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The semantic side of Service-Oriented Architectures

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Melo

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Semantic Enterprise Application Integration for Business Processes: Service–Oriented Frameworks

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Dedication

To Lily and Maria

Gregoris Mentzas

To Oksana, Daniel, Gregory, and Maximilian

Andreas Friesen

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<i>Stijn Christiaens, Vrije Universiteit Brussel, Belgium</i>	

In this chapter, we will present a methodology, which has resulted in the implementation of a highly customizable collaborative environment focused to support ontology-based enterprise interoperability. An additional key issue addressed by the particular platform is the variety and number of different resources that concur to achieve a cross-enterprise business service. A second key issue is the diversity of agreed (e.g., meaning negotiation when creating online contracts) models, and the difficulty in adapting its integrated features and services to different situations.

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If we try to increase the level of automation in enterprise application integration (EAI) scenarios, we confront challenges related to the resolution of data and message heterogeneities between interoperating services, which traditional EAI technologies are weak to solve. We propose a semantically-enriched approach for dynamic data mediation in EAI scenarios, focusing on the resolution of message level heterogeneities between collaborative enterprise services, facilitating automated data mediation dur-

ing execution time by providing formal transformations of the output and input messages (of the participating services) to a common reference business data model, that is, the enterprise interoperability ontology. Moreover, we present a tool that has been developed to support the user to provide business data-related semantic annotations and XSLT transformations of the input and output message parts of collaborative enterprise services. Finally, we demonstrate the utilization of the proposed approach and toll in a real-world EAI scenario.

Chapter 3

Ontology-based Patterns for the Integration of Business Processes and Enterprise

Application Architectures 36

Veronica Gacitua-Decar, Dublin City University, Ireland

Claus Pahl, Dublin City University, Ireland

Increasingly, enterprises are using service-oriented architecture (SOA) as an approach to enterprise application integration (EAI). SOA has the potential to bridge the gap between business and technology and to improve the reuse of existing applications and the interoperability with new ones. In addition to service architecture descriptions, architecture abstractions like patterns and styles capture design knowledge and allow the reuse of successfully applied designs, thus improving the quality of software. Knowledge gained from integration projects can be captured to build a repository of semantically enriched, experience-based solutions. Business patterns identify the interaction and structure between users, business processes, and data. Specific integration and composition patterns at a more technical level address enterprise application integration and capture reliable architecture solutions. We use an ontology-based approach to capture architecture and process patterns. Ontology techniques for pattern definition, extension, and composition are developed and their applicability in business process-driven application integration is demonstrated.

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Agent-Driven Semantic Interoperability for Cross-Organisational Business Processes 61

Ingo Zinnikus, German Research Center for Artificial Intelligence (DFKI) GmbH, Germany

Christian Hahn, German Research Center for Artificial Intelligence (DFKI) GmbH, Germany

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In cross-organisational business interactions, integrating different partners raises interoperability problems especially on the technical level. The internal processes and interfaces of the participating partners are often pre-existing and have to be taken as given. This imposes restrictions on the possible solutions for the problems which occur when partner processes are integrated. The aim of this chapter is the presentation of a three-tier framework for managing and implementing interoperable and cross-organizational business processes. Thereby the authors want to fill the gap currently existing between processes defined on a strategic level and executed models. We describe a solution which supports rapid prototyping by combining a model-driven framework for cross-organisational business processes with an agent-based approach for flexible process execution. We show how the W3C recommendation for Semantic Web service descriptions can be combined with the model-driven approach for rapid service integration.

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In service-oriented architectures (SOA), service descriptions are fundamental elements. In order to automatically execute SOA tasks, such as services discovery, it is necessary to capture and process the semantics of services. We review several Semantic Web services frameworks that intend to bring semantics to Web services. This chapter depicts some ideas from SOA and Semantic Web services and their application to enterprise application integration. We illustrate an example of logic-based semantic matching between consumer services and provided services, which are described in ontologies.

Chapter 6

Supporting Semantically Enhanced Web Service Discovery for Enterprise Application Integration 105

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The availability of sophisticated Web service discovery mechanisms is an essential prerequisite for increasing the levels of efficiency and automation in EAI. In this chapter, we present an approach for developing service registries building on the UDDI standard and offering semantically-enhanced publication and discovery capabilities in order to overcome some of the known limitations of conventional service registries. The approach aspires to promote efficiency in EAI in a number of ways, but primarily by automating the task of evaluating service integrability on the basis of the input and output messages that are defined in the Web service's interface. The presented solution combines the use of three technology standards to meet its objectives: OWL-DL, for modelling service characteristics and performing fine-grained service matchmaking via DL reasoning, SAWSDL, for creating semantically annotated descriptions of service interfaces, and UDDI, for storing and retrieving syntactic and semantic information about services and service providers.

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Jens Lemcke, SAP Research, Germany

Semantics needs to be considered in two major integration tasks. First, semantically corresponding data types that can be used for communication between components need to be identified. Second, natural language documentation needs to be studied today in order to understand component behavior, that is, dependencies between operation invocations and how semantically different outcomes of operation calls are represented in the technical output format. The approach presented in this chapter supports the two tasks as follows. First, closed frequent itemset mining (CFIM) is employed to help identifying

semantically corresponding data types. Second, a formal representation for component behavior is introduced. However, as component behavior is specified during component development, but used during integration—two distinct phases involving distinct teams—we provide model transformations to ensure the consistent transfer of generic behavioral information to specific integration constraints before automated integration techniques can be applied. We applied the CFIM on the message types exposed by SAP’s standard software components and show that we are able to find semantically relevant correspondences. Furthermore, we demonstrate the practical applicability of our behavioral model transformations on the basis of an SAP best practice business scenario. With the little more effort to specify behavioral information at development time in a formal way instead of in natural language, our approach facilitates the reuse of behavioral component descriptions in multiple integration projects and eases the construction of correct integrations.

