The semantic side of Service-Oriented Architectures

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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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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.

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 during 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.

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.

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.

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.

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.

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-S[1] (Martin, Burstein & Hobbs, 2004) and Web Service Modelling Language, WSML[2] (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, SAWSDL[3] (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 section[4] 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 Lumina[6] and Radiant[7], both part of the METEOR-S project.

Web Service Modelling Language (WSML)

WSML[8] (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).

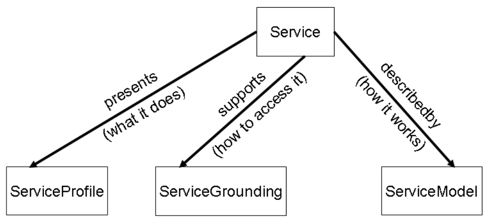
The Web Service Modelling Ontology (Roman, Lausen & Keller, 2004), WSMO uses the WSML as the underlying representation language. WSMO defines four main modelling components: ontologies, goals, services and mediators. WSMO goals represent the objectives of the service requester to be fulfilled when consulting 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, WSMX[9] (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 studio[10], WSML-DL and WSML-Rule reasoner and the WSML validator. For instance, the SUPER[11] 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.

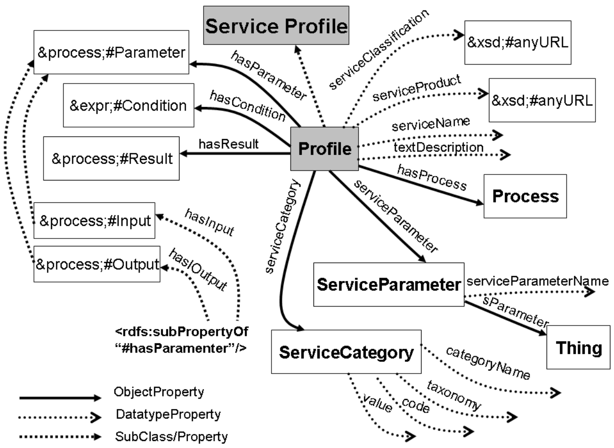
OWL-S consists in three parts: the *service profile*, the *process model* (captured by the *ServiceModel* class, Figure 1) and the *grounding* (through the *supports* property referring to the *ServiceGrounding* class, Figure 1). The service profile sets out what a service does and is used to advertise 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)



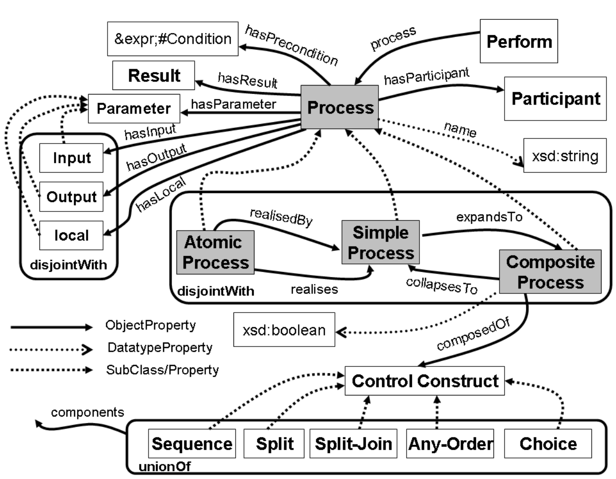
processes that are referenced in the profiles of the respective services.

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 API[13] and OWL-S service matchmakers, like OWLS-UDDI[14], OWLSM12[15] and OWLS-MX13[16], 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 WSML 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).

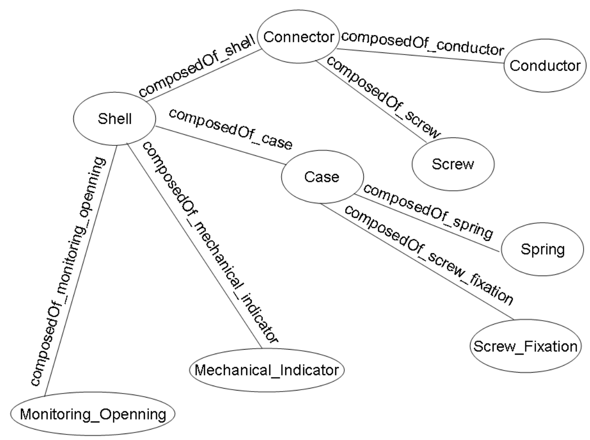
Currently, most Semantic Web Service matchmakers perform service profile rather than service process model matching. Service profile matching determines the semantic correspondence between services based on the description of their profiles. Semantic matching of service process models, in general, is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

