A Survey on Workflow Annotation & Composition Approaches

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Abstract: Efficient business processes are key to economic success. With the need to frequently adapt or restructure business processes and workflows in a dynamic market, agile processes and (semi-)automatic workflow and process composition would be useful. Currently, this is a manual and time-consuming task. Automating and optimizing this task is of high interest in research communities. Nevertheless, the orientation differs: Some focus on semantic web services, others on Grid workflows or concentrate on business process management. In this paper we present a survey of available workflow annotation and composition approaches in all of these areas. We additionally categorize and compare them and describe future work.

1 Introduction

In times of dynamic shifting markets, companies, especially those integrated in electronic supply chains, have to adapt or even restructure their business processes frequently. In the last years more and more companies apply the service-oriented approach (SOA) to obtain highly flexible and agile business processes. Using e.g. web services ensures loosely coupled components and hence enables a faster reaction to new business requirements. But still, these changes need to be done manually. However, in the research community there are several attempts to (semi-)automatic workflow composition.

Firstly, the tasks in a workflow have to be annotated with semantic information. Semantic annotation is mostly proposed in literature to annotate documents and web pages. In *Merriam-Webster online* it is defined as “(1) a note added by way of comment or explanation and (2) the act of annotating”. Similarly, Euzenat [1] formalized semantic annotation in the context of the Semantic Web: from two sets of objects, documents and formal representations, two functions can be created: a function from document to formal representations, called annotation and a function from formal representations to documents called index. The corresponding activities are annotation and indexing. Anotation can take place in a descriptive way (plain text) or in a formal way using an underlying logic. The semantic annotation can either be embedded in the workflow itself or can exist as an ontology outside the workflow (e.g. using the TOVE-ontologies [2]).

In: M. Hepp, K. Hinkelmann, D. Karagiannis, R. Klein, N. Stojanovic (eds.): Semantic Business Process and Product Lifecycle Management. Proceedings of the Workshop SBPM 2007, Innsbruck, April 7, 2007, CEUR Workshop Proceedings, ISSN 1613-0073, online CEUR-WS.org/Vol-251/

Automatic workflow composition can enhance workflow reuse and workflow repurposing. According to [3] workflow reuse enables the sharing of workflows by a community as best practices and reduces workflow authoring time, improve the quality and experimental provenance (in e-Science). In workflow repurposing user take workflow fragments that are close enough to be the basis for a new workflow and make small changes to its structure to fit to a new purpose (customizing). Workflow composition can be done with semantic annotated process actions which are annotated with concepts of an ontology and which are then composed to a complete workflow according to a specified goal (Figure 1 shows a small example of a travel expense process).