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In service-oriented business applications, B2B integration happens when a service requester invokes services of one or more service providers. Typically, there are several candidate services with similar capabilities that can be chosen by a requester in order to serve his business needs. The selection of the service to be invoked may depend on different functional and non-functional properties. The non-functional properties usually address security, reliability, performance, and so forth. The functional properties address the business process interplay at the level of the technical Web service interface and the message choreography associated with it. At the technical integration level, the description of functional and non-functional service properties has been exhaustively addressed in the scientific literature in the past. The business level however, namely, the requester’s business need, the business meaning of an offered service, and the capability of a service provider to successfully perform the requested business transaction, has been rather ignored. This chapter describes a solution for service discovery and selection at the business level, that is, at the level of offered business capability of a service provider and the ability to serve a concrete requested business transaction. The proposed solution is based on semantic interpretation of offered service capabilities, contractual restrictions, business rules of the requestor specifying selection preferences, and the parameters of the run-time service request. The applicability of the proposed solution is demonstrated on a shipper-carrier integration scenario.

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Currently in the travel domain, most of the travel products are sold through global distribution systems (GDSs). Since only major airline companies or hotel chains can afford to join GDSs, it is difficult for small and medium enterprises to market their travel products. In this chapter, we describe a middleware, called SATINE, to address this problem. In the SATINE middleware, existing travel applications are wrapped as Web services. Web services, as such, is of limited use because the service consumer must know all the details of the Web service like the functionality of the Web service (what it does) and the content and the structure of input and output messages. Therefore, we annotate both the service functionality and the service messages with Web ontology language (OWL) ontologies. Service functionality ontology is obtained from the “Open Travel Alliance (OTA)” specifications. Service message ontologies are automatically generated from the XML schema definitions of the messages. These local message ontologies are mapped into one or more global message ontologies through an ontology mapping tool developed, called OWLmt. The mapping definitions thus obtained are used to automatically map heterogeneous message instances used by the Web service provider and the consumer using a global ontology as a common denominator. This architecture is complemented by a peer-to-peer network which uses the introduced semantics for the discovery of Web services. Through the SATINE middleware, the travel parties can expose their existing applications as semantic Web services either to their Web site or to Web service registries they maintain. SATINE middleware facilitates the discovery and execution of these services seamlessly to the user.

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The research project FUSION aims at supporting collaboration and interconnection between enterprises with technologies that allow for the semantic fusion of heterogeneous service-oriented business applications. The resulting FUSION approach is an enterprise application integration (EAI) conceptual framework proposing a system architecture that supports the composition of business processes using semantically annotated Web services as building blocks. The approach has been validated in the frame of three collaborative commercial proof-of-concept pilots. The chapter provides an overview on the FUSION approach and summarises our integration experiences with the application of the FUSION approach and tools during the implementation of transnational career and human resource management services.

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<i>Pawel Rubach, Telekomunikacja Polska S.A., Poland</i>	

The application of semantic technologies promises boosting business process management because semantic integration of business and IT is achieved. To enable the vision of semantic business process management, semantic technologies like ontologies, reasoners, and semantic Web services must be integrated in BPM tools. We extended a professional BPM tool to allow semantic business process modelling using the EPC notation. In addition, we adapted the tool's EPC to BPEL transformation to preserve the semantic annotations. By introducing a proxy service, we are able to perform Semantic Web service discovery on a standard BPEL engine. We evaluated our approach in an empirical case study, which was replicated 13 times by 17 participants from 8 different organisations. We received valuable feedback, which is interesting for researchers and practitioners trying to bring semantic technologies to end-users with no or only limited background knowledge about semantics.

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Chapter 5

The Semantic Side of Service-Oriented Architectures

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ABSTRACT

In Service-Oriented Architectures (SOA), service descriptions are fundamental elements. In order to automatically execute SOA tasks, such as services discovery, it is necessary to capture and process the semantics of services. We review several Semantic Web Services frameworks that intend to bring semantics to Web Services. This chapter depicts some ideas from SOA and Semantic Web services and their application to enterprise application integration. We illustrate an example of logic-based semantic matching between consumer services and provided services, which are described in ontologies.

INTRODUCTION

A new paradigm of information systems design – the service-oriented architecture (SOA) – has been consistently gaining acceptance. It is an architectural paradigm aiming at dealing with business processes distributed over a large landscape of former and newer heterogeneous systems that are under the control of different owners (Josuttis, 2007). The

goal of SOA is to structure large distributed systems based on the abstractions of business rules and functions.

In SOA approach, traditional business logic is extracted from inside silo applications and exposed as reusable services. These, in turn, can be easily composed into higher-level business processes using graphical tools. Changes become much easier and the gap between needs and IT support is narrowed. The organizations become more agile and flexible.

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However, some challenges remain in assembling business processes from services. Business processes carry semantics, which are usually neither explicitly nor formally expressed. To represent semantic content in an explicit way can be a hard task because it requires domain experts to formalise the implicit knowledge about services or processes. Still, representing semantics explicitly through formal ontologies of products, processes or services, may help describe, compose and match services, such as between consumer-required services and provider-specified services.

