ONTOLOGY-BASED MODEL ANNOTATION OF HETEROGENEOUS GEOLOGICAL REPRESENTATIONS

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Abstract: In this work we study the process of petroleum reservoir modelling as a case of study for applying ontology-based integration techniques and model annotation. A complete reservoir model gathers information resulting from several interpretations using heterogeneous representations. We propose that the different geological interpretations and representations should be annotated, for being integrated. We describe an approach based on local ontologies for the specific domains, whose concepts are mapped to a shared global ontology which contains the basic terms used in reservoir modelling.

1 INTRODUCTION

In this work we will study the process of petroleum reservoir modelling as domain for applying ontology-based annotation techniques. The models used for petroleum exploration (earth models) correspond to final representations of the geological objects resulted from successive steps of interpretation operated by professionals from various earth science domains.

Considering this *Reservoir Modelling Workflow*, one difficulty for semantic integration is the heterogeneity of representation, since one same geological item is likely to be pictured in many different ways within the different geomodelling applications.

To meet this issue, we will propose here an approach based on *semantic annotation* of models. We define *local ontologies* for annotating the domain specific models and a *global shared ontology* for gathering the vocabulary common to all these domains. We will focus on a branch of reservoir modelling activities which will be detailed in the next section.

2 RESERVOIR MODELLING WORKFLOW: A CASE STUDY

As a case study, we will consider here the part of workflow going from the *Seismic Interpretation* to the *Structural Model building*, starting from a real field data set and choosing real geo-modelling applications.

Seismic Interpretation: considering the seismic image of Figure 1(a), it can be interpreted by identifying the *portions of horizontal traces* as *reflectors*, or by considering that aligned *vertical traces* correspond to *interruptions*. So, on Figure 1(b), the user identify several *reflectors* (*r1*, *r2*, *r3*) and two main *interruptions* (*int1* and *int2*). The user then saves these seismic items as "cloud of points" in data files, that will be the input of the structural model application.

Structural Modelling: the files corresponding to interpreted seismic will be imported into a *structural modelling application*. Geologists will then apply definite geological rules to assemble them. For example, in the Figure 1(c) the faults *f1* and *f2*, interrupt the horizon *h1*. The structural model is saved in specific structural modelling formats.

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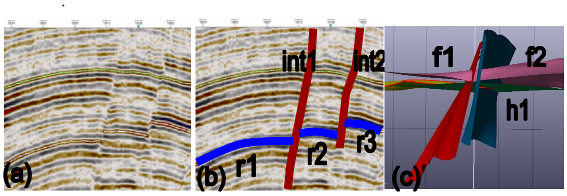

Figure 1: (a) Raw seismic image, (b) Interpreted seismic and (c) Structural model.

The practical issue that has to be solved is how the concepts of the "Seismic domain" can be put in correspondence with those of the "Structural modelling domain". This is not possible at present since we cannot recover the relation between objects identified in different phases of the process.

2.1 Geological Objects

Geological objects are identified in the beginning of the workflow and evolve within the different earth models. Geological objects appear as the red thread to which all interpretations and representations in the workflow should be attached and that can thus guide most of the modelling process. For this reason, we believe that the entities considered in the various representations should all be characterized as actual *geological objects* having a *unique identification*. The geological objects that we will use in this case of study are represented in a geology ontology formerly presented in (Perrin, Zhu, Rainaud, & Schneider, 2005) and (Mastella, Perrin, Abel, Rainaud, & Touari, 2007). An extract of the whole ontology is shown in Figure 2. It represents the basic vocabulary shared by all earth science domains.

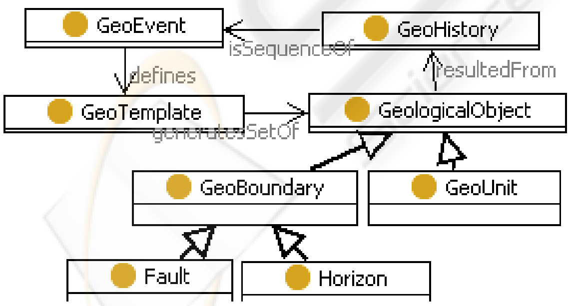

Figure 2: Extract of Basic Geology ontology [1].

