AAPG Hedberg Research Conference
“Interpretation Visualization in the Petroleum Industry”
1-5 June 2014, Houston Texas USA

Visualization, Interpretation and Cognitive Cybernetics

James Lowell* Jon Henderson, Gaynor Paton, Joe Valenti
ffA, Generator Studios, Trafalgar Street, Newcastle upon Type, NE1 2LA, UK

*Corresponding author, Email: jlowell@ffa-geosciences.com

Seismic interpreters face an enormous challenge to ensure that the ever increasing amounts of data does result in improved exploration success and better recovery. Seismic data contains vast amounts of information and interpreters need to analyse a number of attributes of the data simultaneously to understand the behaviour of geological systems [1]. A high level of cognition is required to collate the different types of information into a single, comprehensive interpretation in which heterogeneous information is progressively transformed into coherent models.

A coherent model begins with an initial “guess”, and the mind continuously adjusts its hypotheses as new information is discerned through more in depth interpretation of the data. With each hypothesis the mind forms a conceptual geological model which it compares to information that is extracted from the available data. Misfits between the conceptual model and the observed data lead to the formation of a new hypothesis, which is then further refined as new information or new data becomes available. This cognitive circularity is known as cybernetics.

Development of an accurate model of the geology imaged in seismic data can be made much more efficient through using techniques that convert seismic images into geological images [2]. Such techniques exploit the abilities of the human visual system and help reduce cognitive overload.

In this paper we look at how the fundamentals of cybernetics can be used to influence the design of techniques for two important aspects of 3-D visualisation and analysis of seismic attributes: attribute selection / parameterisation and object delineation.

Attribute Selection and Parameterisation

When approaching a new situation or having to consider new concepts, we start from an initial mental guess [3]. For example, the effective application of seismic attributes requires decisions to be made regarding which attribute or attributes and associated parameters to use. This can be a non-trivial process and often involves running multiple workflows.