The concepts of SOA may be applied to provide for several tasks, and among those the ones usually associated with Enterprise Application Integration (EAI). Web Services and SOA technology can be used to support EAI tasks, like process modelling, process execution, message routing, transformation and delivery among systems (Haller, Gomez & Bussler, 2005). The use of a common representation for data (usually XML) however does not preclude mismatches between systems, and while syntactic and structural mismatches may be solved using common Web Service standards, semantic mismatches are usually solved in an ad-hoc fashion. Similarly, process modelling using common tools does not guarantee the easy or automatic selection of adequate services (from a pool of common or domain-specific services).

This chapter intends to explain how semantically SOA and its technologies can be used to perform some integration tasks. The goal is more to depict some ideas from SOA and Semantic Web Services and their application to EAI than to provide new research. On the practical side, we show how we can use formal domain ontologies to describe and to match services. We review several semantic web services frameworks that intend to bring semantics to Web Services. We discuss the loose coupling aspect of SOA regarding semantic enrichment of Web Services description. Then we illustrate our approach related to the discovery of services in the context of a product catalogue using semantic web services represented in OWL-S.

We then use a logic-based matchmaker to detect if services match. The use of reasoning is intended to be a consistent way to verify matching services.

BACKGROUND

By nature, all large systems are heterogeneous, *i.e.* they lack uniformity. These systems were initially developed with different purposes, and evolved towards accretions of different platforms, programming languages and even middleware. SOA paradigm aims at dealing with heterogeneous systems in a decentralised way as much as possible. Decentralisation helps to obtain loose coupling. SOA key technical concepts are services, loose coupling and interoperability. We briefly describe these three concepts below.

Although several definitions exist, in short, a service is an information technology (IT) representation of self-contained business functionality.

Loose coupling minimises dependencies and thus helps scalability, flexibility and fault tolerance. When dependencies are reduced, modifications have minimised effects and the systems still run when part of them are down. When problems occur, it is important to decrease their effects and consequences. Josuttis (2007) elaborates on several strategies to apply loose coupling.

The ISO/IEC 2382-01 (1993) states that interoperability is the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units. Thus, interoperability enables systems to communicate, understand each other and exchange information. Syntactic and structural interoperability is already set up with transformations, for instance, using standards like XML and XML Schema and associated tools. Syntactic and structural transformations are used to convert schema representations into a target format. Approaches that target at enhancing interoperability based on structure and on syntax

can only produce improvements when a certain conceptual homogeneity between graphs to compare exists. Solving mismatches on the semantic level, *i.e.* to come up to semantic interoperability, is a complex accomplishment. More and more semantic resources are available, for instance within the Web, that are as many different cognitive viewpoints over application domains.

Particularly, semantic interoperability is the ability to exchange information and use it, ensuring that the precise meaning of the information is understood by any other application that was not initially developed for this purpose (“European Interoperability Framework, ” 2003). Semantic interoperability enables systems to process the information produced by other applications, *i.e.* use it isolated or combined with their own information, in a meaningful way. Therefore, semantic interoperability is an important requirement for improving communication and productivity.

Although many SOA definitions include the term Web Services, these are one possible way to realize a SOA infrastructure by using a specific implementation strategy (Josuttis, 2007). Anyway, web services are emerging as the *de facto* standard for SOA implementations. However, web services related technologies deal with almost exclusively syntactic and structural aspects of information and lack of semantics considerations.

Traditionally, services are described using XML language (Bray, Paoli & Sperberg-McQueen, 2006), for instance with the Web Services Description Language, WSDL (Christensen, Curbera & Meredith, 2001) or its second version, WSDL 2.0 (Chinnici, Moreau & Ryman, 2007). This language specifies a format to define service interfaces, *i.e.* the technical aspects of calling web services. It can describe two different aspects of a service that are its signature, particularly service name and service parameters, and its binding and deployments details, such as protocol and location. Although WSDL 2.0 provides the ability to extend WSDL files, the underlying XML language does not enable to convey precise and unambiguous

semantics. This means a WSDL file is not enough to manage the whole service contract.

According to Haller, Gomez & Bussler (2005) determining the semantics for services interfaces means to define the concepts as well as the relationships between them through ontologies. According to frequently quoted Gruber (1993) an ontology is a formal explicit specification of a shared conceptualization. Thus, an ontology defines a common agreement upon terminology by providing a set of concepts and relationships among the set of concepts. In order to capture semantics of relations and of concepts, an ontology generally also provides a set of axioms, which means expressions in a logical framework.

Representational techniques being developed for the Semantic Web can be used to capture and process semantics. Some of these techniques ground on XML language, bringing other complementary language constructors. From the W3C, the Semantic Web Activity group (“W3C Semantics,” 2004) recommends specific languages such as Resource Description Framework, RDF (Beckett, 2004), Resource Description Framework Schema, RDF(S) (Brickley & Guha, 2004) and Web Ontology Language, OWL (McGuinness & Van Harmelen, 2004). Particularly, OWL includes three sublanguages: OWL-lite, OWL-DL, and OWL full. The first two, but not the third, correspond to decidable description logics (Baader, Calvanese & McGuinness, 2003). Decidability implies that fundamental questions about an ontology are guaranteed to be answerable, such as the question of subsumption. A specific class *A* subsumes another class *B* when it is a superclass of a class *B*.

