Towards a Taxonomy of Web Service Composition Approaches

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Abstract. Service-Oriented Architecture (SOA) is a well known paradigm for development of flexible and loose coupled software applications using services that are available in a network. The latter provide business functionality through well-defined interfaces that can be dynamically discovered. Services can be aggregated into more complex ones called composite services. Currently, there exist a lot of composition approaches that serve different goals. In order to be able to comprehensively study the web-service composition process, different approaches should be analyzed and organized into appropriate taxonomy framework. This paper presents an overview of current approaches for service composition and further analyzes them toward various aspects of the composition model.

Keywords: Composition model, Service-Oriented Architecture, Web services.

1 Introduction

Latest trend in software engineering is presented by the so-called Service-Oriented Architecture (SOA). It makes possible development of software intensive systems via loosely coupled services, which provide business functionality through contractually specified interfaces. The promise of services is for increased maintainability and scalability of systems, achieved at predictable time with less efforts and decreased cost of development.

The preferred way to realize SOA is based on web services. The basic web service infrastructure founded on standards like WSDL, SOAP and UDDI provides simple interaction between clients and web services. Functionality of the latter is often combined into composite ones that satisfy specific business goals. In such case, additional composition models, languages, as well as development and run-time environments should be elaborated. Although a lot of efforts for development of web service composition methods are available, most of them aim toward satisfying particular needs. Some composition approaches focus mainly on QoS aspects of the composition [2], [8], [9], while the goal of others is to provide web service orchestration [4], [6], [7], [12], [14]. In such context this paper aims to study the fundamental characteristics and essential aspects of different approaches. For this purpose we extend the number of the dimensions of an existing composition model and provide comparative analysis of different web service composition approaches according to these dimensions.

Some currently existing literature surveys on web service composition approaches directly relate to our work. For instance, in [21], authors present in details a large number of approaches, but only few of them are compared according to the preliminary defined criteria. In [22] only the approaches based on AI Planning are discussed. The approaches using Petri nets, statecharts and other techniques for orchestration modeling are not considered. In this paper several categories of orchestration modeling techniques are presented and used as a comparison criterion of presented approaches. Evaluation of QoS Based web service selection techniques for service composition is given in [23]. In this paper, other dimensions of the composition process such as data modeling, transaction modeling and exception handling, are not mentioned. In our work we extend the above mentioned research, by establishing a more sound classification and comparison scheme, which could serve as a basis for a taxonomy framework of the web service composition process.

The rest of the paper abstract is organized as follows: Section 2 analyzes the web service composition approaches with respect to aforesaid dimensions and Section 3 concludes the paper[1].

2 Analysis of Web Service Composition Approaches

The analysis of web service composition approaches is based on a composition model proposed by Alonso et al. [1]. According to this model, web service composition is characterized with six different dimensions: Component Model (CM), Orchestration Model (OM), Data and Data Access Model (DDAM), Service Selection Model (SSM), Transactions (T), and Exception Handling (EH). The CM considers the type of components that participate in a composition as well as assumptions about them. The OM deals with the way in which web services are composed into more complex services. DDAM is responsible for data exchange among components. The SSM defines whether a particular web service is selected as a component dynamically or statically. Transactions define transactional semantics associated to the composition. Finally, the EH specifies the mechanisms for handling of exceptional situations that is possible to occur during composition invocation.

Evaluation of the composition quality is an important aspect of the composition process. When several candidate web services have the same functionality, their QoS properties are examined in order to select the best one. Thus we identify QoS support as an additional dimension of the composition model, called Quality Model (QM).

Table 1 summarizes the comparison of the web service composition approaches. The first column refers to composition approaches. The last column, named Tool Support (TS), shows which of the approaches are implemented as software tools or platforms. They are marked with filled circle. The rest of the columns correspond to the dimensions of composition model presented above.

[1] Due to space limitations, detailed description of the approaches examined will be provided into the full paper.

Table 1. Comparison of web service composition approaches.