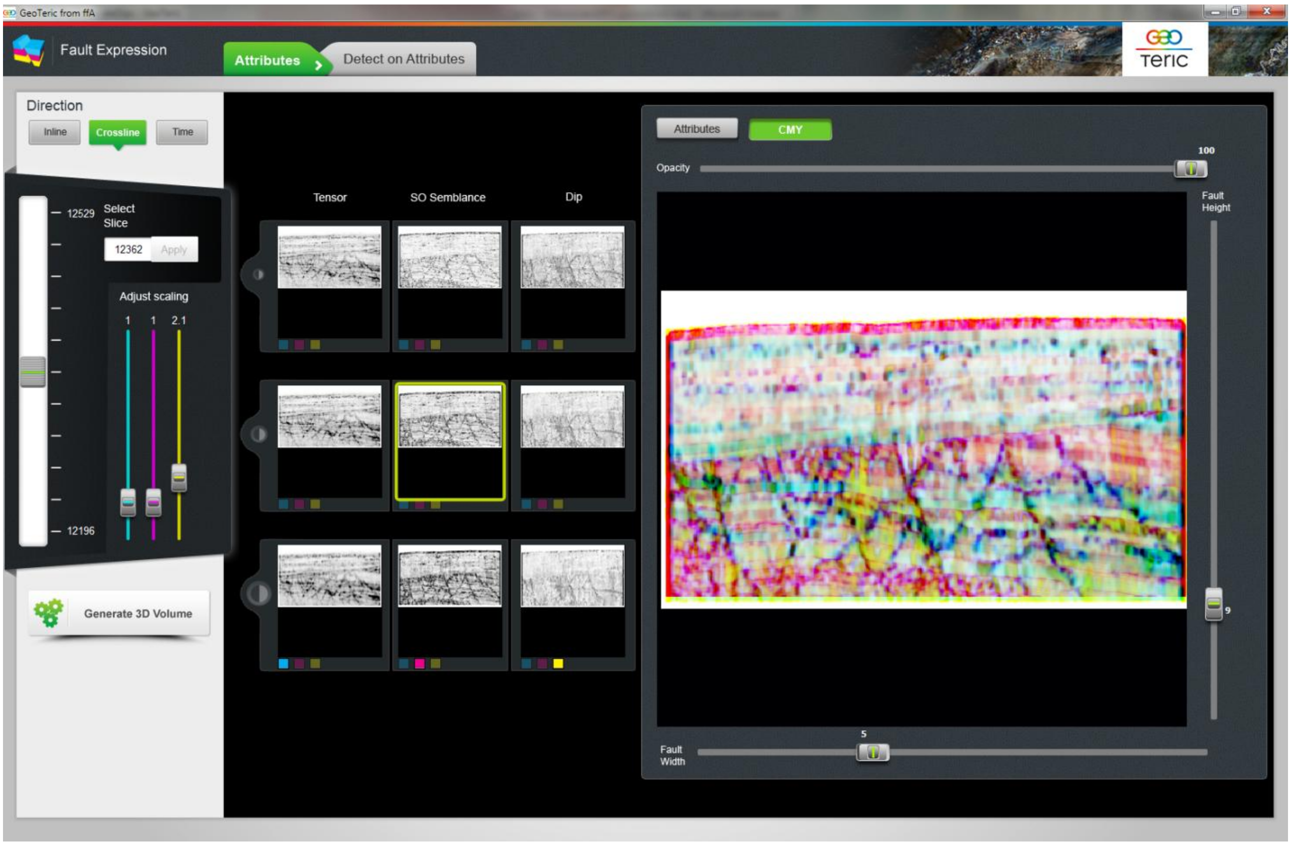
Even if the initial guess (attribute selection or default parameters) worked well and the results looked reasonable they may be far from optimal. Conventionally, at this stage a recursive loop would begin where model parameters influencing the result are corrected as a fit function between the data and the attribute. In the case of seismic attribute data the fit function is generally a subjective visual assessment of the output by the interpreter. This recursive approach is called back propagation and can be used to understand how the different parameters influence the fit or misfit of the data with a desired result.

We rely on continual visual feedback in all aspects of our everyday life. For instance to pick up a cup of tea there is continual feedback between our muscles and our neural activity as we reduce the misfit between our hand and the tea cup [3].

When faced with complex workflows (such as fault imaging) that require parameterization of multiple attributes, which when combined form a geological feature, the process of back propagation is less instinctive and, therefore, significantly more challenging. To this end a visually guided parameter optimisation framework for fault imaging has been developed, which we have called "Fault Expression".

Fault Expression is an example-driven interactive fault imaging tool. It presents the user with a selection of results prior to any large scale processing being carried out, so that parameters can be adjusted and optimised very quickly. The example driven method also allows you to see how a range of different attributes, individually or in combination, can highlight the imaged faults. In effect, the Fault Expression tool provides an effective way of sampling a complex multi-dimensional parameter search space before you have made any decisions.

The example driven framework has been designed to be cognitively friendly and enables an informed initial mental guess to be made. Due to the interactive nature of the approach the influence of altering the parameter settings can be quickly understood making optimisation very efficient. A critical part of Fault Expression is the use of colour to display the results from multiple attributes, which differ but are highly correlated, simultaneously.