In the domain of Semantic Web Services, the research community proposed several structured service description languages. Examples of these languages are Semantic Markup for Web Services, OWL-S¹ (Martin, Burstein & Hobbs, 2004) and Web Service Modelling Language, WSML² (De Bruijn, Lausen & Polleres, 2005) which have formal logic semantics groundings. Another outcome

in this domain is the Semantic Annotations for WSDL and XML Schema, SAWSDL³ (Farrell & Lausen, 2007), a W3C 2007's recommendation, which does not have any formal semantics. In this chapter, we briefly survey these approaches and languages hereafter.

Haller, Gomez & Bussler (2005) state that the usage of semantic web services and semantic SOA can help overcome the limitations of traditional SOA. This can be done by facilitating the matching of semantically similar operations in different systems, by supporting service mediation through ontology adaptation (for both process mediation and data mediation, according to the definitions of Fensel & Bussler (2002)) and by providing the standard Web Services communication mechanisms for system and process-independent communication.

To support these tasks and increase the automation in EAI, Bouras et al. (2007) proposed ENIO, an ontology that permits shared understanding of data, services and processes within B2B integration scenarios while Izza, Vincent & Burlat (2006) proposed OSDOI, a framework for EAI evolution using semantic Web Services.

Semantic Annotations for WSDL and XML Schema (SAWSDL)

SAWSDL approach (Farrell & Lausen, 2007) proposes a set of extension attributes for the WSDL and XML Schema definition languages that allows description of additional semantics of WSDL components. The SAWSDL specification defines how semantic annotation is accomplished using references to semantic models, such as ontologies. It provides mechanisms by which concepts from these semantic models, typically defined outside the WSDL document, can be referenced from within WSDL and XML Schema components using annotations. SAWSDL defines the following three extensibility attributes to WSDL 2.0 elements for their semantic annotation:

- A `modelReference` extension attribute; This is used to specify the association between a WSDL or XML Schema component and a concept in some semantic model. It is used to annotate XML Schema type definitions, element declarations, and attribute declarations as well as WSDL interfaces, operations, and faults. In terms of the WSDL 2.0 component model, a SAWSDL model reference is a new property.
- `liftingSchemaMapping` and `loweringSchemaMapping` extension attributes, that are added to XML Schema element declarations and type definitions for specifying mappings between semantic data and XML. Particularly, `lifting schema mapping` transforms XML data into instances of a semantic model, and `lowering schema mapping` does the opposite, it transforms semantic model instances into XML data. This SAWSDL schema mapping intends to address post-discovery issues when using Web services, such as how to overcome structural mismatches between the semantic model and the service inputs and outputs.

Hereafter we discuss some limitations and advantages of this approach. Quoting from the example section⁴ of the SAWSDL recommendation: "Practice has shown that it is a very hard task to create XSLT or XQuery transformations that take arbitrary RDF/XML as input." As so, to lower schema mappings, they use XML technologies combined with an RDF query language like SPARQL to pre-process the RDF data. Thus, using SAWSDL implies the need to rely on outside software to solve semantic heterogeneities. In real applications, this task is probably assigned to external mediators.

As some OWL sublanguages bring more constraints and expressivity than RDF, a reference model defined in OWL has to be pre-processed with OWL specific tools as well. Regarding

lowering schema mapping, transformations from OWL to XML can cause information loss, since XML is a less expressive language. Thus, we think using only SAWSDL may not be the best choice when the available reference model is defined in OWL.

Again, quoting from the SAWSDL recommendation: “Semantics in the scope of this specification refers to sets of concepts identified by annotations.”⁵ As stated by Klusch (2008a), the main criticism of SAWSDL is that it has no formal semantics and is a mere syntactic extension of WSDL.

Nevertheless, SAWSDL is less complex than OWL-S or WSML in the sense it only adds three basic constructs to connect XML WSDL representations to outside metadata information. As so, SAWSDL is convenient for applications and domain reference models that do not need the complexity or expressivity of OWL-S or WSML languages. To support SAWSDL some software is being developed, such as Lumina⁶ and Radiant⁷, both part of the METEOR-S project.

Web Service Modelling Language (WSML)

WSML⁸ (De Bruijn, Lausen & Polleres, 2005) is a formal language for the semantic markup of web services. It is used to describe a semantic web service in terms of its functionality (service capability), imported ontologies and interface to enable access. WSML syntax mainly derives from F-logic. It also has a normative human-readable syntax, an XML and RDF syntax. WSML comes in five variants that are WSML-Core, WSML-DL, WSML-Flight, WSML-Rule and WSML-Full.

“A WSML service capability describes the state-based functionality of a service in terms of its precondition (conditions over the information space), postcondition (result of service execution delivered to the user), assumption (conditions over the world state to met before service execution), and effect (how does the execution change

the world state). Roughly speaking, a WSML service capability consists of references to logical expressions in a WSML variant that are named by the scope (precondition, postcondition, assumption, effect, capability) they intend to describe.” (Klusch, 2008a, p. 47).

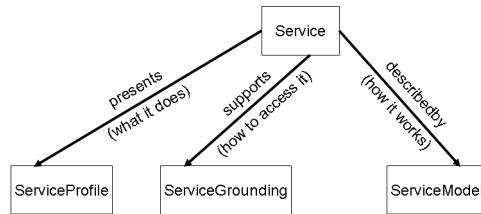
The Web Service Modelling Ontology (Roman, Lausen & Keller, 2004), WSMO uses the WSML as the underlying representation language. WSMO defines four main modelling components: ontologies, goals, services and mediators. WSMO goals represent the objectives of the service requester to be fulfilled when consulting a Web Service. The provider side declares the service capability within a web service declaration. WSMO mediators should help matching goals and capabilities.