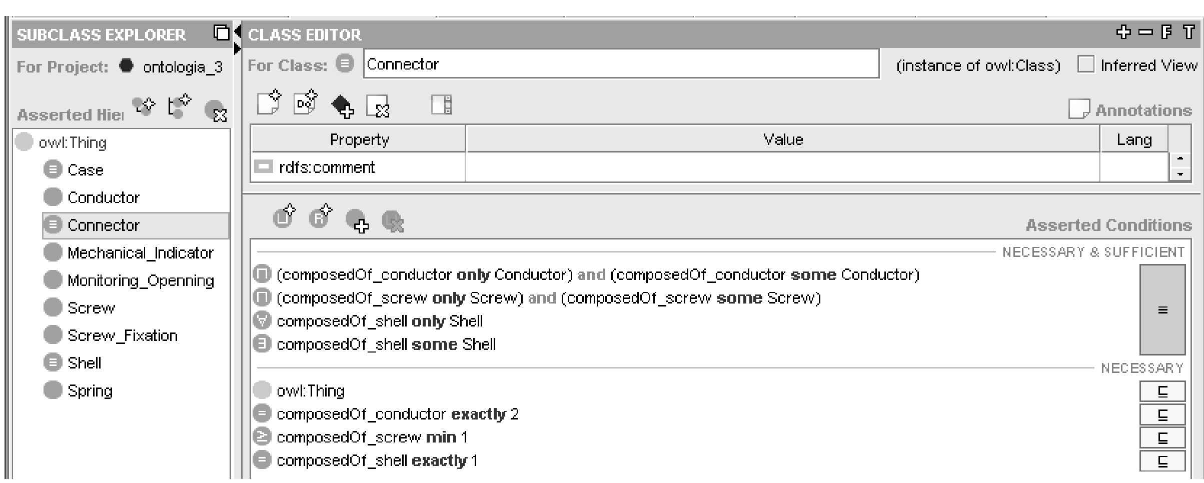
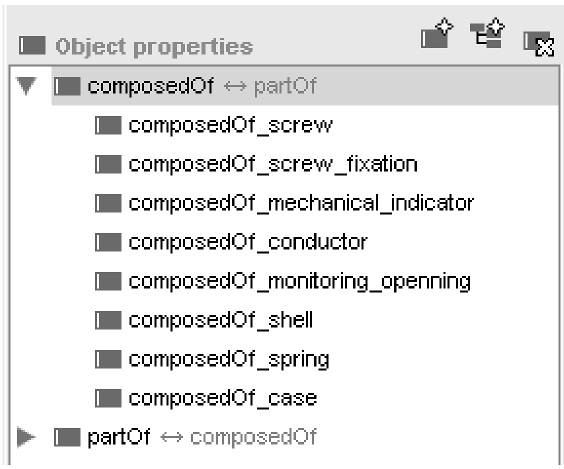


Figure 6. List of properties defined for the first connector product



1. ∀composedOf_conductor.Conductor ⊓ ∃ composedOf_conductor.Conductor
2. ∀composedOf_screw.Screw ⊓ ∃ composedOf_screw.Screw
3. ∀composedOf_shell.Shell ⊓ ∃ 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

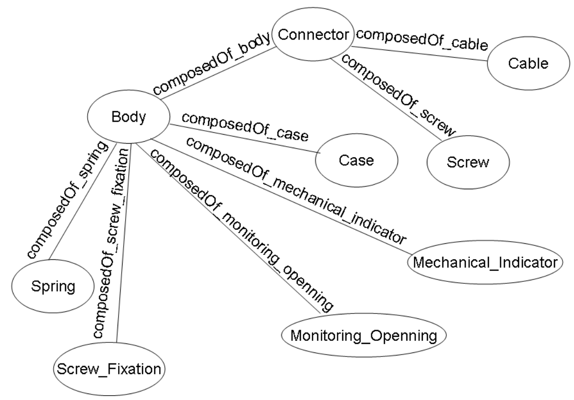


Figure 8 shows the necessary and sufficient definition, as shown in Protégé tool.

