

DISCOVERY AND COMPOSITION OF WEB SERVICES USING ARTIFICIAL
INTELLIGENCE PLANNING AND WEB SERVICE MODELING ONTOLOGY

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To my beloved mother and father

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ABSTRACT

In today's Web environment, Web services are the preferred standards-based way to realize Service Oriented Architecture (SOA) computing. A problem that has become one of the recent critical issues is automated discovery and composition of Semantic Web services. A number of approaches have been presented to solve the problem. However, most of these approaches only consider discovery or composition of Web services but not both. In this study, an effective approach called AIMO, based on Artificial Intelligence (AI) planning, Web Service Modeling Ontology (WSMO), and Semantic Web has been proposed to tackle the problem. The main purpose of this study is to investigate and develop a novel approach for automated Web service discovery and composition. In this case, a comparative evaluation of state-of-the-art approaches for Web service composition approaches has been done and the strengths and weaknesses of those approaches have been discussed. Moreover a translator for interaction between WSMO and AI-planning based on Description Logics has been proposed. In addition, some parts of AIMO architecture have been tested on a practical case study, and the results based on the experimental validation demonstrate that AIMO provides an effective and applicable solution. AIMO continues to support loose coupling paradigm of SOA by separating the discovery from the composition of Web services.

ABSTRAK

Dalam persekitaran Web pada masa ini, perkhidmatan Web adalah kaedah piawai yang menjadi pilihan utama bagi melaksanakan pengkomputeran Senibina Berorientasikan Perkhidmatan (SBP). Permasalahan yang menjadi salah satu daripada isu kritikal pada masa ini ialah penemuan dan gabungan perkhidmatan Web Semantik secara automatik. Beberapa pendekatan telah diperkenalkan untuk menyelesaikan masalah ini. Walau bagaimanapun kebanyakan pendekatan tersebut hanya menumpukan kepada penemuan atau gabungan sahaja, dan bukan keduanya. Dalam kajian ini, pendekatan berkesan yang dipanggil AIMO, berasaskan perancangan Kepintaran Buatan, Ontologi Permodelan Perkhidmatan Web (OPPW), dan Semantik Web telah dicadangkan untuk menyelesaikan masalah tersebut. Tujuan utama kajian ini ialah untuk menyelidik dan membangunkan satu pendekatan baru bagi penemuan dan gabungan perkhidmatan Web secara automatik. Untuk tujuan ini, kajian perbandingan terhadap pendekatan-pendekatan terkini dalam gabungan perkhidmatan web telah dilakukan, dan kekuatan serta kelemahan pendekatan-pendekatan tersebut telah dikenal pasti. Penterjemah untuk membantu interaksi di antara OPPW dan perancangan Kepintaran Buatan berasaskan Logik Deskripsi telah dicadangkan. Beberapa komponen penting dalam senibina AIMO telah diuji dengan menggunakan kajian kes sebenar, dan hasil daripada pengesahsahihan ujikaji menunjukkan AIMO menyediakan penyelesaian yang berkesan dan boleh dilaksanakan. AIMO juga mengekalkan sokongan terhadap paradigma gandingan longgar SBP dengan memisahkan penemuan daripada gabungan perkhidmatan Web.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xii
	LIST OF FIGURES	xiii
	LIST OF ABBREVIATIONS	xvi
	LIST OF APPENDICES	xvii
1	INTRODUCTION	1
	1.1 Background of the Problem	1
	1.2 Statement of the Problem	2
	1.3 Objectives of the Study	5
	1.4 Scope of the Study	6
	1.5 Significance of the Study	7
2	LITERATURE REVIEW	9
	2.1 Definition of Web Service	9
	2.2 Definition of Semantic Web	12

