SWAPT
Semantic Workflow Architecture for Petroleum Techniques

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Abstract: In the petroleum industry, many engineering studies are conducted to evaluate the potential of the geological structures to be exploited as hydrocarbon reservoirs. They are realized following series of complex workflows composed by activities realized by geologists. Nowadays these workflows are build mainly according to the experience gained by experts along their previous realizations. It is not possible to share this experience between geologists by reusing and composing activities if a minimum of semantics is not applied to describe them and the workflows that use them. The focus of our work is to evaluate the benefit of using semantics to make the geologist daily work easier. In this article, we first explain how we can operate today without semantics. Then, we enrich such complex workflows and the data they manipulate with semantic annotations through ontology-based characterizations (Geological Data and Activities Ontologies). As future work, we plan to use these annotations for a full architecture that would assist geologists in building their workflows.

1 INTRODUCTION

In the petroleum industry, several engineering studies are conducted in order to deal with reservoir modeling. Indeed, seismic, geological and structural models are set up. The geological modeling task is composed of a series of multiple and complex processes or activities. Workflows model these processes and their composition. The orchestration is the action that supports the execution of these workflows.

Several work focus on automating or semi-automating particular geological modeling activities. However, the geologists knowhow and the compounding activities are transfered into workflows without any methodological rule. Our work focuses on automating the activities orchestrations in the various processes of the geological modeling. The originality of our work lies on the semantics it brings in different ways. This work suggests to use ontologies to characterize both activities, their composition and the data they manipulate. Such a characterization will help geologists in building their workflows by abstracting implementation details and focusing on their semantics.

The remainder of this article is structured as follows. In section 2, we show the classical workflows approach and its limitations and describe related work aiming at bringing semantics to workflows. In section 3, we propose a semantic workflow approach. As a case study, we present, in section 4 one of the workflows of the petroleum field and in section 5 the geological data it manipulates. The workflow activities implementation is detailed in section 6. We finally conclude and give some outlooks for future work.

2 FROM CLASSICAL TO SEMANTIC WORKFLOWS

In classical workflow systems, activities manipulate data model instances. No software vendor has implemented such systems for geologists due to the fact that depending on the objectives they establish, the geologists have to adapt their workflows.

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Because the activities in geology are strongly linked to the technical descriptions of specific proprietary workflows, it would be difficult to combine together atomic activities supplied by different vendors in order to create new workflows even if we could isolate the atomic activities. To address this problem, we suggest to enrich the geological data and the geological activities with semantic annotations.

Our final objective is to propose an architecture that would enable geologists to perform tasks with a minimum of geological knowledge instead of a technical computing knowledge.

Bringing semantics to workflows and Web services is in the middle of the two hottest research areas associated with the Web: on the one hand, the dynamic part through Web services and on the other hand, the static part aiming at providing semantics to knowledge and data.

The final goal of Web services is to equip the Web with distributed programs able to interact, to be retrieved automatically and to be composed into more complex services. However, the interactions consensus is not enough to allow unambiguous interaction without Explicit semantics.

Ontologies have played their role in associating a formal semantics to the Web service description. The goal of OWL-S (Martin et al., 2004), is to enable users and software agents to discover, invoke, compose, and monitor Web resources. Another example is SAWSDL. It is an upper layer added to WSDL and recommended by the W3C (Farrell and Lausen, 2007) that allows to define semantic terms used in WSDL by referencing RDF-based ontologies. Many work focus on the automatic discovery of Web services. For example, (Bernstein and Klein, 2002) uses ontologies of processes to describe the services behavior and define a Process Query Language. Finally, many other work focus on the automatic composition of Web services. For example, (Hendler et al., 2003) exploit annotation tools for services and scheduling in order to be able to compose services to create predefined functionalities.

3 SEMANTIC WORKFLOW ARCHITECTURE (SWA)

The main idea behind our SWA is to try to bring semantics to every part that composes workflows. Current work are concerned with interpreting the data by annotating them with ontological concepts (see Section 5).The first part of our proposal for a SWA uses this enriched data as the exchanged elements of the workflows supported by the architecture. The second part consists in providing a semantic characterization to the workflows themselves.

Figure 1 shows the layers of our SWA and the annotations that link them.