Ref.	OM	CM	QM	T	DDAM	EH	SSM	TS
[2]	BPMN	WSDL	●	○	⦿	●	●	●
[3]	BPEL	WSDL	⦿	○	○	○	●	●
[4]	PG	WSDL	○	○	○	○	○	●
[5]	PMC	WSDL	○	○	○	●	●	●
[6]	AIP	OWL-S, OWL	○	○	○	○	○	●
[7]	OWL-S	SWRL	○	○	●	○	○	●
[8]	WS-BPEL	WSDL, SLA	●	○	⦿	○	○	○
[9]	GM	WSDL, UDDI	●	⦿	○	⦿	○	●
[10]	GM	WSDL, WSLA, OWL	⦿	○	○	○	○	●
[11]	S	OWL-S or SAWSDL	⦿	○	●	○	○	●
[12]	HTN	OWL-S	●	○	○	○	●	●
[13]	PMC	WSDL	○	○	●	●	●	●
[14]	AIP	WSDL	●	○	○	○	●	●
[15]	S	WSDL, SLA	⦿	○	○	●	●	●
[16]	SM	WSDL, UDDI	○	○	○	○	○	●
[17]	XML Nets	OWL-QoS	●	○	●	○	●	○
[18]	HTN	OWL-S	○	○	○	○	○	●
[19]	OWL	WSDL	○	○	●	○	○	●

● Consider ⦿ Partially consider ○ Do not consider

OM column in table 1 shows the abstractions and languages used for modeling of control flow of the compositions in terms of sequence of operation execution. Here, variety of paradigms exists. Most common are techniques based on AI Planning such as Hierarchical Task Networks (HTNs), Planning Graphs (PGs), Semantic Markup for Web Services (OWL-S) and Web Ontology Language (OWL) [4], [6], [7], [12], [14], [18], [19]. Planning as Model Checking (PMC) is another planning technique that is also applicable to OM [5], [13]. The languages for description of business processes like BPEL and BPMN are also proposed for web service orchestration [2], [3], [8]. Statecharts (S) are abstractions that extend state machines with possibility to define activities while moving between states [11], [15]. HPNs have the ability to model concurrency of the systems, analyze concurrent behavior, and express the dynamically changing software. Here, they are presented by XML nets, which provide advantages in the description of process objects and inter-organizational exchange of XML structured data [17]. Graph Models (GM) are another way for design of OMs, where web services are presented with graph nodes and the sequence of their execution is shown by the graph edges. They are applied in [9] and [10]. Signature Matching (SM) is a technique used in [16] in order to compose web services. It is instance of more general problem, called function realization problem [20]. A classification scheme that summarizes web service orchestration techniques is shown on Fig. 1.

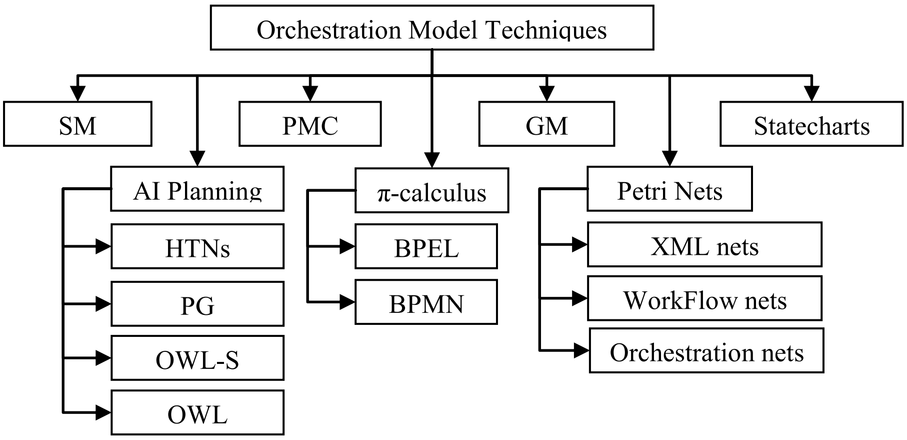

Fig. 1. Classification scheme of web service composition approaches according to the OM

The CM column shows the standards and languages used for implementation of composition components. Currently, most of the composition approaches (along with the analyzed ones here) assume that components are WSDL services based on standards such as HTTP, SOAP and WS-Transaction. As shown in Table 1, some approaches rely on additional standards like SLA and OWL-S in order to enrich the composition model with QoS and semantic data. They take into account the QoS properties of candidate web services in order to produce composition that aggregates web services with the maximum quality. This aspect of the composition process is presented in column QM of the table. Here, "●" means that the proposed QM is capable to covers all QoS properties. The "⦿" symbol shows that given approach supports QM with limited number of QoS properties. We call such approaches QM limited. For example, the QM proposed in [3] concerns only Response time.