2.3	Definition of Semantic Web Services	13
2.4	Definition of Web Service Discovery and Composition	16
2.5	General Framework for Web Service Composition	17
2.6	Web Service Composition as Planning	20
2.7	HTN Planning for Web Service Composition	23
2.8	Prominent Approaches in Web Service Composition	24
2.8.1	EFlow	24
2.8.2	Polymorphic Process Model (PPM)	25
2.8.3	Situation Calculus	25
2.8.4	HTN-DL	26
2.8.5	BPEL4WS	30
2.8.6	OWL-S	31
2.8.7	WSMO	33
2.8.8	Other Web Service Composition Approaches	37
2.9	The Differences between OWL-S and WSMO	38
2.10	The Similarities between OWL-S and WSMO	39
2.11	Description Logics (DLs) and Reasoning	39
2.12	Summary	42
3	COMPARATIVE EVALUATION OF STATE-OF-THE-ART WEB SERVICE COMPOSITION APPROACHES	43
3.1	Classification of Approaches in Web Service Composition	43
3.1.1	AI-Planning-Based Approaches	43
3.1.2	Workflow-Based Approaches	44
3.1.3	Syntactic-Based Approaches	45
3.1.4	Semantic-Based Approaches	46
3.2	Comparative Evaluation	46
3.2.1	Security	47

3.2.2	Quality of Service (QoS)	48
3.2.3	Automatic Composition	50
3.2.4	Composition Scalability	51
3.2.5	Correctness Verifiability	52
3.2.6	Discovery	52
3.3	Discussion	53
4	RESEARCH METHODOLOGY	55
4.1	Research Design	55
4.2	Research Procedure and Activities	58
4.2.1	Literature Review	58
4.2.2	Analysis of Requirements	59
4.2.3	Development	59
4.2.4	Evaluation	60
4.3	Operational Framework	63
4.4	Instrumentation	64
4.5	Assumptions and Limitations	64
5	FORMALIZING WEB SERVICE DISCOVERY AND WEB SERVICE COMPOSITION PROBLEMS	66
5.1	Description Logics	66
5.2	Definition of Semantic Web Services	68
5.3	Definition of Web Service Discovery Problem	70
5.4	Definition of Web Service Composition Problem	74
5.5	Summary	78
6	AIMO ARCHITECTURE TO SUPPORT WEB SERVICE DISCOVERY AND COMPOSITION	79
6.1	Motivating Scenario	79

6.2	HTN-Planning and HTN-DL Limitations	81
6.3	Security Capability and Constraint Types	83
6.3.1	Security-related Goal Constraints	84
6.3.2	Security-related Choreography Constraints	85
6.3.3	Security-related Orchestration Constraint	86
6.4	AIMO	87
6.4.1	Overview	87
6.4.2	AIMO Architecture	91
6.4.3	Planning Process for AIMO	97
6.5	Translating Web Service Descriptions to AIMO	102
6.5.1	Relation between WSMO and AIMO	104
6.5.2	Translation of WSMO to EHTN-DL	106
6.6	Summary	123
7	IMPLEMENTATION AND EVALUATION	125
7.1	The Prototype Implementation	125
7.1.1	Introduction	125
7.1.2	Infrastructure	126
7.1.3	Discovery Phase	129
7.1.4	Composition and Invocation Phases	131
7.1.5	Graphical User Interface (GUI)	134
7.2	Experimental Validation	137
7.2.1	Determining Replication Number or Sample Size	138
7.2.2	ANOVA Test	139
7.2.3	Testing Correlation	142
7.2.4	Multiple Regression and Single Variable Regression	143
7.2.5	AIMO-Composer Performance and Scalability	146

7.2.6	Comparison of AIMO with Other Approaches	149
7.3	Discussion	151
7.4	Summary	152
8	CONCLUSIONS AND FUTURE RESEARCH	153
8.1	Summary of the Research	153
8.2	Contributions of the Research	155
8.3	Open Issues and Future Work	156
	REFERENCES	158
	APPENDIX A	169-170

LIST OF TABLES

TABLE NO.	TITLE	PAGE
3.1	Comparison of state-of-the-art Web service composition approaches	53
4.1	Operational framework	63
5.1	An example for Web service discovery problem	74
5.2	An example for composition problem based on Sequential services	76
5.3	An example for composition problem based on Parallel services	77
6.1	A matching task and a composite Web service	90
6.2	Security capabilities and constraints of Web services	97
6.3	AIMO translator to translate WSMO transition rules into HTN-DL	110
7.1	Correlation	143
7.2	Comparative evaluation of AIMO with other approaches	150