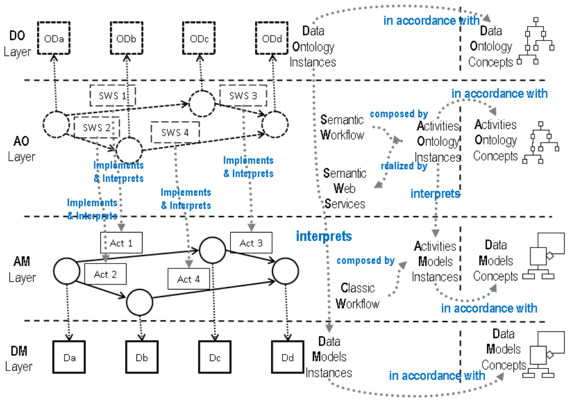

Figure 1: Semantic Workflow Architecture.

- **Data Models (DM)**
  The DM instances are the basic units manipulated in our architecture. They can be basic types like integers or strings, complex types or even files. They are instances of DM concepts which represent types or formats. Classical workflows manipulate instances of DM.
- **Data Ontology (DO)**
  The DO instances are instances of DO concepts. They can interpret DM instances through annotations (semantic relations) which link pairs of instances (an instance of DM is semantically annotated by an instance of DO).
- **Activities Models (AM)**
  Currently, activities use as input and output DM instances. Different activities manipulate DM Instances which are in accordance with different and specific formats that are interpreted as being the same DO instance. Moreover, the same format may have different meanings according to which activity manipulates it. Different DO instances can interpret different DM instances which are defined in a common format.
- **Semantic Workflows (AO)**
  AO represents semantic Web services and each Web service implements a specific geological AM. The semantic services annotate one or more AM. One or more implementations of Web services may correspond to a semantic Web service. Likewise, to a semantic workflow can correspond one or more implementations of workflows and Web services. AO can be semantic Web services (atomic activities) or semantic workflows (composite activities).

4 CASE STUDY: GEOLOGICAL MODELING WORKFLOWS

The geological modeling with the view to securely store CO_2 can be seen as a high level workflow. This workflow aims at transforming a "3D-image" obtained from a seismic exploration to a flow simulation forecast. This enables to predict how any fluid, and in our case CO_2, would propagate in a studied prospect.

The seismic interpretation is the up-stream of the geological modeling. Its objective is to interpret a 3D-image represented by a seismic cube to create a structural model and recognize the geological structure elements like horizons, faults or channels.

The seismic interpretation is a complex process and can be modeled as a workflow. It manipulates data, such as 3D-images (SEG-Y Files) representing seismic cubes or files of coordinates points (XYZ Files) representing horizons, reflectors etc. After a sequence of interpretation activities, a structural model is obtained. Figure 2 zooms on a candidate seismic interpretation workflow.

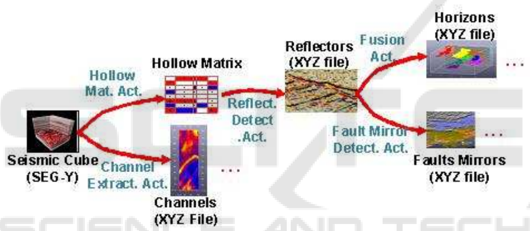

Figure 2: Up-stream fragment of a seismic interpretation workflow.

5 GEOLOGICAL DATA (GD)

The geological modeling workflows manipulate geological data which are instances of DM concepts. One of the objectives of our work is to make it possible for the activities to manipulate DO instances.

In (Mastella et al., 2008), the idea is to create an ontology for each geological field; the seismic ontology for instance. Then, an annotation model able to link the data to the ontology instances is set up. Figure 3 shows the relation between the geological data models (A), the geological data ontology (B) and the annotations model (C).

- **Geological data models (GDM)**
  In the geology field, the geologist manipulates GDM such as *SEG-Y Files* that represent seismic cubes (see Figure 3.A).

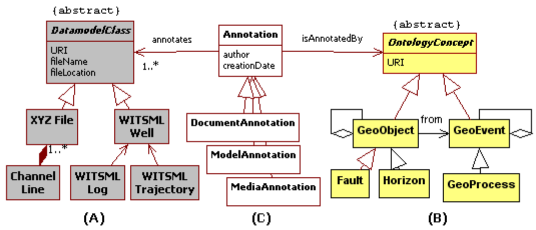

Figure 3: Fragment of the geological data ontology, the data models and the annotations model.