QMs can be further classified according to the formalism that is applied to the composition when QoS properties are taken into account. For example the QM proposed in [2] is based on Multi Criteria Decision Making. It considers quality in three aspects: QoS that is related to web service execution, Quality of Contents (QoC) referring to the quality of the content with which the web services work, and Quality of Devices (QoD), concerning physical environment.

The T column shows whether given approach consider transactional behavior of web service composition. Since the underlying middleware is often responsible for providing transactional capabilities, approaches presented in Table 1 do not consider this dimension of the composition model. For example, the compensation logic for roll back of web service activities may be handled by engine that implements WS-Transaction specifications.

The DDAM column shows which approaches compose web services in terms of data types and data transfer. According to [1] the data of given web service composition can be divided into application-specific data and control flow data. Data exchanged by web service messages is called application-specific data. Data that is used for evaluation of branching conditions is called control flow data. Data transfer method can follow blackboard approach or explicit data flow approach. The first one relies on a blackboard, which is a collection of variables defining the output and input of each web service activity. The explicit data flow allows developers to specify that the input data of an activity should be taken from the output data of previously executed activities. For instance, the DDAM presented in [17] uses data type definitions of XML Schemas. The proposed approach solves a problem with message passing, where an output message of a web service may be incompatible with the required input message of another WS. The approach uses XML nets to create mediating transition between two web service invocation transitions. In [19] the similarity of an output and input parameter of web service activities are checked according to preliminary defined rules using OWL.

The EH column indicates approaches that take into account unexpected behavior of web service compositions. A possible solution is to use conditional branch that checks the result from invocation of an activity for failures or timeout according to which an activity will be terminated if the timeout expires. Another solution is to associate exception handling logic to an activity or group of activities. Rule-based languages are also applicable to the exception handling problem. For example, the approach presented in [13] uses Computation Tree Logic (CTL) to model web service composition failures. A global planning approach is used in [15] to reconfigure composition execution in case of one or several failures during web service invocations.

The SSM column show which approaches support dynamic binding of web services in a composition. Dynamic binding have advantage on dealing with web services that change their URIs.

3 Conclusion

Composition of web services is appealing tactic to enable even more powerful business processes and enrich software applications. A lot of web service composition approaches exist in the literature differing in the applied techniques and strategies for web service orchestration, data modeling, transaction support, QoS awareness and exception handling. In this paper we analyze a number of such approaches and distinguish them according to their essential characteristics.

Directions for future work include further developing the proposed classification into ontological framework for web service composition process and also a composition meta-model. This will help software architects to choose a particular approach best suited for a given application domain.

References

1. Alonso G., Casati, F., Kuno, H., Machiraju, V.: Web services, Concepts Architectures and Applications. Springer-Verlag Berlin Heidelberg (2004)
2. Chang H., Lee K.: A Quality-Driven Web Service Composition Methodology for Ubiquitous Services. In: Journal of Information Science and Engineering 26(6) (2010) 1957-1971

