is the process of locating existing services based on the description of their functional and non-functional properties. In general, a system for discovering services needs a service description language, a service selection means (i.e., matchmakers) and discovery architecture (e.g., decentralized P2P). Service composition combines roles and functionality to aggregate multiple services into a single composite service that can be used in further compositions; composing services involves complex issues that exceed human capabilities to address this process completely manually. The discovery and composition of services have been addressed by several approaches to facilitate the outsourcing of functionality in SOA-based applications (Dustdar and Schreiner, 2005; Rao and Su, 2005). However, the services resulting from discovery and composition might fail to fulfill required QoS concerns or business goals, leading developers to build new services by using development guidelines. Far from being a random process, the development of service alternatives is generally driven by a set of guidelines, incorporating knowledge about recommendable

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design practices, in order to select the most suitable among the numerous alternatives available, even for small search spaces.

In the light of the above, the use of AI arises as a suitable strategy to explore possible solutions for discovering, composing and developing services. Choosing a suitable alternative can be both error-prone and time-consuming (Tekinerdogan and Aksit, 2002); therefore, developers need to be assisted by AI in selecting among effective design alternatives that are also suitable in terms of quality-attribute properties. Considerable advances in AI research and the popularity of AI Planning and Evolutionary Computing in software development have made it possible to widen the research field towards assisting developers in discovering, composing and developing services that satisfy certain QoS concerns, among other constraints.

In this paper, we provide a detailed, conceptualized and synthesized analysis of 69 significant research works that describe AI-based approaches aimed at discovering, composing, or developing services. We also identify open research issues and challenges in the aforementioned research area. Our results can be used by both researchers and practitioners, who can analyze current approaches to identify potential niches for further research or analyze strengths and weaknesses of current approaches and select the most suitable for their professional contexts, respectively.

This article is organized as follows: Section 2 describes our research methodology; Section 3 reports on approaches for discovering services; Section 4 discusses works that have attempted to compose services; Section 5 presents works that have addressed automated or semi-automated development of services; Section 6 discusses future trends and open issues in discovering, composing and developing services. Final remarks and conclusions are stated in Section 7.

## 2. Research methodology

The goal of this research is to identify major works on the use of AI in discovering, composing and developing Web Services, and thereafter, to classify these works so as to discover gaps, critical issues and opportunities for further study and research. We executed our survey according to Kitchenham's well-established guidelines for systematic literature reviews in software engineering, aiming to achieve objective, unbiased and reproducible results (Kitchenham and Charters, 2007). We present the research questions (RQ) that guided our review process:

- *RQ1:* What evidence is there that AI contributes to achieve better results in comparison with other approaches for discovering, composing or developing services?
- *RQ2*: What are the main characteristics, common features, and differences among the available AI-based approaches for discovering, composing or developing services?
- *RQ3*: Should we expect more accurate results when discovering, composing or developing services by using Planning, or by using Genetic Algorithms?
- *RQ4*: What are the research challenges, needs and future trends in the areas of discovering, composing or developing services?

Our survey procedure starts with a keyword-based search using the following databases:

- Google Scholar
- ACM Digital Library
- IEEE Explore
- Science Direct
- Springer Link

The publication search was firstly conducted in terms of a structured combination of related keywords. Any "Web Service composition", "Web Service discovery", "service-matchmaking", "semantic service composition", "semantic service discovery", "Web Service development", or "Web Service realization" related problems involving the concepts of "automatic", "intelligent", "service-oriented computing", "service-oriented architecture", were covered by highlighting the support of AI techniques to achieve optimal results. After a first quick check, the qualified publications were acquired through cross-referencing. The delimitation of the publications is listed as follows:

- Only publications concerning Web Service discovery, Web Service composition, and Web Service development problems are considered.
- Only publications involving the use of AI-based approaches are considered.
- Only peer-reviewed journal/conference papers written in English are considered.

Our research spans over twelve years (2002 to 2014) and we reviewed a total of 69 AI-based approaches for discovering (29 approaches), composing (34 approaches) and developing services (6 approaches). Fig. 1 depicts the distribution of the research works by year of publication. The number of research works that use the support of AI for discovering, composing and developing services has increased from 2007 to 2012, since the SOA paradigm has gained important popularity in software industry. It is worth noting that the application of AI in service-oriented software development research has been increasing since 2007 and this trend seems to increase even more. The most popular AI techniques surveyed are AI Planning, Evolutionary Algorithms, Markov Chains, and Clustering, among others. Our study of the surveyed works has revealed that more research in this field is required to overcome current limitations of the application of such AI techniques to solve open issues in service discovering, composing or development.

### 2.1. Classification schema

To evaluate the works reviewed and make a comparative description among them, we have identified common criteria in terms of strengths and weaknesses regarding relevant issues in the field of service discovery, service composition and service development. First of all, we read all the analyzed research works. Then, we searched for common features within the whole set of articles; if more than half of the articles contained a feature, it was selected

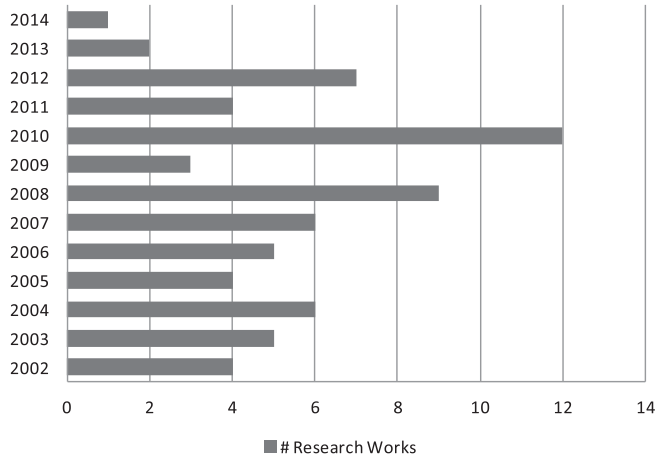


**Fig. 1.** Distribution of research works by year of publication.