- **Geological Data Ontology (GDO)**
  In the context of the project *e-Wok Hub*[1] that deals with the storage of CO_2 by ontologies-based modeling[2], experts have defined a consensual and shared geological ontology (see Figure 3.B).
- **Geological Data Annotation Model (GDA)**
  An annotation can be for example *DocumentAnnotation* when the annotation refers to GDM which are files (see Figure 3.C).
  When the geologist creates an annotation, it references an instance of an *OntologicalConcept* and an instance of a *DataModelClass*. As an example, Figure 4 shows an instance of a GDM instance of *XYZ File* (whose name is "*reflect3D_0047.xyz*") that is annotated by a GDO instance of the concept *Reflector* (whose URI is "*r1*").

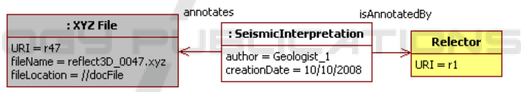

Figure 4: Example of a data annotated by an ontological instance.

6 SEMANTIC WORKFLOWS: IMPLEMENTATIONS

We have created a model and an ontology for the activities. We then created an annotation model to link the model and the ontology instances. Figure 5 shows the relation between the geological activites models (A), the geological activites ontology (B) and the annotations model (C).

A semantic activity ontology is the first part toward an architecture that proposes workflows and assists geologists in their geological modeling tasks.

[1]http://www-sop.inria.fr/edelweiss/projects/ewok/

[2]ANR project involving the following partners: LISI/ENSMA, IFP, BRGM, INRIA, EADS, Paris Mines School and the CRITT Informatics.

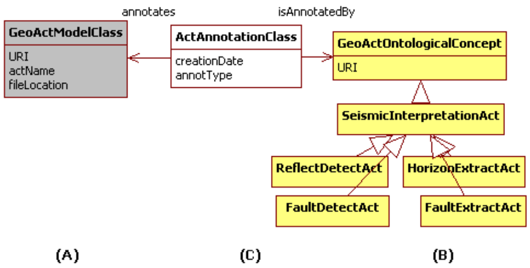

Figure 5: Fragment of the geological activities model, the geological activities ontology and the annotation model.

- **Geological Activities Models (GAM)**

  In geology modeling workflows, the activities are designed independently one from the others. As a consequence, a set of heterogeneous activities and models, that manupulate instances of GDM, are created (see Figure 5.A).

- **Geological Activities Ontology (GAO)**

  As a second step, we have then created an ontology of semantic activities (Web services) that would enable a semantic search over the Web services (see Figure 5.B). Indeed, when many Web services implement the same activities, a unique GAO concept corresponds to the given action. It is possible then to retrieve one or more (in the case of multiple Web services) WSDL descriptions and/or one or more workflows (e.g. BPEL).

- **Geological Activities Annotation (GAA)**

  GAM instances are annotated by GAO instances in the same way GDM instances are annotated by GDO instances.

  For example, the semantic activity *FaultsDetectAct* annotates both *FaultsDetectAct Wf1* and *FaultsDetectAct Wf2* (see Figure 6 for the annotation example).

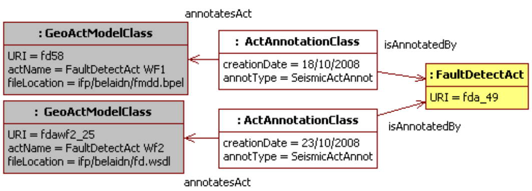

Figure 6: Example of an activity annotation.

7 CONCLUSIONS

We have described our proposal for an approach that intends to assist geologists in building their workflows by adding semantic annotations to the activities and to the data they manipulate through ontologies characterization.

The work presented in this article was the first part toward a full architecture supporting semantic geological workflows. In future work, we turn to the persistence of atomic and composite activities executions.

Recently, several systems were proposed to store in the same database the data and the ontologies describing them: ontology-based databases (OBDBs). OntoDB is one of them (Dehainsala et al., 2007). One of the advantages is the possiblity of querying the databases at the ontology level (Jean et al., 2006).

Thus, we plan to store GDO, GDM and the annotation instances in the same OntoDB. We intend to establish a meta-model of activities and record all GAO, GAM and annotations instances in the same previous OntoDB which will enable complex semantic queries.

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