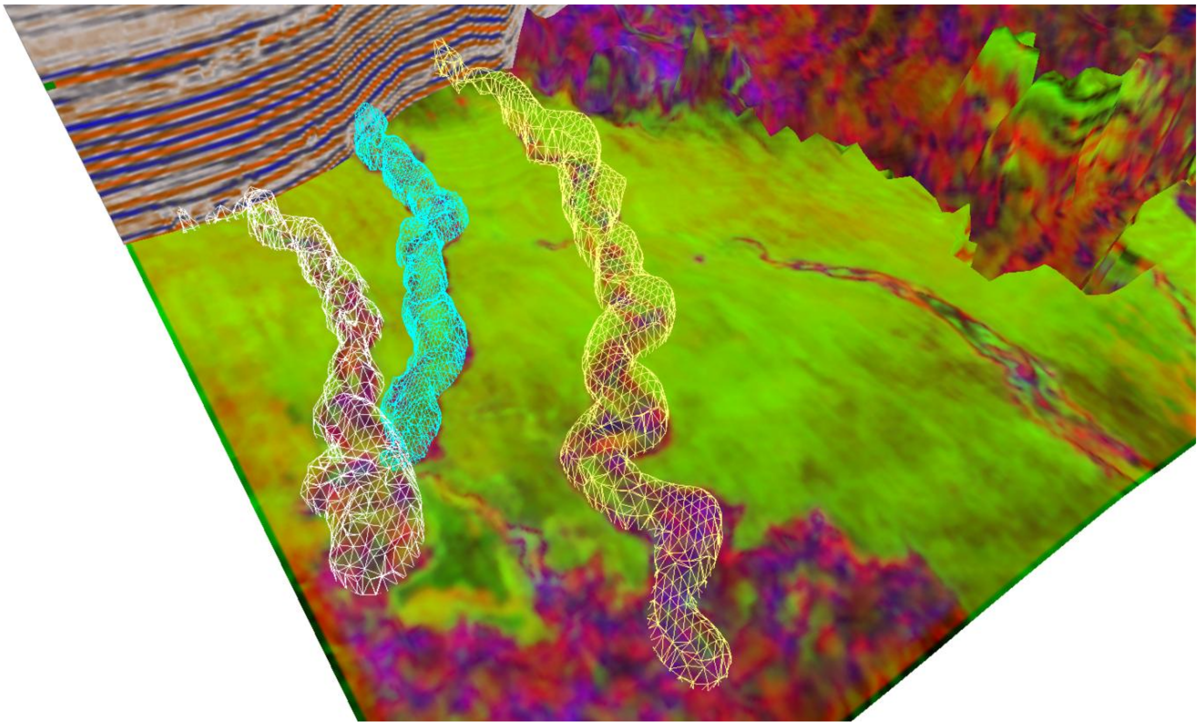


Data Driven - Interpreter Guided Object Delineation

The concept behind data driven interpreter guided object delineation is very simple but technologically demanding. The user wants to extract a 3-D geological feature that they can see within the data. The boundary of this feature although visible to the user is difficult to extract automatically using without any interpretation input as the character of the data can vary greatly throughout a specific geologic structure. We have developed a method that interactively grows a geobody based on prior information provided by the user.