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

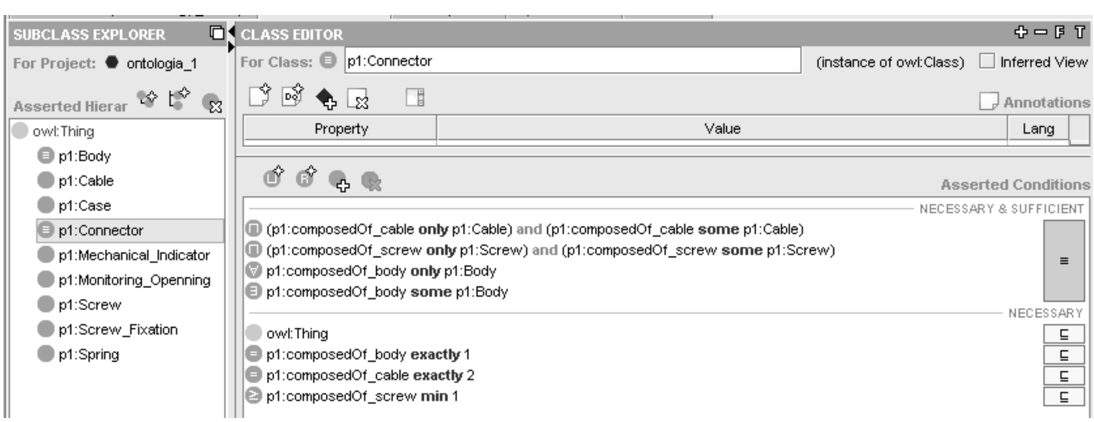


Figure 9. Display of the Pellet inference engine result

```
<!-- 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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Andreas Friesen is senior researcher and project manager at SAP Research. His research interests comprise for more than 4 years application of semantic technologies in software engineering. He is currently working on new technologies merging model-driven and ontology-driven software engineering methods. In this role he is shaping the vision of hybrid software engineering approach combining the benefits of the well established software modeling methodology with the expressive descriptive power of ontologies and logical reasoning and its application for SAP and partner ecosystem. Previously he was coordinating a project on semantic Business Process Fusion for heterogenious Enterprise Applications especially providing process-oriented interoperability solutions for cross-organizational application integration scenarios. Dr. Friesen is with SAP Research for over 4 years working on different research projects. He holds a Doctoral Degree from the University of Siegen and is author of around 30 articles and scientific papers.

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Spiros Alexakis studied Computer Science at the University of Karlsruhe and visited a post graduate course in Economics. After two years at SIEMENS he joined CAS Software in 1992 as a software engineer. In the following he became System Engineer and Project Manager. Since 1996 he is in the position of Director Innovation & Business Development, in charge of innovation management, business development and research. Spiros has collected extensive experience in management of research initiatives. He has co-ordinated over 20 international research projects, that have delivered successful and exploitable results. He has published a number of papers on collaborative working, customer relationship management and enterprise application integration. Spiros has been a member of the FUSION management board, in charge of the validation pilots.

András Balogh was born in Tatabánya, Hungary on 15 October 1981. He started his studies at the Faculty of Electrical Engineering and Informatics at the Budapest University of Technology and Economics. He took part in several competitions during his university years (most significant results: 1st place: IBM 48 Hours Programming Contest, 2nd place: University Scientific Conference). Andras was awarded several scholarships, Marie Curie Fellowship being one. He has published articles on a variety of topics. His focus is on technical rather than on scientific issues, and he is experienced in a wide range of current technologies and tools. In the context of FUSION, Andras has developed a graphical tool for (semantic) process design, and was involved in the use case planning and implementation.

Markus Bauer started his career in 1998 as researcher at the research group Programmstrukturen at Forschungszentrum Informatik (FZI) in Karlsruhe. In 2003, he became manager of the research group Programmstrukturen leading nine full-time researchers. During his time at FZI, his work was focused on software architecture, software reengineering and software quality. In 2005, he joined CAS Software AG, where he is now leading the development of the company's next generation CRM software and the underlying software platform. In the frame of FUSION Markus worked on the implementation of cross organisational business processes using semantic web services. Markus Bauer has received a PhD from Universität Karlsruhe for his work on the analysis of subsystem structures in object-oriented software systems. He published approx. 15 research papers on software architecture, software reengineering and software quality.

Veli Bicer has worked in various projects at all stages of software development life-cycle. He has extensive experience in Business Process Management Systems, Semantic Web Technologies, Web Services, Ontologies, P2P networks, Agent Technologies, e-Health systems and Trust and Security Services. He has worked on several IST projects, namely IST-1-002104-STP SATINE, IST-1-002103-STP Artemis, IST-027074-STP SAPHIRE and IST-02765-STP RIDE.

Thanassis Bouras holds a Diploma from the School of Electrical and Computer Engineering of the National Technical University of Athens (Greece). His Thesis was in the area of System Analysis and Design for Knowledge Management Applications. In the past, he has worked on several ATHOC (ATHENS 2004 Olympic Games) projects. During the last 5 years, he has participated as research engineer in several EC and National co-funded projects in the areas of knowledge management (INKASS), business and semantic interoperability (FUSION, COMMIUS), assisted and independent living (SOPRANO) and e-learning (ELEVATE). He is currently a research engineer at the Institute of Communication and Computer Systems of NTUA. His current research interests include the emerging semantic web and business (re-) engineering of media that support knowledge distribution and transfer in an intra- and inter- organizational level and web services that implement e-Business and e-Government applications.