Haller, Gomez & Bussler (2005) propose a specific SOA architecture that applies WSMO framework and uses a specific execution environment, Web Service Execution Environment, WSMX⁹ (Zaremba & Oren, 2005). In this environment, they need specific adapters to transform external messages into the WSML compliant format understood by WSMX, and mediators that perform tasks such as translation between ontologies.

Major criticism of WSML concern the lack of formal semantics of its service interface and the lack of principled guidelines for developing the proposed types of WSMO mediators for services and goals in concrete terms (Klusch, 2008a). WSML complete connection with W3C standards, such as WSDL and SAWSDL, is missing. To make up for this seems to be an ongoing work.

To support WSML some software is being developed, such as the WSML service editor associated with the WSMO studio¹⁰, WSML-DL and WSML-Rule reasoner and the WSML validator. For instance, the SUPER¹¹ project uses WSMO as the underlying ontology.

Figure 1. Top level of OWL-S 1.1 service ontology. (adapted from Martin, Burstein & Hobbs, 2004)



Semantic Markup for Web Services (OWL-S)

Based on OWL, Martin, Burstein & Hobbs (2004) propose OWL-S also known as OWL for Services. OWL-S currently supersedes DAML-S (Burstein, Ankolenkar & Paolucci, 2003) and intends to add precise semantics to service description and not to replace WSDL description or other existing and useful descriptions. In order to link OWL-S to WSDL some attributes are added to WSDL extensions, thus connecting both languages and generated files. For instance, maps were specified between OWL-S parameters and WSDL message parts.

OWL-S consists in three parts: the *service profile*, the *process model* (captured by the *ServiceModel* class, Figure 1) and the *grounding* (through the *supports* property referring to the *ServiceGrounding* class, Figure 1). The service profile sets out what a service does and is used to advertise the service. The process model aims at describing how the service is used, *i.e.* gives a detailed description of a service's operation. The grounding provides details on how to interact with a service, via messages.

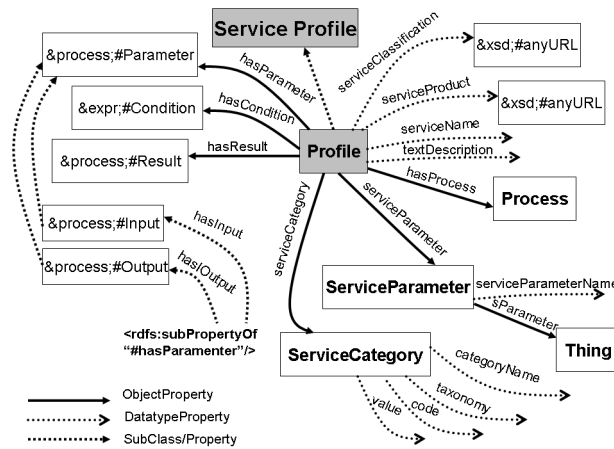
The service profile intends to allow service providers to advertise their service and service requesters, also known as service consumers, to specify what capabilities they expect from the service they need. In OWL-S 1.0, a service profile includes functional parameters that are *hasInput*,

hasOutput, precondition and effect (known colloquially as IOPEs), as well as non-functional parameters such as *serviceName*, *serviceCategory*, *qualityRating*, *textDescription*, and meta-data about the service provider. Inputs and Outputs parameters specify the data transformation produced by processes. Here a process means a specification of the ways a client may interact with a service. Therefore a process can generate and return new information based on information it is given and the world state. Information production is described by the inputs and outputs of the process. A process can produce a change in the world and this transition is described by the preconditions and effects of the process. Preconditions specify facts required prior to the execution of the service. Effects are the expected result from the successful execution of the service. In OWL-S 1.1, the IOPE parameters are specified in the process model with unique references to these definitions from the service profile (Figure 2).

The semantics of each input and output parameter is defined as an OWL concept formally specified in a given ontology, while preconditions and effects are represented as logical formulas that can be expressed in any appropriate logic (rule) language such as KIF, PDDL, and SWRL. In fact, the formal representation of the execution behaviour associated with the process model constructs related to preconditions and effects can not be adequately expressed in OWL-DL.

Quoting (Martin, Burstein & Hobbs, 2004): "The Profile of a service provides a concise description of the service to a registry, but once the service has been selected the Profile is useless; rather, the client will use the Process Model to control the interaction with the service. Although the Profile and the Process Model play different roles during the transaction between Web services, they are two different representations of the same service, so it is natural to expect that the input, output, precondition, and effects of one are reflected in the IOPEs of the other."¹² In OWL-S 1.1, the process model also specifies IOPEs of all

Figure 2. Structure of the OWL-S 1.1 service profile. (adapted from Martin, Burstein & Hobbs, 2004)



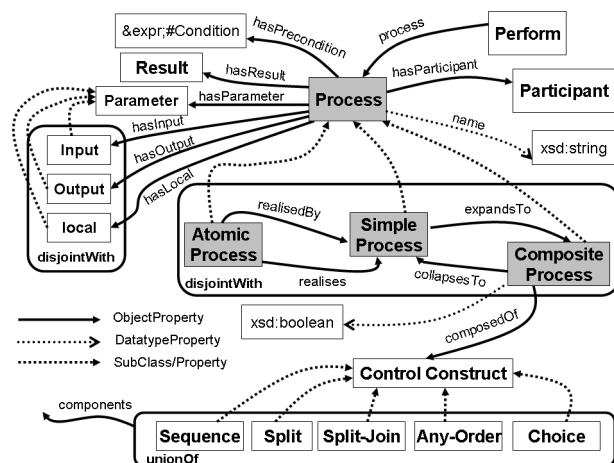
processes that are referenced in the profiles of the respective services.