Another problem is that current software systems are not able to take into account the fact that the successive categories of data have been interpreted as corresponding to the same geological object.

To address this issue, we believe that each of these geological objects should also be linked to its specific representation along the modelling chain.

2.2 Geological Applications' Metamodels

Each task of the workflow uses a different earth modelling application, which represent the geological objects in a different way. So as to identify the objects within applications, we need to semantic annotate *their metamodel*, which represents the primitives used by the application to represent a geological object. For example, the metamodel of a seismic interpretation analysis tool is as shown in Figure 3.

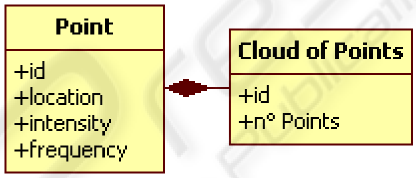

Figure 3: Metamodel for the seismic interpretation [2].

This metamodel stipulates that an object has different seismic associated properties (frequency, etc), which will be useful to identify the concept in the ontology later on. We will describe in the next section the approach that we propose.

3 ONTOLOGIES FOR MODEL ANNOTATION

Ontology-based annotation of resources allows to assign explicit meanings to objects and features interpreted by an observer. In this work, we intend to use ontologies to annotate *domain specific models*. We describe here an annotation architecture that helps users to make explicit their interpretation about the geological models. Unlike the common methods, the annotation architecture in this work are not automated; it is expected that human users will provide the detailed annotations of the models, subject to the contents and constraints of the ontology. The goal of the completed annotations is to offer a knowledge base (knowledge = geological models' data + annotations) which stores the geological interpretation.

3.1 Model Annotation Architecture

We are choosing ontologies because it is a consolidated approach to solve the problem of *integration of heterogeneous information* (Noy, 2004; Uschold & Gruninger, 2005). The work of (Lin, Strasunskas, Hakkarainen, Krogstie, & Solvberg, 2006) describes an approach of semantic annotation of process templates, for better reuse of this process in the business workflow using a general ontology.

We intend to set up the hybrid approach of ontologies (general + local) to the problem of the reservoir modelling workflow. Indeed, we have different specific knowledge domains and one pivot field that is shared by the others. For this reason, we propose an annotation methodology resting on (1) *local ontologies* (LO) which represent the concepts of the local domains of expertise or activities, such as Seismic (an extract represented in UML-like class diagram is shown in Figure 4), Structural Geology, that are required for annotating each specific representation; (2) *a global ontology* (GO), the Basic Geology Ontology (section 2.1), which links concepts used in the local ontologies; (3) *application metamodels*, for specifying how computing applications represent geological objects.

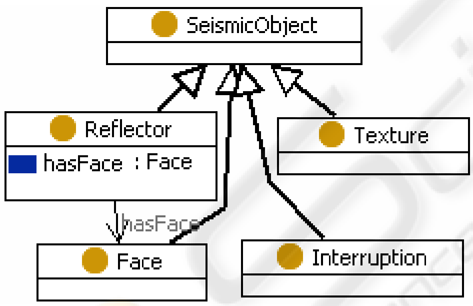

Figure 4: Extract of Seismic Interpretation LO [1].

The objective is not to integrate the concepts of the local ontologies inside the global ontology, but to establish subsumption links (*isA* and *isCaseOf*) between the local concepts and the shared concepts. Accordingly, we require to each LO concept instance to be an instance of at least one subsuming concept in the GO. We will use LO concepts to annotate the specific applications metamodels by (i) creating an *interpretation* link between an ontological concept and a metamodel entity and (ii) assigning a unique identifier to the metamodel entity that is interpreted. The objective is to allow the *ontological manipulation* of the application aspects. This implies that each instance of the LO can be referred and accessed from the GO level without any specific knowledge nor expertise of the LO level.

In the moment when the geologist performs an interpretation, he assigns a unique identifier to the instance of the local ontology, which is the same of the entity in the modeling tool. Figure 5 shows how to annotate an entity of the seismic metamodel (*Cloud of Points*) with a concept of the seismic local ontology (*Reflector*).