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	How Web services work	11
2.2	The nature of Semantic Web services	13
2.3	Annotation of a Semantic Web service identified with WSDL	14
2.4	The general framework of service composition system	17
2.5	HTN-DL algorithm	28
2.6	HTN-DL algorithm for translating If-Then-Else control construct	29
2.7	HTN-DL algorithm for translating Repeat-While control construct	29
2.8	The conceptual model of OWL-S	31
2.9	Four top-level elements of WSMO	33
2.10	WSMO Web service – general description	35
2.11	Architecture of Knowledge representation systems	40
3.1	Classification of Web service composition approaches	44
4.1	Research procedure	61
4.2	Research flow chart	62
5.1	Matchmaking notions for semantically enabled discovery	72
5.2	Web service discovery algorithm	73
5.3	Example of composition using Sequential Web services	76
5.4	Example of composition using Parallel Web services	78
6.1	The user's goal	81

6.2	Capability Level of the flight booking service	81
6.3	An example of security ontology in WSMO	84
6.4	Security-related Goal constraints	85
6.5	Security-related choreography and orchestration constraints	86
6.6	Architecture of the AIMO in an abstract level	93
6.7	Example of matching between two goals and a Web service	95
6.8	The EHTN-DL algorithm for the planning process	99
6.9	High-level of the OWL-S process ontology	103
6.10	From Service to Transition Rules in WSMO	105
6.11	An example of State Signature for a composite service	108
6.12	An algorithm for translating transition rules of WSMO	112
6.13	An example of WSMO If-Then transition rule with else statement	115
6.14	An example of WSMO forAll-With-Do transition rule	119
6.15	An HTN-DL based algorithm for translating Choose-With-Do	121
6.16	An example of WSMO Choose-With-Do transition rule	122
7.1	An illustration of the implemented prototype using UML diagram	127
7.2	The run-time mediator and the ontology mapping tools	130
7.3	The specified goal for the example as a given task	133
7.4	The matched method to the specified task	133
7.5	Four operators to perform the matched method to the given task	134
7.6	Discovery process for the motivating scenario using WSMT tool	135
7.7	A screen shot from AIMO-Composer tool	136
7.8	Boxplot of Web service composition time	139
7.9	A Predicator assumption checking (A)	143
7.10	A predicator assumption checking (B)	144
7.11	Linear model (1,Y)	144

7.12	Quadratic model for (1,Y)	145
7.13	Linear model for (X,50)	146
7.14	The planning process for the motivating scenario	147
7.15	Composition execution time for the motivating scenario	147
7.16	Scalability of the AIMO-Composer for the motivating scenario	148

LIST OF ABBREVIATIONS

<i>AI</i>	-	Artificial Intelligence
<i>AIMO</i>	-	AI planning– web service Modeling Ontology
<i>ASM</i>	-	Abstract State Machine
<i>BPEL4WS</i>	-	Business Process Execution Language for Web Services
<i>DL</i>	-	Description Logic
<i>EHTN-DL</i>	-	Enhanced Hierarchical Task Network- Description Logic
<i>HTN</i>	-	Hierarchical Task Network
<i>HTN-DL</i>	-	Hierarchical Task Network- Description Logic
<i>Iff</i>	-	if and only if
<i>OBS</i>	-	Online Banking System
<i>OCRS</i>	-	Online Conference Registration System
<i>OWL</i>	-	Web Ontology Language
<i>OWL-S</i>	-	Web Ontology Language for Web Services
<i>PPM</i>	-	Polymorphic Process Model
<i>SOA</i>	-	Service Oriented Architecture
<i>SOAP</i>	-	Simple Object Access Protocol
<i>SWS-TC</i>	-	Semantic Web Service Test Case
<i>UDDI</i>	-	Universal Description, Discovery, and Integration
<i>WS</i>	-	Web Service
<i>WSC</i>	-	Web Service Composition
<i>WSD</i>	-	Web Service Discovery
<i>WSDL</i>	-	Web Services Description Language
<i>WSML</i>	-	Web Service Modeling Language
<i>WSMO</i>	-	Web Service Modeling Ontology
<i>WSMX</i>	-	Web Service Modeling eXecution environment

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	List of publications	169

CHAPTER 1

INTRODUCTION

In this chapter an introduction to the current research is provided. Firstly, the background of the problem to be solved is described. After that, the problem statement, and also objective, scope, and importance of the study are described respectively.

