An Approach to Seismic Interpretation Based on Cognitive Vision
The Horizon Identification as an Application for the Cognitive Vision

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1/ Introduction

In industry, advanced seismic interpretation most commonly rests on transforming original data representations by considering more or less numerous seismic attributes. Interpreters develop specific know-how for selecting and combining them in order to highlight some geological objects that cannot be directly identified by considering the reflectors present within seismic blocks. Recent progress have been recently made by proposing technologies such as Active Contour (Admasu 2006), Ant Tracking (Randen 2001), Reflector Classification (Borgos 2005) or by using combined seismic attributes defined thanks to neural networks (Meldhal 2000). A common characteristic of these various methods is that the tools on which they rest (image processing, numerical approaches, artificial intelligence) bear no explicit relation with geology. In consequence, they hardly allow fully solving problems such as reassembling sparse geological surface elements or specifying geological relationships either chronological or topological (erosion, on lap, interruption by fault).

Some geology-based approaches have recently appeared. Monsen (2007) and de Bruin (2007) both propose to classify reflectors into a 3D Wheeler diagram. This allows interpreting a seismic block as a time-ordered succession of sedimentary deposits. The present work intends to make further progress in geology-based interpretation of seismic data by using artificial intelligence tools based on *cognitive vision*.

2/ The cognitive vision approach

Cognitive vision has recently appeared as a science combining computer-based vision and cognition. A cognitive vision system can achieve, in an intelligent way, the four levels of generic computer functionalities of detection, localization, recognition and understanding. To achieve these capabilities, a cognitive system is endowed with cognitive faculties: i.e. ability of knowing, ability of understanding, ability of reasoning and ability of learning things. (Vernon 2005).

In the case of seismic interpretation, we propose to operate a cognitive vision approach similar to the one that has been successfully applied by INRIA to various applicative domains (Hudelot 2003) (Maillot 2004) (Maillot 2008). We propose to associate to geological objects, visual geologic attributes and visual seismic attributes. For example, we propose in the table 1 for the geological object "Conformable Sedimentary Succession", the following specifications:

CONFORMABLE SUCCESSION *Definition* Conformable refers to a set of strata that are parallel to each other without interruption (definition of *The American Heritage® Dictionary of the English Language, Fourth Edition*) In reference to Vail & al. (1997), a conformable sedimentary succession can be seen as a portion of a sedimentary sequence.	GEOLOGIC VISUAL ATTRIBUTE A set of parallel horizons, each being younger than the preceding one from bottom to top.
SEISMIC VISUAL ATTRIBUTES A set of parallel reflectors having locally one same orientation and each showing some lateral continuity in amplitude and thickness. Parallelism involves that the distance between two reflectors belonging to the same set remains approximately constant laterally.	

Table 1 : specification of a Conformable Sedimentary Succession

The architecture of the cognitive vision based tool for seismic interpretation that we are developing is described on figure 1.

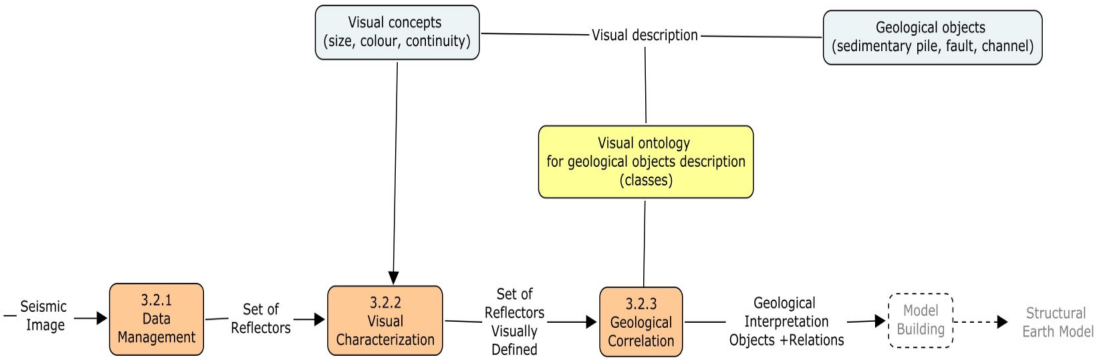

Figure 1 : Proposed cognitive vision workflow for seismic interpretation

3/ Methodolgy

3-1 Initial visual ontology building.

