Geological Expression, a data driven and interpreter guided approach to interpretation

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Abstract

Fully volumetric interpretation needs to encompass 3D delineation of geological features beyond the extraction of top and base horizons. To address this issue 3D geobody delineation techniques based on thresholding and voxel connectivity have been developed. Such techniques have limited applicability as there is often insufficient information to enable the discrimination of the constituent components of a geological system based on the seismic data alone.

Understanding how we perceive objects in images is central to the development of better interpretation tools. What we perceive in data is strongly influenced by geological knowledge, previous experience and analogues. These are subjective factors but to produce geologically realistic results we need to find a way of incorporating them within 3D geobody interpretation. A large step in this direction has been taken with a technology known as "adaptive geobody delineation". The adaptive geobodies technique combines an adaptive, classification based region growing method, with interactive 3D surface manipulation techniques. This enables delineation of 3D geobodies that are a best fit to the data whilst matching the interpreter's view of what is geologically realistic.

We present the potential utility of these techniques applied to the delineation of a variety of geological elements from seismic data acquired from the North Carnarvon Basin, North-Western Australia.

Introduction

Delineation of geological elements via manual interpretation of a seismic dataset or derivative thereof can be an arduous task with a great degree of subjectivity. In particular, the location of a geological boundary drawn by an interpreter is dependent on how a sub-surface image is perceived. In order to create a system of interpretation that minimises subjectivity yet retains experienced interpreter judgement and control it is necessary to understand how we perceive boundaries through changes in colour and contrast in an image. From this we can build a system that can better define such boundaries automatically and in a way that matches an interpreter's perspective and understanding of a geological system.

This paper will discuss how we perceive objects in images and, in the context of 3D geobody definition, how we can improve data analysis techniques for objectively delineating what we understand the image to represent and we apply this to a data from an active hydrocarbon setting in North Western Australia. A number of geological features are considered; these include fluvial and deltaic systems, submarine canyons and fans, carbonate reefs and clinoform complexes through to sub-reservoir scale lithofacies variation. The wide range of features of varying scale, morphology and depositional origin that have been successfully extracted within the sample sets demonstrates the broad applicability of the tool.

Colour perception and the Adaptive Geobody tool

Although the human visual system allows individuals to interpret visual information, it is uncertain what exactly an individual perceives. This is because visual perception is a neurological process; we gather information from the world around us using our eyes and interpret this information largely based on memory. Vision is the result of unconscious inference, making assumptions based on visual clues and previous experience stored in memory (von Helmholtz, 1866). As memory influences the interpretation of this visual information, knowledge, experience, cultural and social backgrounds could all play a part on an individual's perception. Knowledge transferred by colleagues can also influence ones interpretation (Davies et al., 2005).

Geological interpretation is very much based on inference as interpreters make visual assumptions based on incomplete data using visual clues. Generally, as interpreters we compare the visual information from seismic data with a frame of reference based on geological analogues retained in our memory. This process becomes easier over time as the level of experience increases. Within the context of the visual interpretation of geological features, colour perception is of key importance as colour is a very powerful means we can use to represent data. Remarkably we have the ability to distinguish ten million colours, as compared to a mere 500 shades of grey (Judd and Kelly, 1939; Vision Health Optometry). This is why multi-dimensional seismic attributes can be displayed so effectively in colour blends (Henderson et al., 2008; Henderson et al., 2007).

The way we perceive colour and variations in colour can have a significant impact on the accuracy and precision of measurements made from seismic and seismic attribute data that rely on manual definition of boundary or edge points. For example, using hue variation to visualise attribute data can have an unwanted visual effect as different hues appear more prominent than others (most notable with the green hue) although the colour bar has been constructed uniformly. This effect is better highlighted in Figure 1, where an RGB image has been created using three of the radial profiles. In the resulting image the radial profiles all tend to appear as different sizes, the green being the largest followed by red and finally blue.

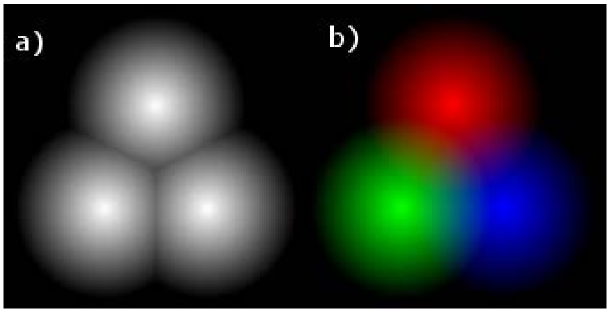

Figure 1: a) Composite image of three radial profiles viewed with a grey-scale colour bar: the three profiles are symmetrical and of the same size. b) An RGB image of the same data: the green hue is the most prominent, followed by red and finally blue.