1.1 Background of the Problem

In today's Web environment, a number of companies which are planning to implement the core of their business as a service on the Web are growing dramatically. Therefore, selection and integration of heterogeneous services over the Internet is considered as an outstanding issue in order to realize Web services applications. Current studies on the area of Web service applications are based on specifying them in an expressive and formal language, discovering them on the Web, combining them in an automatic manner, and considering security issues during all Web service processes. The main focus of this research is dedicated to the processes of discovery and composition of Web services.

In some cases if a single Web service does not fulfill the service requestor's goals, the current Web services should be combined together to achieve the goal. That issue has inaugurated a number of studies on the area of composition of Web services both in industry and academia. It is possible to consider a composed service as a workflow [6] which involves a collection of single services with data flow and

control flow. In order to automatically bind the concrete resources or services with the abstract nodes, the workflow-based approaches can be applied dynamically.

On the other hand, AI-planning based approaches treat with a service like a software component that includes inputs, outputs, preconditions, and effects. After execution, the Web service alters the state of the world. Therefore, preconditions can be treated as world state prerequisites to invoke the service, and effects are the new state produced after the invocation.

In the area of Web services, there are many studies on providing languages and platforms for the process of composition like BPEL4WS (Business Process Execution Language for Web services) [7]. Moreover, in the fourth generation of World Wide Web, the most prominent technology is Semantic Web services like, WSMO (Web Service Modeling Ontology) [9] and OWL-S (Web Ontology Language for Web Services) [20]. Such languages support Semantic representation of available Web services on the Web.

1.2 Statement of the Problem

Currently, majority of approaches for composition of Web services apply the following techniques: Theorem Proving [107], Model Checking [106], Rule-based Planning [105], Classic AI-planning [104], Golog [33], and HTN [103]. Some of them require too much human efforts; some of them neglect consideration of the process of discovery of Web services to support the composition process. However, the key to success of automatic generation of business processes in the fourth generation of World Wide Web, is overcoming both those processes (i.e., discovery and composition) in an integrated manner, which is the focus of this research.

Nowadays, Web services are described by various Semantic Web services standards based on AI-planning. That is, because of expressing preconditions and effects of Web services as logical conditions. Using this analogy, Web services can be treated as planning operators to create composite Web services, such that each

Web service firstly converted to an operator and the goal is described as a logical condition. Therefore, a sequence of services can be generated by the planner.

Although many problems on (semi-) automated Web service composition have been tackled by AI-planning-based approaches, yet there are various obstacles that have not been addressed. The most important problem which has not been addressed is the process of Web service discovery. In order to provide the discovery process, the Web Service Modeling Ontology (WSMO) can be applied to describe all relevant and general features related to services which are available via a Web service interface.

Another problem that has not been considered by majority of Web service composition approaches is security constraints of Web service composition. For instance, a Web service provider may not want to proceed with requests which are sent by a specific IP address, or to define some additional security constraints like Authentication, Authorization, Access control, Privacy, Anonymity, Confidentiality, and Policy on the composition process. Such constraints must be taken into account during Web service composition.

This research aims to provide a semi-automated approach, called AIMO, based on AI-Planning to combine two or more Web services together which are described with Web Service Modeling Ontology (WSMO) for increasing accessibility and facilitating their integration with respect to nonfunctional properties of Web services such as security and Quality of Service. The general research question this research has aimed to answer is:

How to enable WSMO and AI-planning to automatically discover and combine Semantic Web services in order to fulfill the users' goals?

To address the above question, the following research questions which can address the problem are defined:

- **RQ1:** What is a Web service and how a set of Web services can be combined together?
 - What are the requirements for identifying Web services over the Internet?
 - How to deal with specifying the plan for the composite Web service interoperability?
 - What technologies are needed to support discovery, selection, composition, mediation and invocation of Web services?

- **RQ2:** Why existing approaches for Web service composition are still not able to satisfy all users' requirements?