An OWL-S process model describes the composition (choreography and orchestration) of one or more services. Composite processes are hierarchically defined workflows, consisting of atomic, simple and other composite processes. These process workflows are constructed using a number of different control flow operators that are Sequence, Unordered (lists), Choice, If-then-else, Iterate, Repeat-until, Repeat-while, Split, and Split+Join (Figure 3).

The grounding of a service specifies the details of how to access the service. These details have mainly to do with protocol and message formats, serialization, transport, and addressing. Martin, Burstein & Hobbs (2004) exemplify a grounding of OWL-S services in WSDL: each atomic process is mapped to a WSDL operation, and inputs and outputs are mapped to respectively named XML data types of corresponding input and output messages.

Regarding limitations of OWL-S approach, Klusch (2008a) argues that:

Figure 3. Top-level structure of the OWL-S 1.1 process model. (adapted from Martin, Burstein & Hobbs, 2004)



- OWL-S has limited expressiveness of service descriptions, which corresponds to that of its underlying OWL-DL;
- The static and deterministic aspects of OWL-DL may limit OWL-S expressiveness, particularly regarding the specification of some conditional effects;
- In contrast to WSDL, an OWL-S process model cannot contain any number of completely unrelated operations;
- The semantics of the OWL-S process model is missing.

Yet, OWL-S benefits from a large support from the community. Several software and applications were developed and are being developed for this language and ontology of semantic service descriptions, such as the OWL-S editor, the OWL-S API¹³ and OWL-S service matchmakers, like OWLS-UDDI¹⁴, OWLSM12¹⁵ and OWLS-MX13¹⁶, to name a few.

Moreover, OWL-S grounds its success on existing W3C Web standards such as WSDL and semantic web languages like OWL. It does not seem to us that the choice of SAWSDL as a W3C recommendation can endanger the future adoption of OWL-S as a W3C Semantic Web Services standard because both languages have different goals and are appropriate to different technological situations.

According to Klusch (2008a), neither OWL-S nor WSMML provide any agreed formal standard workflow-based semantics of the service process model (orchestration and choreography). Alternatively, for abstract service descriptions grounded in WSDL, the process model can be intuitively mapped to BPEL orchestrations with certain formal semantics. In the EU project SUPER, an extension for BPEL, named sBPEL, is proposed which allows a process to interact with Semantic Web Services (Bhiri et al., 2008). We do not detail sBPEL further because it is out of the scope of this chapter.

LOOSE COUPLING AND SEMANTIC WEB SERVICES

Independently of specific SOA infrastructure or public registries of services, at some moment in SOA lifecycle it is necessary to match service request descriptions with available service descriptions, in order to verify if the latter corresponds to service consumer needs. This kind of task is common in inter-EAI where it is assumed that a market for services exists and to find the service best suited to the required task is needed, but it can also be present in intra-EAI situations where a company comprises sub-units that evolve individual solutions (even if service-enabled) in partial isolation. To automate this task as much as possible, both consumer and provider service descriptions have to be precisely described, such as within ontologies of services.

Loose coupling usually leads to a situation where only a few fundamental and stable concepts, attributes and data types are defined as a common data model or ontology. However, there will always be ontologies for the same domain created by different communities around the world. Thus, services are described in different ontologies. Therefore, it is necessary to provide the means of finding semantic similarities between them, *i.e.* by aligning the service ontologies. Mediators can do this task, for instance within an Enterprise Service Bus (ESB), that can help a service call performed by a consumer to find the service provider that can process this request. Josuttis (2007) details functionalities of ESB.

Aligning ontologies means discovering a collection of binary mappings between concepts of these ontologies (Ferreira da Silva, 2007; Kalfoglou & Schorlemmer, 2003). Keeping ontology consumer services separated from ontology provider services serves loose coupling.

If we try harmonizing the different ontologies by introducing a common ontology inside the ESB, for instance by merging the input ontologies instead of aligning them, we will easily disable

the effect of loose coupling. Moreover, since in dynamic runtime environments the partners, *i.e.* service consumers and service providers, are not known beforehand, to build a merged ontology during design time does not seem feasible or worthy.

ALIGN SEMANTIC SERVICES

Mappings are frequently a manual task (Grau et al., 2005). However, some approaches try to bring about automation in order to help the complex and tedious mapping task, especially when reference models, such as ontologies, are huge. For instance, CtxMatch-2.1 (Bouquet, Serafini & Zanobini, 2006) incorporates a DL-based reasoner to find mappings and to align ontologies. Klusch (2008b) classifies semantic matchmaking techniques, and their associated tools, as logic-based, non-logic-based and hybrid:

- Non-logic-based matching applies techniques such as graph matching, data mining, linguistics, or content-based information retrieval to exploit semantics that are either commonly shared (in XML namespaces) or implicit in patterns or relative frequencies of terms in service descriptions;
- Logic-based semantic matching of services like those written in the service description languages OWL-S and WSML exploit standard logic inferences;
- Hybrid matching refers to the combined use of both types of matching.

Klusch (2008b) states hybrid matchmaker, based on syntactic matching techniques, produce better results than only logic-based matchmaker under certain conditions (that are not specified), as resulted of the first experimental evaluation of the performance of hybrid semantic service matchmakers OWLS-MX (Klusch, Fries & Sycara, 2006) and iMatcher2 (Kiefer & Bernstein, 2008).