Although, we are very good at compensating for changes in hue and intensity when determining which parts of an image belong to a given object, the converse is not true in that we perform poorly if asked to decide whether two parts of an image have the same hue and intensity. This can make it difficult to examine the variability within a feature of interest robustly and consistently.

This suggests that we should be looking at developing interpretation technology from a data driven – interpreter guided perspective. Interpreter guidance is required to:

- Identify the geological elements imaged in a seismic data set.
- Understand the importance of the imaged geological elements to the overall interpretation.
- Understand the relationship between the imaged geological elements.

The data driven aspects are required to:

- Enable reliable and repeatable measurements to be made of the imaged geological elements.
- Enable efficient delineation of the imaged geological elements.

Adaptive Geobody Delineation is ffA's first technology that embodies the concept of data driven – interpreter guided delineation. The Adaptive Geobody technique is much more robust than standard region growing or threshold based techniques. Robustness in the data driven aspect of the technique arises mainly from a combination of factors.

- Variations in the data characteristics representative of the object of interest are accommodated by painting cells of data clusters directly on the 3D volume.
- In situations where the contrast is particularly low or highly variable, external data clusters can be defined to tell the region growing technique which areas to avoid.
- The classification statistics that constrain the region growing can be derived from up to five different attributes. If the Adaptive Geobody technique is applied to an RGB colour blend then the 3 attributes that contribute to the RGB blend are automatically included in the classification.

As the geobody grows, the Adaptive Geobodies technique automatically computes a “goodness of fit” measure between the geobody surface position and the data. Where the data suggests there is a strong boundary in the data it is ascribed a high confidence value and where there is little indication of a boundary we get a low confidence value. Figure 2 demonstrates how a geobody will adapt along search lines in order to fit a surface contour to data.

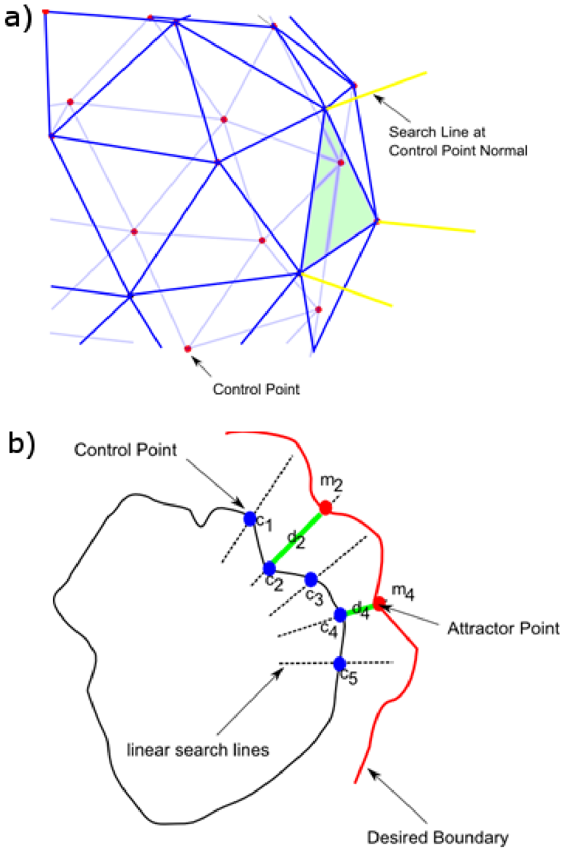

Figure 2: Schematic of an adaptive geobody deformable surface. a) During adaptation the surface grows along search lines, orthogonal to the surface at that control point. b) As the geobody grows the new boundary position is defined by fitting to internal data characteristics. Deformation occurs within a predefined distance along the search lines and is balanced by internal and external forces.