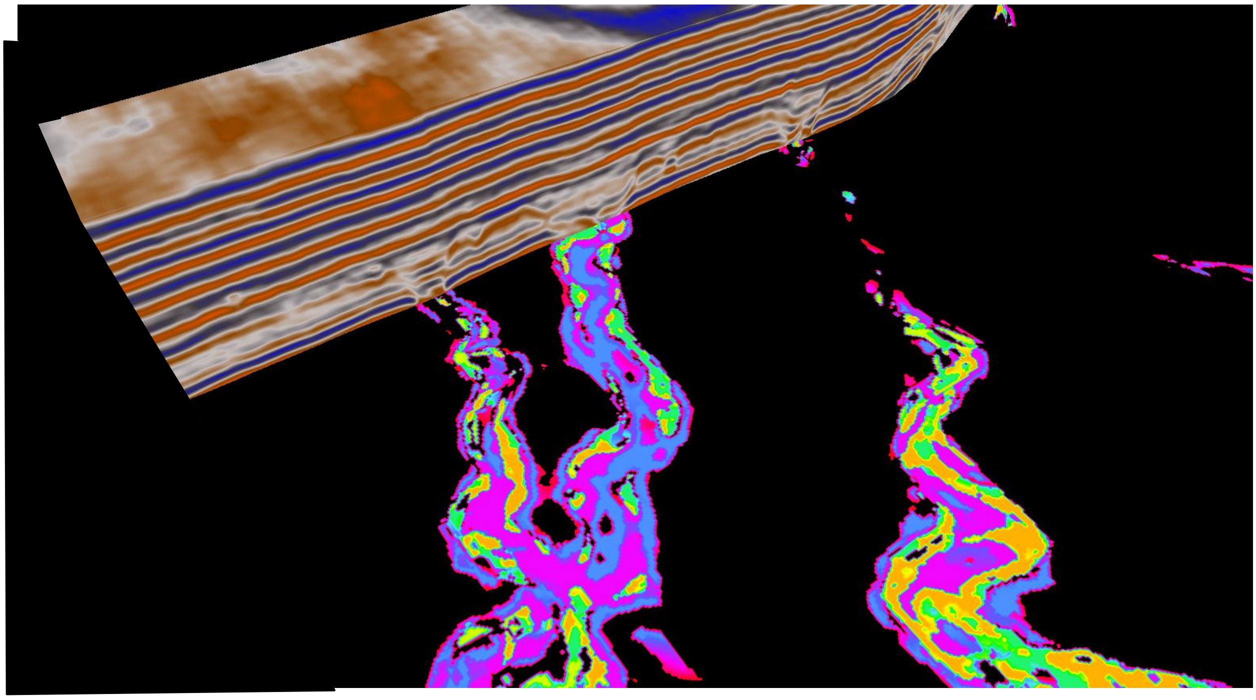
The workflow starts by identifying a small region of data within a geological feature of interest, such as a fan or a channel system. The defined data sample provides an adaptive model with the information it requires to progressively explore and flow through the data, adapting its shape to follow regions of data with characteristics similar to the initial sample area. We have termed this approach "Adaptive Geobodies". The recursive nature of an Adaptive Geobody's evolution is similar to that of back propagation; after each iteration, the fit/misfit between the model and the data is re-evaluated.

Adaptive Geobodies evolve in a manner that is similar in some respects to how the mind constructs its own geological model. The interaction that it allows between the data and the interpreter means that any feature seen in 3-D seismic data can be captured as a 3-D object in a way that makes optimal use of both the data and the interpreter's understanding of the geological system. In other words 3-D surfaces representing geological elements are generated that match the interpreter's view of what is geologically feasible whilst honouring local data characteristics.



Having delineated a geological element such as a reservoir, the next step is to explore its internal architecture. This can also be approached using a cognitive cybernetics approach.
A cognitive friendly interactive facies classification tool has been designed to aid visualisation and delineation of the extent and heterogeneity of facies. The interactive facies classification approach is similar to that used in the Adaptive Geobodies tool in that the user defines one or more clusters that are believed to be representative of different components of the imaged geology. Hierarchical clustering is then used to automatically split each facies into a number of sub facies groups.

By adjusting the number of sub-facies and an acceptance level (probability that a voxel is part of the specific geological group defined by a user defined cluster) the user can review the fit/misfit of the classification to the data. As the model parameters influencing the classification are visualised immediately; back propagation occurs effortlessly reducing the cognitive overload.



Cognitive cybernetics are an implicit part of the way that we interact with the world and will play an ever increasing role in the analysis and interpretation of complex data sets. This will lead to an evolution of interpretation technologies allowing an ever closer connection between objective numerical analysis of large data sets and the domain expertise required to understand the relevance of that analysis.

[1] Henderson, J., Purves, S., Fisher, G. and Leppard, C., 2008, Delineation of geological elements from RGB color blending of seismic attribute volumes. The Leading Edge, 27(3), 342–350.

[2] "The Geological Approach to Seismic Interpretation", HART's E&P Nov 2012.

[3] Aversana, P.D, (2013), Cognition in Geosciences, EAGE Publications, 2013, ISBN 978-90-7384-41-5