All the geological objects of interest have first been completed with geologic and seismic attribute as shown in section 2. For being used in a software based process, the corresponding knowledge must be formalised. We have operated this formalisation by building a visual ontology (an ontology being “a formal specification of a shared conceptualization” as Borst (1997) defined it). This visual ontology has been built using OWL. (McGuinness, 2004)

3-2 Seismic interpretation workflow

3-2-1 Data management

This first module corresponds to pre-processing, which allows to threshold the data, to store them in a sparse matrix and to detect first order reflector continuity using voxel connectivity.

3-2-2 Visual characterisation

This module allows to affect to detected reflectors the attributes and relations, which have been defined in the visual ontology. The attributes defined at present are the reflector amplitudes (positive or negative), the reflector thickness and their 2D dip (observed on seismic cross-sections). We also characterise the chronological relationships between reflectors (younger than/older than) by means of a specific algorithm.

At present, chronological relationships between reflectors have been established considering that a reflector located upper in the image is a younger one. Upper/lower relationships are locally computed as shown on figure 2a.. For each reflector R, a graph can be established specifying the vertical distance relationships with its various neighbors, i.e. with all the reflectors that are visible from R on at least one voxel column.

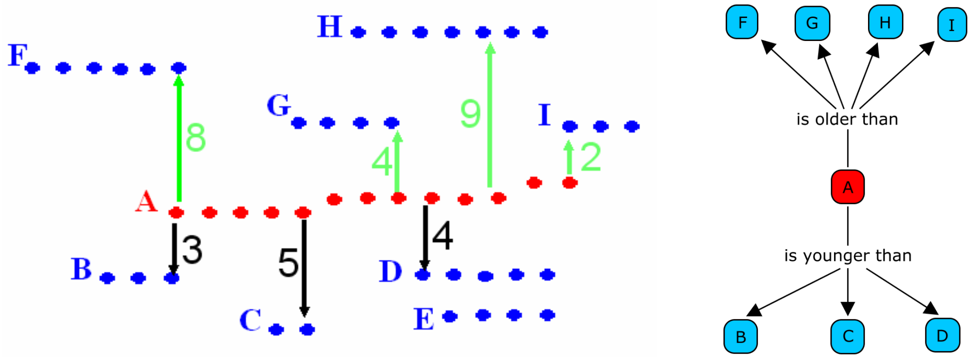

Figure 2 : Vertical distance computation (left), resulting graph (right)

By merging the graphs related to the various reflectors, a global graph can be obtained showing all the neighbor relationships (cf. figure 3 right). Additional information is put by showing the visual attributes related to each node in a symbolic way (shape, color, orientation of the polygon describing the node).

3-2-3 Geological correlation

The last step of the workflow consists in performing a geological interpretation by identifying the geological horizons corresponding to the various identified reflectors. In classical seismic interpretation procedures, this operation is not trivial and is frequently performed “by hand” by the interpreter. In our case, it can simply be done by simplifying the global graph obtained at the end of the visual characterisation step.

For this, we fuse all the nodes which both:

- share similar visual attributes (amplitude, thickness, dip),
- are located at similar distances from at least one other reflector.

These two criteria are applied in accordance with tolerance rules defined by the user.

The result is a set of chronologically ordered horizons that we can represent thanks to various geological interpretation representation such as a Geological Evolution Schema (Perrin 1998) or a Wheeler diagram. .

4/ Results

Results related to a seismic block of size 1160 x 850 x 350 voxels is shown on figure 3. It corresponds to a geology made of eroded tilted blocks covered by on lap deposits.

Today, after one iteration, the wider 70 reflectors were fused into 40 horizons (cf Figure 4) More iterations will ameliorate the ratio.