Stijn Christiaens is a researcher at the Semantics Technology and Applications Research Laboratory (STARLab) at the Vrije Universiteit Brussel in Brussels, Belgium. He is currently working on theories, methods and tools to support ontology creation and maintenance at the domain expert level.

Asuman Dogac is full professor in the Department of Computer Engineering of Middle East Technical University (METU). She is also the founder & director of Software Research and Development Center, METU and the general manager of the SRDC Ltd. Her expertise includes Internet Computing, semantic Web, agent technology, interoperability, e-Business, and eHealth. She has been consulting the industry and government organizations. In 2004, Dr. Dogac received IBM (USA) Faculty award. She is also the recipient of several local awards: 1991 Mustafa Parlar Research Award, 1994 Husamettin Tugac Research Award, 1999 METU Achievement Award, 2000 METU Tarik Somer Superior Achievement award, 2000 Mustafa Parlar Science award and 2001 Tarik Somer award. She has published more than 100 papers in refereed international conferences and journals including Communications of the ACM, IEEE Transactions on Software Engineering, IEEE Transactions on Information Technology in Biomedicine, Information Systems Journal (Elsevier), Journal of Parallel and Distributed Databases and the ACM Computing Surveys.

Marwane El Kharbili is working in the ARIS research department of IDS Scheer AG, working on IDS Scheer's business rules management solution for business process management (BPM). As part of his research activities, Marwane is involved in various research projects, such as the European project SUPER (www.ip-super.org). Marwane is also a PhD student currently working on his thesis tackling semantic compliance management issues in BPM. His topics of interest are business rule management, business process management, semantic web, compliance management, and complex event processing. Marwane has an engineering degree (Diplom-Inform. Eq. Master) from the university of Karlsruhe in Germany and a Masters degree of engineering (ingenieur informatique) from the ENSIMAG school of applied mathematics and informatics at the Grenoble INP university in France.

Catarina Ferreira da Silva is currently a post-doc research assistant at the Centre for Informatics and Systems of the University of Coimbra (CISUC) within the Information Systems Group. Previously she was a teaching and research assistant in computer science department of University of Lyon I and in the collaborative Information Systems research team of LIRIS UMR 5205 lab (Laboratory of Computer Graphics, Image and Information Systems). She holds a Ph.D. (2007) from the University of Lyon 1 and a M.Sc. (2003) from the French Institute of Applied Science (INSA) of Lyon, both in computer science. Her main research interests are Semantic Interoperability, Semantic Web, Information Systems Interoperability, Knowledge Representation and Reasoning.

Klaus Fischer is DFKI Research Fellow and head of the Multiagent System (MAS) Research Group at DFKI. He holds a diploma and doctoral degree from Technische Universität (TU) in München. In 1992 he joined the MAS Research Group at DFKI in Saarbrücken and assumed the responsibility of group leader in November 1993. He is deputy head of the department of Agents and Simulated Reality. In his work he has a long record of successfully managed projects for industrial partners as well as for public authorities.

Veronica Gacitua is a postgraduate research student at the School of Computing at Dublin City University. Previously, she has worked as an enterprise architect in a large size mining company for three years. The main projects during this period encompassed the creation of an architectural instrument to support IT planning within the company, and the initialisation of a long-term enterprise applications architecture migration project. The support to IT planning has been provided through the initial and incremental development of an enterprise architecture that relates IT assets, business processes and organizational units of the company. The architectural migration has considered the migration from a heterogeneous enterprise applications architecture toward a service-oriented architecture. She has graduated in Electronic Engineering and obtained a master degree in Electronic Engineering from the Universidad Técnica Federico Santa Maria, Chile.

Parisa Ghodous is currently full professor in computer science department of University of Lyon I. She is head of collaborative Information Systems team of LIRIS UMR 5205 (Laboratory of Computer Graphics, Images and Information Systems). Her research expertise is in the following areas: Interoperability, Semantic Web, Web services, Collaborative modeling, Product data exchange and modeling and Standards. She is in editorial boards of CERA, ICAE and IJAM journals and in the committees of many relevant international associations such as concurrent engineering, ISPE, Interoperability.