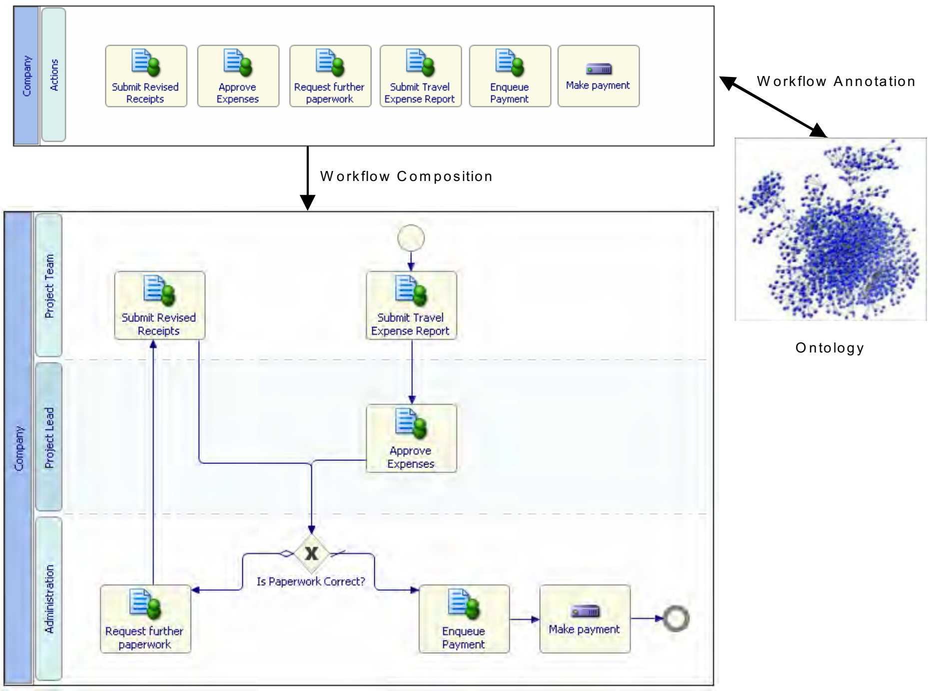

Figure 1: Correlation between workflow annotation and composition

Therefore, to get a deeper understanding of the different research areas as well as on differences and similarities, we describe in this paper the most significant approaches or projects for annotation and composition in the domains business process management, web service and Grid computing and compare them according to predefined requirements. Business process management focuses more on high level processes whereas web services and Grid computing are more concerned with the technical details of processes.

This paper is organized as follows: section 2 gives a short overview about the different domains web services, semantic web, Grid computing and business process management and describes ongoing projects which are going to combine these areas and cover aspects like process annotation or composition. In section 3 we describe the requirements which are used to compare the different approaches. In section 4 and 5 we introduce existing workflow annotation and composition methods. We show a comparison of these approaches in section 6 and describe further research in 7.

2 Workflow in web services, business processes and Grids

Workflow has been defined as "the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules." [4]. Business Process Management and workflow are seen as essentially the same, albeit with some differences on emphasis [5]. The same can be said for web services or grid services. A business process describes the actions of an enterprise without any technical information. A workflow might include some technical information, but can still be platform independent. Web services and Grid already describe the platform which is used and all technical information for the invocation. Henceforth, we use the concept 'workflow' as collective term for business processes and the orchestration of web and Grid services.

Workflow composition consists of those activities required to combine and link existing workflow fragments and other components to create new processes. This definition is similar for service composition [6] and for Grid workflow composition. However, the automatic composition of application components is challenging, because it is difficult to capture the functionality of components and data types used by the components [7]. That is where the semantic web community comes into play.

Based on the vision described e.g. in [8] and [9] that the usage of ontologies and semantic web standards can extraordinarily improve current business processes, several projects have been launched to combine research areas like business process management and semantic web & web services.

In EU-funded projects like SUPER (http://www.ip-super.org/) and FUSION (http://www.fusionweb.org/fusion) the consortia aim at the development of innovative approaches for business process management using semantic web standards. Methodologies and integration mechanisms for the semantic integration of heterogeneous sets of business applications, platforms and languages should just as well be developed as business process mediation frameworks including semantic business process modelling environments. These projects are in an initial state and there are no deliverables on the topic of workflow annotation or composition available yet, but they show the importance of the usage of semantic information in workflows. SUPER is based on the DIP project, where the interoperability between workflows and ontologies has already been analysed [10].

ASTRO (http://astroproject.org/) supports the composition of distributed business processes for the entire business process lifecycle. The partners create an automated synthesis of composite web services using BPEL4WS in [11]. They import abstract BPEL4WS processes and generate a composite process using the planner MBP. However, their approach is only based on a syntactical level and semantic annotations are not yet considered at the time of this survey.

Many projects in the grid research area focus on business services and workflow aspects. Some of them have developed languages and composition algorithms which will be explained in the next sections in more detail.