In our viewpoint, the choice of the matchmaker depends on the context, particularly on the ontologies and service descriptions at hand. For instance, if only logic-based semantic service descriptions are available, then it seems inappropriate to apply non-logic-based or hybrid matching.

Each of the implemented Semantic Web service matchmakers supports only one of the many existing Semantic Web Service description formats. Refer to Klusch (2008b) for more information. Very few matchmakers ignore the structured Semantic Web Service description formats, using monolithic descriptions of services in terms of a single service concept written in a given DL. In such case, semantic matching directly uses DL inferencing, such as performed by Pellet (Sirin, Parsia & Cuenca Grau, 2007) and Racer (Li & Horrocks, 2004).

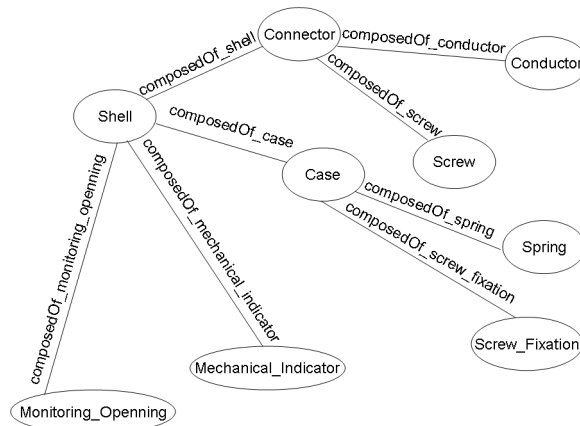
Currently, most Semantic Web Service matchmakers perform service profile rather than service process model matching. Service profile matching determines the semantic correspondence between services based on the description of their profiles. Semantic matching of service process models, in general, is very uncommon.

DISCOVERY OF SEMANTIC WEB SERVICES IN A CATALOGUE OF PRODUCTS

To illustrate our approach, we take a hypothetical situation of services discovery. On one hand, an online catalogue of electrical products includes electrical connectors among other products. These products are described in ontologies and also by service descriptions. The ontology describing design information of an electrical connector included in the catalogue is represented in Figure 4.

The service descriptions were previously created using the OWL-S editor plugin (Elenius, Denker & Martin, 2005) within the Protégé tool, and were then manually associated to each product

Figure 4. Graphical representation of the first connector, arcs represent non-hierarchical properties



of the catalogue. In order to describe services we use OWL-S because the ontologies of products were already defined using OWL.

On the other hand, an agent in charge of the electrical plan of a civil engineering building needs detailed design information about an electrical connector for which the main design information is represented in Figure 7. As so, this agent requests a service that looks for information detail about an electrical connector. Figure 9 represents part of its service description. This service looks for the information of an electrical connector, the definition of which matches information in the associated ontology.

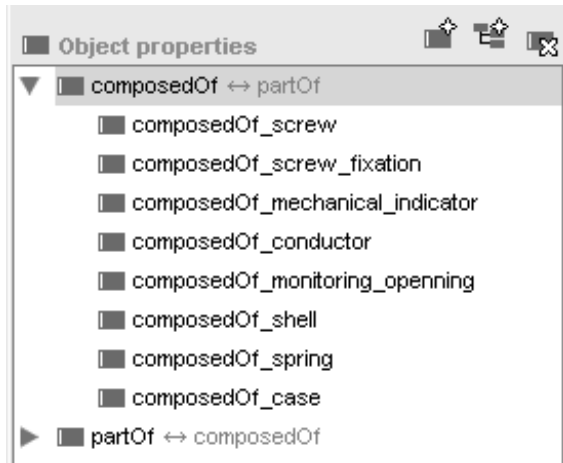
Figure 4 shows the main ontological classes and non-hierarchical properties, while Figure 5 shows the definition of the “Connector” concept. Protégé ontology development tool (Noy & McGuinness, 2001) is used to display the connector OWL representations.

According to this ontology, the Connector concept comprises other products’ concepts, namely: “Conductor”, “Screw” and “Shell”. In other words, the “Connector” concept is necessarily and sufficiently defined using existential and universal restrictions by the following parts (1) to (3):

Figure 5. Definition of the first connector using Protégé ontology development tool



Figure 6. List of properties defined for the first connector product



1. $\forall \text{composedOf_conductor.Conductor} \sqcap \exists \text{composedOf_conductor.Conductor}$
2. $\forall \text{composedOf_screw.Screw} \sqcap \exists \text{composedOf_screw.Screw}$
3. $\forall \text{composedOf_shell.Shell} \sqcap \exists \text{composedOf_shell.Shell}$

Figure 6 shows the object properties hierarchy of the first electrical connector.

The ontology of the agent in charge of the electrical plan describes a different electrical connector (Figure 7). In this one, the “Connector” concept is composed by the concepts “Cable”, “Screw” and “Body”.

Figure 7. Graphical representation of the second connector, arcs represent non-hierarchical properties

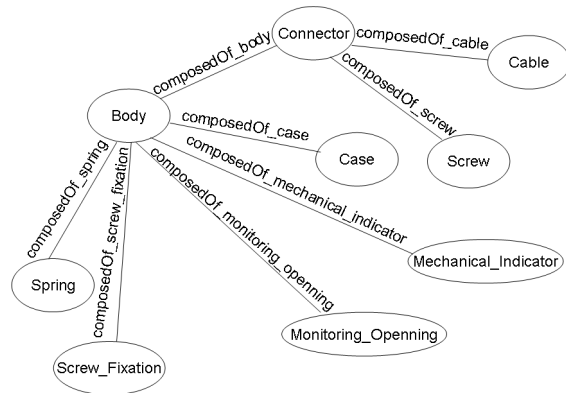


Figure 8 shows the necessary and sufficient definition, as shown in Protégé tool.