Panagiotis Gouvas graduated in 2004 from the School of Electrical and Computer Engineering of the National Technical University of Athens (NTUA). His Diploma Thesis was in the area of Mobile and Personal Communications (Location Based Services in Wireless LANs). During 2001-2009 period, he participated as software and research engineer in several research ICT, IST and e-Contect projects. At present, he is a PhD candidate in the School of Electrical & Computer Engineering at NTUA, as well as, a research associate in the Institute of Communication and Computer Systems of NTUA. His research interests lie in the field of Multi-Agent systems, Service Oriented Architectures, Knowledge Representation and Management, Semantic Web and Grid-based architectures.

Christian Hahn is a research scientist at the MAS research group at DFKI. He holds a Diploma in computer science from the University of Saarbrücken in 2004. He has been doing research and development on agent-based systems, model-driven systems engineering, and software development methodologies the last 4 years. He has experience from a number of IST projects including ATHENA and INTEROP in FP6, and SHAPE in FP7.

Yildiray Kabak has been working as a software engineer for research and industrial projects in eBusiness and eHealth domains since year 2000. Yildiray Kabak has extensive expertise on Internet Computing, Semantic Web Technologies, Agent Technology, Interoperability, e-Business, e-Health and IT Security & Privacy. Yildiray is a PhD candidate in METU Computer Engineering Department. He has developed middleware applications for eHealth and tourism systems including a ebXML and web based framework for the testing of Integrating Healthcare Enterprise (IHE) Profiles. He also has worked on several IST projects, namely IST-2000-26429 HERMES, IST-2000-31050 AgentAcademy, IST-2000-31046 HUMANTEC, IST-1999-20216 LEVER, INCO DC 97 2496 MARIFlow, MEDFORIST, IST-1-002104-STP SATINE, IST-1-002103-STP Artemis, IST-027074-STP SAPHIRE, IST-02765-STP RIDE, IST-213031 iSURF and IST-027306 ABILITIES.

Akos Kiss studied Electrical and Computer Engineering at Budapest University of Technology and Economics. Since September 2006 he is working as Java Developer and Project Manager at InfomatiX Ltd. In the frame of FUSION, he has developed the integration between CRM systems and HR databases.

Dimitrios Kourtesis is a Research Associate at the South East European Research Centre (SEERC) in Thessaloniki, Greece, and a PhD candidate in the Department of Computer Science at the University of Sheffield. He holds an MSc (Distinction) in Software Engineering and Telecommunications, and a BSc (Hons) in Computer Science, both from the University of Sheffield. His research interests are in the areas of Service Oriented Computing and Semantic Web Technologies, and he has worked in a number of research projects related to these areas. He is a professional member of the British Computer Society (BCS).

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Jens Lemcke is both a Research Associate at SAP Research in Karlsruhe and an external Ph.D. student at the Forschungszentrum Informatik (FZI), where he is supervised by Prof. Rudi Studer. Jens' Ph.D. topic is scalable, ontological EAI and e-business integration. Prior to joining SAP, Jens received his Diploma in Computer Science from the University of Rostock. During his studies at Rostock University, Jens did an internship at the IBM Silicon Valley Lab in California, USA. While at SAP Research, Jens has contributed to the EU-funded research projects: DIP, FUSION, and MOST. Part of his time at SAP was also spent at the SAP Labs in Palo Alto, USA, where he collaborated with the Stanford Logic Group in the POEM project.

Aggelos Liapis is a senior researcher currently working on a Marie Curie supported programme at Vrije Universiteit Brussel, Brussels. He is a computer scientist whose particular specialism is the development of computer supported collaborative environments, semantics, ontologies, and computer graphics. While doing his PhD in Computer Mediated Collaborative Design Environments at The Robert Gordon University, Aberdeen, Scotland he developed a prototype collaborative environment focused to assist professional product designers when distributed during the early stages of the design process.

Cristina Martinez has a background in Science Philosophy (Cum laude), in Communication (Cum Laude and Major) and has an MSc in Telematics (Cum Laude) from the Université Libre de Bruxelles. She started her career with the United Nations working for an IT track and trace development project for Africa, Asia and Latin-America. She joined the Andersen Consulting company in 1998 to work for the eCommerce group of the Technology department as a solutions engineer. She became a member of the staff of the European Commission in 2002 and is currently Administrator for Research in the Enterprise Networking and RFID Unit of the Information Society and Media Directorate-General. In addition to her responsibility for research projects in the ICT area, she devotes part of her time on policy aspects related to the future of Business Collaboration and Interoperability. She is head of the Future Internet Enterprise Systems cluster responsible for giving research directions in the Enterprise Interoperability and Collaboration domain. Cristina Martinez is married and has two children.