3 Requirements for Annotation and Composition approaches

To give a more detailed overview about each described method and language, we categorize them and compare each approach in the following aspects:

- Language: Which underlying (proprietary) language has been used: was an own language developed or were existing languages adapted and extended?
- Application domain: The focus of the approach is specified. Does the language concentrate on web services only, on grid services or is it mainly focused on business processes?
- Semantics: Are semantic annotations possible and does the language directly or indirectly support ontologies? Thereby it does not matter which language the ontologies have (RDF, OWL, WSML, etc.).
- Annot./Comp.: Is the focus of the approach more on annotation, composition, does it consider both or none of them? Some languages are simply designed to annotate existing standards (e.g. WSDL-S) and might additionally be used to automate a composition, but this is not included in the approach itself.
- Hierarchical: details whether a hierarchical decomposition of activities is possible. This hierarchical decomposition includes workflow views, abstraction levels and visibility of processes and activities.
- Research vs. industrial: Has the approach been developed in the research community or is it an industrial standard?

According to [12] there are 5 key workflow aspects which are widely recognised as essential workflow characteristics: functional, behavioural, informational, organisational and operational aspects. These will be used to differentiate the web service, grid service and business process approaches, too.

- Functional: describes whether the functional aspects like inputs, outputs, preconditions and effects of a service / process are included or not. Each service or process can be annotated with functional attributes to describe the functionality, the state of the world before or after execution and the information space before or after its execution.
- Behavioural: describes the *control flow* and shows whether simple or more complex workflow patterns [13] have been considered in the design of the language. These are, e.g., sequence, parallel split, synchronization for simple workflow patterns or arbitrary cycles, discriminator or deferred choice for complex workflow patterns.
- Informational: The informational aspect is defined by the *data* and *data flow* perspective. The three basic modelling elements are parameters, variables and the data flow itself. This includes type definitions and data passing.
- Organisational: characterizes whether the organization structure of a company can be recorded using the language or not and who is responsible for specific tasks in a workflow.

- Operational: The operational aspect is defined by the workflow application perspective. It depicts e.g. whether different invocation methods and styles are offered (like Web Services, Java objects, WSRF, etc.), how the coupling is defined, whether user interaction is required, etc.

4 Workflow Annotation

There are several workflow annotation methods: Semantic-annotated web services are simply called semantic web services; there are several semantic grid workflow language approaches and there already exist first attempts for the annotation of business process models.

4.1 Web Service Annotation / Semantic Web Services

For orchestrating web services the de-facto standard WS-BPEL [14] can be used. Pistore et al. [15] show an approach to annotate the syntactical BPEL-constructs with semantic information. Analogue the underlying web service description language (WSDL) has been enhanced with semantic descriptions in WSDL-S [16] as well as in SAWSDL [17]. OWL-S [18] on the other side stores the semantic information into a new file, but has a clearly defined grounding to the WSDL-file. SWSF [19] extends OWL-S to first-order logic to accomplish more complex statements. One of the most prominent approaches especially in European countries, WSMO [20], has four main elements: ontologies, goals, web services and mediators.

All these approaches are based on overlapping logics: OWL builds on description logics; SWSF extends this to a first-order logic and WSMO in the direction of Logic Programming. A more detailed description about these standards is out of the scope of this paper and can be found in [21].

4.2 Business Process Annotation

Business process models are widely common to capture the workflow of key processes in companies. Therefore, several graphical notations are available: some use the business process modeling notation (BPMN) which is based on the business process definition meta-model (BPDM), Event-driven process chains (EPCs), simple Petri nets or even UML activity diagrams. To execute a business process one can either use languages like XPDL [22] or do it manually. There are currently first efforts to annotate these languages (the graphical as well as the XML-based languages) with semantic information:

In [23] a proposal to annotate EPCs with semantics (sEPC) is presented which includes four instances of ontologies named Business Ontology, Business Process Concepts, sEPC model and the underlying EPC model. We outlined in [24] that activity diagrams can be annotated with inputs, outputs, preconditions and effects (functional semantics) to start an automatic synthesis of business process fragments. In [25] business processes are modeled using Petri-nets and are aligned with domain ontologies using similarity computation and aggregation. [26] developed a multi meta-model process ontology (m3po) to relate choreographies to workflow models. In the context of the SUPER project several ontologies for different languages such as BPMN, BPEL, EPC, etc. are proposed to cover not only behavioural aspects, but also organisational, functional or data perspectives [27].