3. Ming, Q., Khendek, F., Serhani, A., Dsouli, R., Roch, G.: An Architecture for Automatic QoS Adaptation for Composite Web Services. In: Int. Journal of Web Services Practices, Vol. 4, No.1 (2009). 18-27
4. Zheng, X., Yan, Y.: An Efficient Syntactic Web Service Composition Algorithm Based on the Planning Graph Model. In: 8th IEEE Int. Conf. on Web Services (2008) 691-699
5. Yu, H. Q., Reiff-Marganiec, S.: Semantic Web Services Composition via Planning as Model Checking. Technical report CS-06-003, University of Leicester (2006)
6. Klusch, M. Gerber, A.: Evaluation of service composition planning with QWLS-XPlan. In: Int. Conf. on Web Intelligence and Intelligent Agent Technology (2006) 117-120.
7. Bartalos, P., Bielikova, M.: Fast and Scalable Semantic Web Service Composition Approach Considering Complex Pre/Postconditions. In: Int. Workshop on Web Service Composition and Adaptation, (2009) 414–421
8. Cardellini, V., Casalicchio, E., Grassi, V., Lo Presti, F.: Flow-Based Service Selection for Web Service Composition Supporting Multiple QoS Classes. In: IEEE Int. Conf. on Web Services (2007) 743-750
9. Chakhar, S., Youcef, S., Mousseau, V., Mokdad, L., Haddad, S.: Multicriteria Evaluation-Based Conceptual Framework for Composite Web Service Selection. http://www.lipn.univ-paris13.fr/~youcef/BookQoS
10. Aiello, M., Khoury, E.E., Lazovik, A., Ratelband, P.: Optimal QoS-Aware Web Service Composition. In: IEEE Conf. on Commerce and Enterprise Computing (2009) 491-494
11. Lecue. F.: Optimizing QoS-Aware Semantic Web Service Composition. In: 8th Int. Semantic Web Conference, LNCS Vol. 4273 (2009) 375-39
12. Sohrabi, S., McIlraith, S. A.: Optimizing Web Service Composition While Enforcing Regulations. In: 8th Int. Semantic Web Conference (2009), USA 601-617
13. Pistore, M., Barbon, F., Bertoli, P., Shaparau, D., Traverso, P.: Planning and Monitoring Web Service Composition. Lecture Notes in Computer Science Vol. 3192 (2004), 106-115
14. Farhan, H.K., Javed, M. Y., Saba, B. and Sikandar, H. K.,: QoS Based Dynamic Web Services Composition & Execution. In: Int. Journal of Computer Science and Information Security, Vol. 7, Issue 2, USA (2010) 147-152
15. Zeng, L., Benatallah, B., Ngu, A., Dumas, M., Kalagnanam, J.t, Chang, H.: QoS-aware Middleware for Web Services Composition. In: IEEE Transactions on Software Engineering, Vol. 30 Issue5 (2004) 311-327
16. Mili, H., Tremblay, G., Caillot, A., Tamrout, R. B.: Web service composition as a function cover problem. In: MCeTech Montreal Conference on eTechnologies, Canada (2005) 73-85
17. Che, H., Li, Y., Oberweis, A., Stucky, W.: Web Service Composition Based on XML Nets. In: 42st Hawaii Int. Conf. on Systems (2009) 1-10
18. Lin, N., Kuter, U., Sirin, E.: Web service composition with user preferences. In: 5th European semantic web conference on semantic web: research and applications, LNCS Vol. 5021, Spain (2008) 629-643
19. Ge, J., Qiu, Y., Yin, S: Web Services Composition Method Based on OWL. In: Int. Conf. on Computer Science and Software Engineering, China (2008) 74-77.
20. Mili, H., Marcotte, O., Kabbaj, A.: Intelligent Component Retrieval for Software Reuse. In: Proceedings of the Third Maghrebian Conference on Artificial Intelligence and Software Engineering, Rabat, Morocco (1994) pp. 101-114
21. Dustdar, S., Schreiner, W.: A survey on web services composition. In: International Journal of Web and Grid Services, Vol. 1, No. 1 (2005) pp. 1-30
22. Rao, J., Su, X.: A Survey of Automated Web Service Composition Methods. In: 1st Int. Workshop on Semantic Web Services and Web Process Composition, USA (2004), pp. 43-54
23. Sathya, M. Swarnamugi, M., Dhavachelvan, P., Sureshkumar, G.: Evaluation of QoS Based Web- Service Selection Techniques for Service Composition. In: Int. Journal of Software Engineering, Vol. 1 Issue 5 (2011) pp. 73-90