Paulo Melo is an Assistant Professor in the Faculty of Economics of the University of Coimbra. He has received a B.Sc. in Computer Science (1990), a M.Sc. in Systems and Automation (1996) and a Ph.D. in Business Management (2006) from the University of Coimbra. He has been working in Research and Development for the last two decades, in management, research and support roles. He has articles published in several international journals and conference proceedings in Operations Research, Group Decision Support and Management.

George Milis is an experienced senior IT Consultant and Analyst and possesses an MSc in Advanced Computing with specialization in Artificial Intelligence from the Department of Computing, Imperial College London, and a Diploma from the Aristotle University of Thessaloniki, Greece, in Electrical and Computing Engineering. George is currently working as a Consultant and Project Manager at European Dynamics SA. He has contributed in many European research projects, as well as, commercial projects addressing real needs of the public sector. He poses great experience in project quality assurance and quality control, preparation of documentation, and design of advance software solutions. George also participates and contributes in many conferences and workshops, presenting and discussing new ideas according to the European research agenda. He is currently dedicated to the advancement of IT solutions in a way to become easily and efficiently adoptable by the foreseen end-users communities.

Mehmet Olduz received his MSc Degree from the Department of Computer Engineering at Middle East Technical University. He is senior software engineer at SRDC Limited where he has worked in various projects at all stages of software development life-cycle. He has extensive experience in Business Process Management Systems, Semantic Web Technologies, Web Services, Ontologies, P2P networks, Agent Technologies, e-Health systems and Trust and Security Services. He is recently working on industrial applications of high-performance computing and networking, and is one of the architects of tourism and eHealth solutions. He has worked on several IST projects, namely IST-1-002104-STP SATINE, IST-1-002103-STP Artemis, IST-027074-STP SAPHIRE, IST-213031 iSURF and IST-02765-STP RIDE.

Claus Pahl is a Senior Lecturer at Dublin City University's School of Computing, where he is the leader of the Software and Systems Engineering group. Claus has graduated from the Technical University of Braunschweig and has obtained a PhD from the University of Dortmund. He has published more than 170 papers in various journals, books, conference, and workshop proceedings. He is on the editorial board of the four journals and is a regular reviewer for journals and conferences in the area of Web and Software technologies and their applications. He is the principal investigator of several basic and applied research projects in software engineering. Claus' research interests cover a broad spectrum from service- and component technologies in software engineering to infrastructure and development technologies for Web applications such as e-business and e-learning.

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Nikola Radic is a senior Java software developer and analyst at European Dynamics SA, Athens, Greece. His major title is MSc in electronics and telecommunications with the emphasis on design of digital electronic systems. In the last 10 years he was actively working on many IST projects and leading many commercial ones, using the latest cutting-edge technologies. He is always looking for challenges and way to improve his knowledge and experience with the new technologies. His currently one of the leading software engineers at European Dynamics responsible for development and management of several EU enterprise applications.

Pawel Rubach earned an MSc degree in 2003 from the Warsaw School of Economics, where he specialized in Information Systems and Applied Computer Science. Since 2003, he has been employed at the Warsaw School of Economics where he participated in many research projects, the largest of them focusing on Computer-Based Assessment. He gathered also practical experience while working as a systems administrator, application architect, systems analyst, project manager, and IT architect in different environments, ranging from small IT solution providers to large corporations such as the PKO BP S.A. (the largest Polish bank). In the years 2007-2008 as IT Architect at the Polish Telecom, Research & Development Branch (TP R&D), he contributed to two EU-sponsored projects: SUPER (http://www.ip-super.org) and SPICE (http://www.ist-spice.org). He spent the academic year 2008-2009 working on his Ph.D. as a Fulbright Visiting Scholar at Texas Tech University in Lubbock, Texas.