4.3 Grid Service Annotation

Several EU-funded Grid projects focus the annotation of Grid workflows and developed new languages for semantic workflow management.

The Akogrimo (Advanced knowledge through the Grid in a mobile world) project is realising a reference architecture and framework that allows the creation of mobile dynamic virtual organizations in a grid infrastructure to bring together the market orientation and pervasiveness of mobile communication technology in everyday life. It aims to develop languages for the semantic description of resources and workflows. However, at the current stage it only uses syntactic BPEL4WS-constructs and composes services based on keyword search.

In the context of the NextGRID project a semantic workflow language is developed which supports managing both low level (concrete) and high level (abstract) workflows. The grid workflow enactment can cope with dynamic insertion of arbitrary business processes at run-time. Therefore, a language model, based on an OWL-S extension was defined as well as composition and substitution rules for services and workflows (incl. a formal representation). This language is called OWL-WS (OWL for Workflow and Services) and includes (additionally to OWL-S) concrete services and workflows whereby composite processes are used for modelling workflows that are not only intra- but also inter-service processes [28].

The K-Wf Grid (Knowledge-based Workflow System for Grid Applications) project introduces a Grid workflow description language (GWorkflowDL) based on high-level Petri nets and XML and focuses additionally on Grid workflow orchestration and a semi-automatic mapping of abstract workflows onto concrete Grid services. GWorkflowDL includes properties to point to external semantic descriptions as e.g. in an ontology.

In OntoGrid a framework for annotating, discovering and composing semantic grid services in a (semi)automatic way was developed. This includes a virtual organization ontology, a semantic grid service ontology, a problem-solving method (PSM) description ontology (functional attributes) and knowledge representation and data types ontologies. The semantic grid service ontology consists of a profile (non-functional attributes), a model (relationship with the PSM ontology) and the description of the choreography.

The Taverna workbench, developed in the myGrid project (www.mygrid.org.uk), allows users to construct complex analysis workflows based on the workflow language SCUFL (Simple Conceptual Unified Flow Language) whereby ‘workflow’ is defined here as the specification and execution of ad-hoc in-silico experiments. The offered services are distinguished in domain services which perform scientific functions and services which are created during workflow design and execution. These services can be found using the Feta Semantic Discovery tool which compares input and output parameters and the function of services and assists the workflow design [29].

The SIMDAT project enhances the SCUFL-language to a BPEL4WS-based workflow language named XScufl/Freefluo which describes the control and data flow. A composition is made using abstract services. After the service matchmaking process has finished the concrete OWL-S services need to be discovered [30].

5 Workflow Composition

Similar to workflow annotation, again, there are three different research areas focusing on the topic workflow composition: web service composition, business process composition and grid service composition.

5.1 Web Service Composition

Web Service Composition can be divided in two main parts: static composition and dynamic composition. Static composition includes orchestration (one service orchestrating the others) and choreography (each service describes its interactions). For modeling orchestration and composition different languages have been developed (e.g. WS-BPEL or WS-CDL [31]). While there are first approaches to automatically generate static compositions [32], most of web service composition approaches rely on dynamic composition using semantic annotations.

Trying to fulfil all requirements for an automated service composition (as e.g. described in [33] or [34]), most of the algorithms only create one path to reach the goal – neglecting that there would be other paths interesting for the whole business process, too.

Web service composition can be performed agent-based (as in [35] or [36]), based on interaction protocols [37], symbolic transition systems [38] or some other kind of logic (e.g. temporal action logic [39] or linear logic [40]).

In [41] a heuristic search algorithm for automated Web Service composition is presented. It enhances current heuristic search algorithms and solves shortcomings such as missing parallel and alternative control (XOR) flows, the creation of new variables and support of non-determinism. A service is described as discrete business functionality in a technical way and the enforced hill-climbing algorithm (which is a forward heuristic breadth-first search in state space) is extended. The heuristic function is adapted to calculate the length of the generated composition. Therefore, the used planning graph consists of two kinds of nodes: fact nodes (represent literals from states) and activity nodes (represent service invocations) and can be grouped in layers. The heuristic function counts the number of activity layers which include parallel and alternative service invocations.