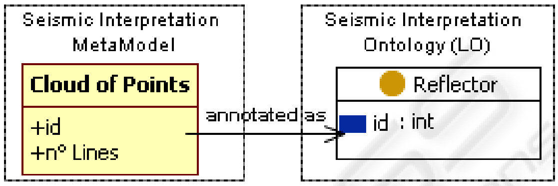

Figure 5: Seismic interpretation: Cloud of Points annotated as Reflector.

We have defined an approach on metamodels and ontological concepts. Next section shows a complete case study involving instances of the concepts described above.

4 APPLICATION TO THE CASE STUDY

Let us consider the two tasks shown in section 2: the Seismic Interpretation and the Structural Model. We will see in Figure 6 the architecture that represents how to annotate the files that represent geological objects.

The objects recognized in the seismic interpretation are the *reflectors* and *interruptions*. When this interpretation is saved in the specific computing application, they are saved as *clouds of points*. In order to annotate the seismic files, we create a link from the metamodel entities to the Seismic Local Ontology (Figure 6 (a)).

In a second phase, the reflectors are interpreted by the geologist as portions of *horizons*; and the aligned *interruptions* are interpreted as *faults*. In this case, the user is using a *Basic Geology* vocabulary. So, the link is made between the concepts of the Seismic Local Ontology to the concepts of the Geology Global Ontology (Figure 6 (b)). This represents the basic *subsumption link* between the concepts of the two ontologies: *Reflector is_a Horizon*, *Interruption is_a Fault*.

When the user passes to the structural modelling phase, his/her interpretation consists in identifying structural objects from the image. The geologist may identify several portions of *horizons* that are likely to be parts of one same *structural horizon*. And he/she can specify the structural category of the fault (normal, reverse), by observing the way it affects the structure. This illustrates the *subsumption link* between the concepts of the GO and the concepts of Structural Geology LO: *NormalFault is_a Fault* (Figure 6 (c)).

Finally, when the user stores the structural model, the objects are saved in binary files that represent a specific structural interpretation metamodel (such as ICarre metamodel [3]), whose entities are annotated with the concepts of the Structural modelling LO. (Figure 6 (d).

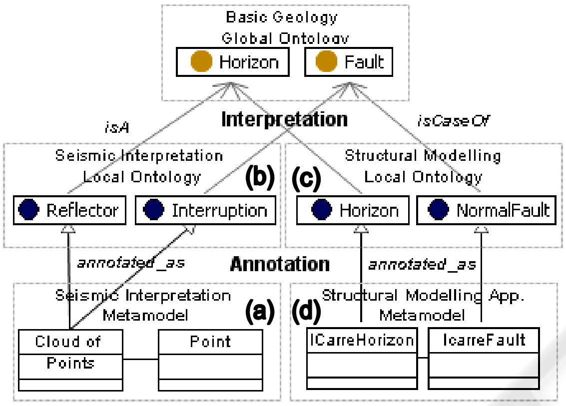

Figure 6: Links between GO, LO and Metamodels.

Setting up this approach, we are able to answer to queries that refer to different domains. Such a query would be, for example, by which seismic reflectors is formed the structural horizon *H1*? An structural horizon is represented as an *ICarreHorizon* (d), which is annotated as *StructuralHorizon* (c), which is subsumed by the concept *Horizon* in the GO. All those instances have the same ID. It is then easy to retrieve the instances of *Reflector* in the Seismic LO that are subsumed by the GO *Horizon* and that are used to annotate the looked-for "cloud of points" files.

5 CONCLUSIONS

We have presented here an approach based on ontologies to annotate specific domain conceptual models. The application domain is the workflow of oil reservoir modelling, which is a multi-representation multi-interpretation domain. In this process, an interpretation can be considered as putting in correspondence concepts belonging to different specialized domains. So, our architecture proposes to create *semantic annotations* from the specific metamodels to the local ontologies. Then, the local ontologies concepts are *subsumed* by the global ontology concepts, which is the pivot of the modelling process.

Creating correspondences between the models is likely to enable us to answer queries that cannot be addressed at present, because we cannot recover the relation between objects identified in different phases of the process.

The next steps in this work will be to automate most complex mapping rules, which will represent inferences that can be made within specific domains. Moreover, we expect to scale up the proposed approach to deal with large file size interpretations. We plan to use persistent models with ontology based databases.

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