- **RQ3:** How to automatically compose the Web services via AI-planning?
 - How to specify the Web services in AI-planning?

- **RQ4:** How to enable the Semantic Web to facilitate the process of Web service discovery and composition?
 - How to handle differences between Web Service Modeling Ontology and AI-planning?

- **RQ5:** How to secure the process of interoperability between Semantic Web services?

Besides these questions, the following problems have to be addressed by this research:

- **Decentralized Configurations:** Descriptions of Web services standards which are produced by different organizations are different from each other. In fact, the structures or vocabularies which are being used by them might be different.
- **Service Properties:** The capabilities of many Web services might be the same as each other. In that case, non-functional properties, like the Web service provider's name or Web service provider's credentials, are the only features to distinguish between Web services. Therefore, the non-functional properties are the key elements to make decision on selection of Web services during Web services composition process.
- **Composite Web Services:** Some of Web services are not atomic such that they are created from some other (either atomic or composite) Web services. Thus, describing and reasoning of such Web services have to be taken into account.
- **Efficiency:** The process of making inference on available Web services on the Internet, like matching between their functionalities, has to be taken into consideration efficiently.

1.3 Objectives of the Study

The research objectives are mentioned based on the problem statement, as follows:

- To evaluate state of the art of Web service composition approaches.
- To investigate and develop a novel approach called AIMO for automated Web service discovery and composition based on AI-planning and Semantic Web services techniques for minimizing the

time and increasing correctness verifiability of Web service composition.

- To enable security constraints for the process of Web service composition.
- To demonstrate the applicability of the proposed approach.
- To evaluate and compare the proposed approach with other current approaches with respect to the related criteria.

1.4 Scope of the Study

When this subject was chosen, four research directions were inspired. They are researches in Semantic Web, Web services, Semantic Web Services, and AI-planning. The above directions have been considered as the scope of the research, as follows:

- Firstly, this research is inspired by state-of-the-art Web services technologies which are being investigated in academia and industry (like, Web Services Description Language (WSDL) [4], Universal Description, Discovery, and Integration (UDDI) [45], and Simple Object Access Protocol (SOAP) [5]). These technologies can provide proper languages and frameworks for discovery, selection, composition, mediation, and invocation of Web services. The Web services are described in section 2.1.
- Second, this research is inspired by the Semantic Web [18] which can improve the interoperability problems between Web applications. Normally, such problems are realized by some ontology languages, e.g. OWL [39] which is an XML-based language. Using this technology, Web services are allowed to be in agreement with

concepts of their own terminologies which are used during all processes of Web services like discovery and invocation. The Semantic Web is described in section 2.2.

- Moreover, the third resource for the proposed approach is Semantic Web services which are the most prominent technologies in the fourth generation of the World Wide Web. The Semantic Web Services are described in section 2.3.

- At last, this research was inspired by the approaches based on AI-planning. As discussed in section 1.2, due to the possibility to express preconditions and effects of Web services as logical conditions, several Web service languages describe services in ways which are influenced by AI-planning. AI-planning-based approaches are described in section 3.1.1.

1.5 Significance of the Study

Currently, there are existing many platforms to realize Web services technology, such as BPWS4J [41], .NET [44], Web Sphere [43], and AXIS [42]. The problem which is raised by those platforms is lack of suitable tools to support dynamic Web service composition such that, if no atomic Web service does satisfy the user's goal, the process of Web service composition might be done manually.

As mentioned before, several different studies on Web services are trying to define proper languages and platforms for Web service composition such as BPEL4WS [7], and also to maintain semantic representations of the available services over the Web like, WSMO [9] and OWL-S [20].

Nevertheless, the process of composition of Web Services still can be considered as a complicated task due to the following reasons [10]:

- Recently, the number of available Web services is increasing dramatically, such that searching on huge repositories might be expected in future.

- Furthermore, many Web services are establishing and updating over the Internet. Therefore, before the process of Web service composition, such updated information must be detected.

- In addition, different organizations are developing different Web services. In order to describe such services, different concept models might be used. Nevertheless, lack of a standard language to describe and evaluate such services is another reason that increases the complexity of Web service composition process.