The semantic web community has used planning techniques to address the problem of automated composition of semantic web services, e.g. based on OWL-S descriptions of inputs output, preconditions and effects. In [42] SHOP2, a hierarchical task network (HTN) planner, is employed for Web Service composition. The HTN planner creates plans by task decomposition. Given a list of tasks that have to be achieved and a set of Web Services that accomplish these tasks and are described as atomic, simple or composite processes in OWL-S, the planner builds a plan representing an ordered sequence of Web Services that need to be executed. Thus, the main idea of the authors is that task decomposition is very similar to the concept of process decomposition in OWL-S and therefore is suited for automatic Web Service composition. For this purpose OWL-S process descriptions are transformed to a SHOP2 domain. SHOP2 is then used to build a plan, which afterwards is transferred back to an OWL-S description of an executable (composite) process. As an example the authors describe the composition of a Web Service for the planning of a medical investigation out of other Web Services that e.g. make appointments for single medical treatments.

A more detailed description about other approaches and an overview about the mentioned web service composition approaches can for example be found in [43].

5.2 Business Process Composition

Several synthesis (or composition) algorithms for business processes have been proposed using different graphical notations: In [44] business processes are modeled using Petri-nets and are annotated with domain ontologies using similarity computation and aggregation. The similarity can be measured using syntactical, linguistical and structural differences as further outlined in [45]. This method presumes that there is a repository where all business processes have been stored: the synthesis combines (existing) process chains rather than single actions. In [46] cross-organizational business processes are automatically generated using the SAP Enterprise Service Architecture. Therefore, message elements and domain ontologies are aligned, each process is semantically annotated and possible mappings are generated.

5.3 Grid Service / Grid Workflow Composition

Most of the Grid research projects described above offer not only the possibility to annotate Grid workflows, but also to make a (semi-)automatic composition of workflows. E.g. Akogrimo defines languages for the semantic description of resources and workflows in order to define complex Grid services by composing existing Grid services. A workflow manager service translates a business process in an orchestrated composition of simple and complex services whereby “extensions of BPEL4WS seemed to be most promising” [46]. At the current stage no semantic annotation is included and the search for BPEL templates which correspond to the Business Process is just based on simple keyword search. In the future, semantic annotations in Akogrimo will probably be written in semantic languages such as OWL-S [47].

The ODESGS environment of the OntoGrid project facilitates the handling of large numbers of semantic Grid services by means of its (semi-)automatic discovery in the composition of new ones. It uses problem-solving methods (PSM) and ontologies for describing grid services in a formal and explicit way. The PSM description ontology contains a profile, a model and choreography. The ontology for the description of the PSM is based on the Unified Problem-Solving Method Language (UPML) and enables the PSM to automatically compose new grid workflows [48].

A more detailed overview is out of the scope of this paper. For taxonomies of workflow management systems and composition algorithms for Grid computing, please refer to [7].

6 Comparison of existing approaches

Table 1 shows a categorization and comparison of the mentioned approaches in the beginning of 2007. The attempts are categorized in their application domain: Web Service (WS), Grid or Business Process (BP) focus. 'I' notes that it is an industrial standard, 'R' an academic approach (research) and 'RI' that people both from research labs as well as from industry have been involved. The table depicts whether semantic information is directly included ('+'), not covered at all ('-') or whether there is simply a link to existing ontologies ('±'). The table shows whether the approach focuses on annotation only ('A'), on composition only ('C'), covers both ('AC') or none at all ('-'). It describes whether there is an abstraction level ('±'), no abstraction at all ('-'), whether it is not stated in any document we found ('?') or it includes workflow views, abstraction levels and visibility of processes and activities ('+'). The functional aspect indicates whether inputs and outputs are outlined ('±') or preconditions and effects are also included ('+'). In the behavioural column simple control flow ('±') or more advanced control patterns ('+') or no flow ('-') are represented. The informational aspect demonstrates whether data, type and variable definition is possible ('+') or not included in the standard ('-'). Organizational aspects like the hierarchy in a company are either included ('+') or not ('-'). The operational column shows whether at least one invocation style ('±') or different ('+') are offered.