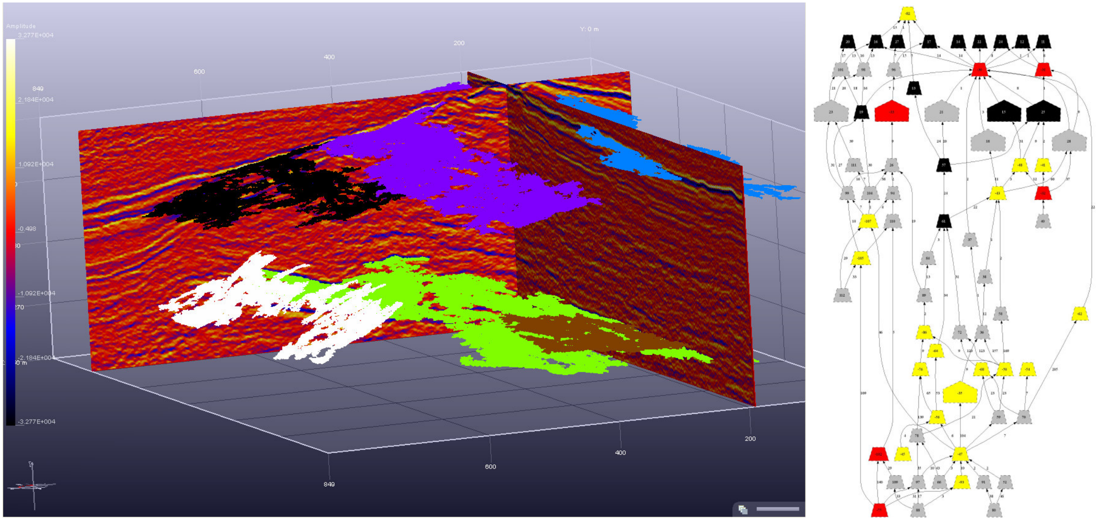

Figure 3 : Main reflectors identified (left), associated graph (right)

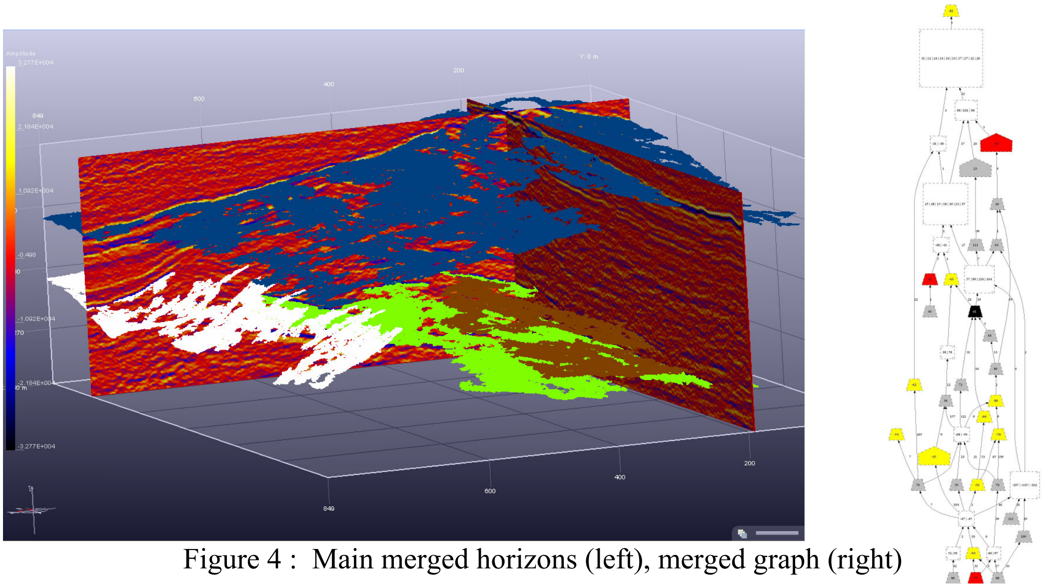

Figure 4 : Main merged horizons (left), merged graph (right)

5/ Conclusion and perspectives

The proposed method allows considering geological criteria at an early stage of the interpretation. This is made possible by defining visual attributes related to the geological objects that have to be detected. We have presented here a preliminary example that deals with a simple sedimentary succession. The method allows, in this case, to easily merge disconnected reflectors within one stratigraphical horizon taking into account simple geological criteria (amplitude, thickness, dip, vertical distance between reflectors).

Since it is very general and very flexible, the cognitive vision method presented is potentially applicable for identifying many geological objects simple (faults) or complex (channels, system tracts). We are presently studying this possibility.

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