Box 1. shows part of the service description of the agent that requests design information about an electrical connector.

The matching can be obtained using a logic-based semantic matchmaker for OWL-S, such as the OWLSM (Jäger et al., 2005) matchmaker and OWLS-UDDI (Paolucci et al., 2002), that focuses on Input/Output-matching. This can detect if the inputs and the outputs of both service description of the requestor and of the provider match. If this is the case, then the ESB calls a DL inference engine, such as Pellet, in order to compare both electrical connector ontological definitions.

Figure 8. The second hierarchical representation of the connector classes and their definition

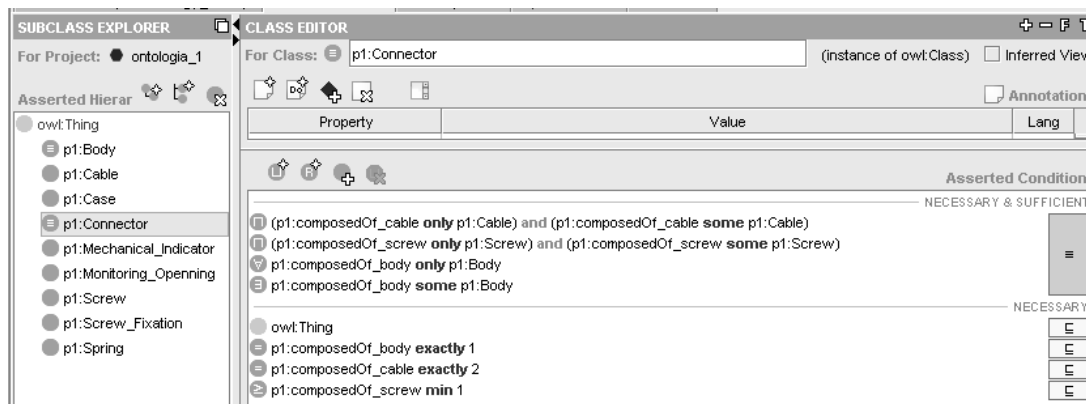


Figure 9. Display of the Pellet inference engine result

```
<!-- Service description of the service requestor, the civil engineering agent -->
<service:Service rdf:ID="ElecConnectorFinderService">
  <service:presents rdf:resource="#ElecConnectorFinderProfile"/>
  <service:describedBy rdf:resource="#ElecConnectorFinderProcess"/>
  <service:supports rdf:resource="#ElecConnectorFinderGrounding"/>
</service:Service>
<!-- Profile description -->
<Finder:ElecConnectorInfoService rdf:ID="ElecConnectorFinderProfile">
  <service:presentedBy rdf:resource="#ElecConnectorFinderService"/>
  <profile:serviceName xml:lang="en">ElecConnector Finder</profile:serviceName>
  <profile:textDescription xml:lang="en">This service looks for the
information of an Electrical Connector, the definition of which matches
information in the ontology.</profile:textDescription>
  <profile:hasInput rdf:resource="#ElecConnectorDefinition"/>
  <profile:hasOutput rdf:resource="#ElecConnectorInfo"/>
</ Finder:ElecConnectorInfoService > (...)
```

In this case, as shown in Figure 9, both electrical connector definitions are compared and no inconsistencies are detected by Pellet. Several parts of both connector definitions match, such as “conductor” and “cable”. This information is returned to the requestor service, the one of the agent in charge of the electrical plan of a civil engineering building.

FUTURE TRENDS

One future trend concerns the problem of dealing with incomplete and uncertain information about services and user preferences for service discovery. As so, approximated matching, applying for instance possibility and fuzzy theories, calls further investigation.

Another trend is related to other aspects a service consumer may take into account in order to decide for a provided service. All service aspects that are important to a service consumer in the decision process should be inputs of a reasoning process. For instance, the specification of the level of expected service during its term, *i.e.* the Service Level Agreement, should be part of a formal service description in order to be accounted for when matching service ontologies.

CONCLUSION

Overall, the main goal of representing Semantic Web Services is to enable automation of SOA tasks, including fostering Enterprise Applications Integration, and that is why we need ontologies of services and tools enabling to reason on service semantics. We review several semantic web services frameworks that intend to bring semantics to Web Services. We describe an example of product catalogue to detect if consumer and provided services match, where services are described in ontologies using OWL-DL and OWL-S. The semantic matching detection is logic-based.

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ENDNOTES

- 1 <http://www.w3.org/Submission/OWL-S>
- 2 <http://www.wsmo.org/TR/d16/d16.1/v0.21/20051005/>
- 3 <http://www.w3.org/TR/sawSDL/>
- 4 <http://www.w3.org/TR/2007/REC-sawSDL-20070828/#Example>
- 5 <http://www.w3.org/TR/2007/REC-sawSDL-20070828/#Terminology>

- 6 <http://lstdis.cs.uga.edu/projects/meteor-s/downloads/Lumina/>
- 7 <http://lstdis.cs.uga.edu/projects/meteor-s/downloads/index.php?page=1>
- 8 <http://www.wsmo.org/TR/d16/d16.1/v0.21/20051005/>
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- 12 <http://www.w3.org/Submission/2004/SUBM-OWL-S-20041122/#4>
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