7 Conclusions and further work

As one can see, none of the approaches fulfils all requirements completely and is constructed for annotation and composition similarly.

Especially the organizational perspective is often neglected, but this is an important aspect for queries and reasoning on responsibilities and workload of employees. Most of the approaches come from research organizations or research projects and support functional and behavioural information. The informational and hierarchical perspective are only covered in some approaches.

The most interesting approaches for workflow annotation and composition in comparison to the defined requirements seem to be the ODESGS ontology of the OntoGrid project, the m3po ontology and maybe in the future the ontologies of the projects SUPER or FUSION. Nevertheless, all of them are still work in progress.

All mentioned research areas are probably converging into one single research field: more and more web services will be available on a Grid in the future and using business process modeling one can also model the control flow of web services (or use model transformations between the abstraction levels). There are attempts in each research community to cover the mentioned aspects, but it is still a long way until standardization is going to be finished and one single standard for all aspects and research areas has been defined. In some cases it seems more promising to focus on one problem field or research area, but in many cases an overall language seems most promising. As one can see in all research communities which include workflow aspects such as business process management, the web service and Grid service community, the necessity of annotating services or process actions has been recognised and there are first attempts of (semi-)automatic composition of workflows in every level of detail.

The identified aspects are considered in our current work on a meta-model for semantic business processes and its model-driven integration with semantic web services [49] which will (e.g. in contrast to m3po) directly include the semantic information into the meta-model and will be ideal for workflow composition.

Table 1: Comparison of the workflow annotation and composition approaches

Project/Organisation	Language	Appl. domain	Research/Industry	Semantics	Annot./Comp.	Hierarchical	Functional	Behavioural	Informational	Organizational	Operational
OASIS	WS-BPEL	WS	I	-	-	±	±	±	+	-	±
W3C	WS-CDL	WS	I	-	-	-	±	±	+	-	±
Uni Trento	„semantic BPEL“	WS	R	±	A	±	±	±	+	-	±
OWL-S Coalition	OWL-S	WS	R	+	A	±	+	+	+	-	±
W3C WG	SAWSDL	WS	R	±	A	-	+	-	+	-	±
WSMO	WSML	WS	R	±	A	-	+	±	+	-	±
DAML.org / SWSI	SWSL	WS	R	+	A	±	+	+	+	-	±
SHOP2	OWL-S	WS	R	+	C	±	+	±	+	-	±
AKOGRIMO	BPEL4WS	Grid	RI	-	C	±	±	+	+	-	±
NextGrid	OWL-WS	WS, Grid	RI	+	AC	±	+	+	+	-	±
K-Wf Grid	GWorkflowDL	Grid	RI	±	A	-	+	±	-	-	±
OntoGrid	ODESGS	Grid	RI	+	AC	?	+	+	+	+	±
myGrid/SIMDAT	XScufl/Freefluo	Grid	RI	±	AC	-	+	±	+	-	±
Uni Innsbruck/Vienna	A-GWL	Grid	R	-	-	±	+	+	+	-	+
WfMC	XPDL	BP	I	-	-	-	+	±	+	+	+
m3pe	m3po	BP	R	+	A	±	+	±	+	+	+
DFKI	sEPC	BP	R	+	AC	-	+	±	-	-	±
Uni Karlsruhe	"semantic Petri-Nets"	BP	R	+	AC	-	+	±	-	-	±
ASTRO	BPEL4WS	BP	R	-	C	±	+	±	+	-	±
SUPER[1]	several ontologies	BP	RI	+	AC	±	±	±	±	±	±
FUSION[1]	FUSION ontologies	BP	RI	+	AC	±	±	±	±	±	±

[1] Since there are currently no results in these projects yet, but only descriptions of the planned achievements, we categorized all workflow aspects with '±'.

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