Paulo Rupino da Cunha is an Assistant Professor at the University of Coimbra and the head of its Information Systems Group. He is a Visiting Associate at Brunel University, UK. He holds a Ph.D. and a M.Sc. in Informatics Engineering - Information Systems. His main research interests are Information Systems Design, Quality Management and Information Systems, Business Models and Strategy, and IT governance issues. For two terms he was the Vice-President of Instituto Pedro Nunes, an Innovation and Technology Transfer organization providing specialized consulting, training and business incubation. For a period of three years, he was the elected Coordinator of the Informatics Engineering Chapter for the centre region of Portugal of the Portuguese Engineering Association, and for a two year term he was a member of the Executive Committee of the Department of Informatics Engineering of the University of Coimbra.

Gérald Santucci has been working in the Information Society and Media Directorate-General of the European Commission since February 1986. In March 2007, he was appointed Head of the Unit Networked Enterprise & Radio Frequency Identification (RFID). The adoption by the European Commission, in March 2007, of a Communication on RFID has constituted a first milestone towards the achievement of a European policy framework regarding RFID. Work underway includes the follow-up of a Recommendation on the implementation of privacy and information security principles in RFID-enabled applications (adopted by the EC on 11 May 2009) and a new series of global consultations on the Internet of Things. Over the years, Mr Santucci has gained extensive experience in the activities of the Directorate-General through his involvement in research management, including heading the Unit

“Applications relating to Administrations” (i.e. eGovernment) 1999-2002, the Unit “Trust and Security” 2003, and “ICT for Enterprise Networking” 2004-2006. Mr Santucci was also the “father” of the AIM exploratory action (Advanced Informatics in Medicine), launched in 1989 under the RACE programme (R&D on Advanced Communications Technologies for Europe).

Christian Stamber is working as a Software Developer for SAP AG, Germany. He holds an engineering degree (Dipl.-Inf., comparable to M.Sc. in Computer Science) from University of Kaiserslautern, Germany. His diploma thesis was aligned to the European research project SUPER (www.ip-super.org) in cooperation with IDS Scheer AG. Christian researched how to use semantic technologies in business process management. The insights gained during accomplishment of the thesis were part of additional scientific publications.

Sebastian Stein is responsible at IDS Scheer, Germany for developing and maintaining the ARIS SOA modelling method. Besides, he is involved in standardisation efforts at OMG and OASIS. He participates in the BPMN standardisation process and he is an author of OMG’s OCEB certification program. Besides those tasks, Sebastian contributes to different public research projects within ARIS Research like the SUPER project. He focuses on integrating business process management (BPM) and service oriented architectures (SOA). He has published several scientific and popular papers. Besides his work assignments, Sebastian is currently finishing his PhD thesis at University of Kiel, Germany. He holds a Master of Science in Software Engineering from Blekinge Institute of Technology, Sweden and a diploma in Business Information Systems from University of Applied Sciences Dresden, Germany.

Tuncay Namli has extensive expertise on context management and IT Security and Privacy in IT systems. He has developed privacy and security applications in eHealth systems. Furthermore, he has worked on several IST projects, namely IST-1-002104-STP SATINE, IST-1-002103-STP Artemis, IST-027074-STP SAPHIRE, IST-02765-STP RIDE, IST-213031 iSURF and IST-027306 ABILITIES. Tuncay is a PhD candidate in METU Computer Engineering Department.

Ingo Zinnikus graduated from Saarland University, Germany in 1998 and is since then working for DFKI. He has been working on the application of multiagent systems for a number of topics such as logistics, recommendation systems and business process execution. Besides numerous publications he has contributed to a number of successful national and European proposals. He served as program committee member for a number of international workshops. Fields of Interest: Multiagent systems, service-oriented architectures and Semantic Web services. Experience with projects: the German government funded project TeleTruck, the EU funded projects SAID (FP5), VITAL (FP6, Technical Coordination), ATHENA (FP 6), and COIN (FP7), as well as domestic industry projects in German.

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