Although the data driven aspects of the Adaptive Geobodies technique are designed to overcome many of the limitations inherent in seismic data, there are still many instances when interpreter guidance is required to produce a geologically reasonable representation of a given geological element. The final level of robustness derives from allowing a high degree of interpreter guidance. This is accommodated in the Adaptive Geobodies technique through providing the interpreter with a simple mechanism for manually deforming the surface of the geobody in 3D. So, for example, if the geobody is not growing into an area into which it is believed to extend, a node point on the surface can be selected and used to drag the surface to where it is interpreted it should be. This 3D surface deformation works by adjusting all the points within a defined radius of influence so avoiding the laborious process of adjusting each point one-by-one.

Geological example: Cretaceous (Barrow Group) fan system

An example workflow is described in Figure 3 applied to a submarine fan system imaged within the Snark3D seismic dataset and located in the Barrow Sub-Basin, North Carnarvon basin, NW Australia. The fan system occurs within the Early Cretaceous Barrow group and is successfully imaged using HD Frequency Decomposition and RGB blending as shown in Figure 3a. Similar workflows have been successfully applied to similar geological features in different geological settings (Henderson, *et al.* 2012; McArdle *et al.* 2010) and this workflow extends from these previous studies. The image shows a horizon slice though the colour blend, which is composed of 20Hz, 30Hz and 40Hz HD Frequency Decomposition magnitude responses. We can see from this example that the colour blend is particularly successful at highlighting the fan system. Using an RGB colour scheme lends itself to emphasising high magnitude anomalies, which appear as high contrast, bright-white anomalies, whereas the subtle changes in colour indicate small scale changes, which can be primarily attributed to thickness variation across the fan system. The aim is to use the RGB colour blend to create a geobody representing the outer surface of the fan system, in a way that fits the interpreter's concept model, whilst remaining faithful to the data. In order to achieve this, the geobody is grown from a data cluster picked in the channel centre. This data cluster provides a statistical representation to which the geobody is fitted as it grows. For a geobody seeded on a colour blend, each cluster is sampling a matrix of values composed of the constituent frequency magnitude values at those points. Subsequent deformation is fitting the geobody boundary to the three frequency responses.

It is observed that this complex system undergoes an evolution through time whereby the position of the channel migrates and the thickness and extents change, particularly in the location of an overbank at the channel meander. In this case it was useful to isolate a stack of geobodies representing different stages of deposition (Figure 3b). This was aided by incorporating conventional interpretation as constraint to the deformation, in the form of a horizon cube as shown in the figure.

In order to get a gross volume it is beneficial to merge the individual channel components and this is shown in Figure 3c. As part of the combination process, the merged geobody is resampled to create a new mesh. Data clusters taken from one of the constituent bodies are used to allow the new merged body to adapt to fit the data. Adaptation can be started and stopped as the interpreter requires or allowed to run until the misfit at the boundary is appropriately minimised and the body is deemed stable.

For a thorough evaluation of the prospect geobody it is important to project different values onto the body surface; data that can be surface mapped includes volumetric attribute values, colour blends, fit of the geobody to the data at the boundary (confidence) or mesh stability. The geobody in Figure 3c is displayed with height values, clearly highlighting the dip closure.

Additional geobody functionality is available through volumetric computation. To do this the surface based geobody is adapted until stable and then converted to a volume. Figure 3d shows a volumetric thickness attribute computed for the fan geobody. The thickest pay in the body is clearly defined in red. Using a geobody volume also proves very useful when combination with traditional seismic attributes is necessary.

An important aspect that is available to the interpreter is the is the ability to manually deform the geobody to fit a pre-existing play concept – this may be necessary when data quality, seismic resolution or other limitations prevent the geobody growing to the size and shape that the interpreter believes is correct. In this situation the geobody can be morphed by stretching, moving and slicing individual or groups of control nodes on the surface mesh. After morphing the geobody, it is then readapted to resample the mesh and to fit the data locally.

Conclusions

Data-driven but interpreter guided geobody interpretation is a method for creating 3D interpretational geobodies of geological features visible in seismic attributes, in a manner that allows interpretation that honours data, whilst maintaining the user's ability to manually override and adapt the body. We have shown here its use in prospect identification and evaluation by creating geobodies that highlight the depositional sequence and prospect geometry within a submarine fan in a proven hydrocarbon system.

The wide range of options and input data types available to this method means that scope for use of this tool is wide and we anticipate that this method of interpretation become standard in future.

Acknowledgments

The authors acknowledge Geoscience Australia for the use of seismic data made available through the 2010 acreage release.

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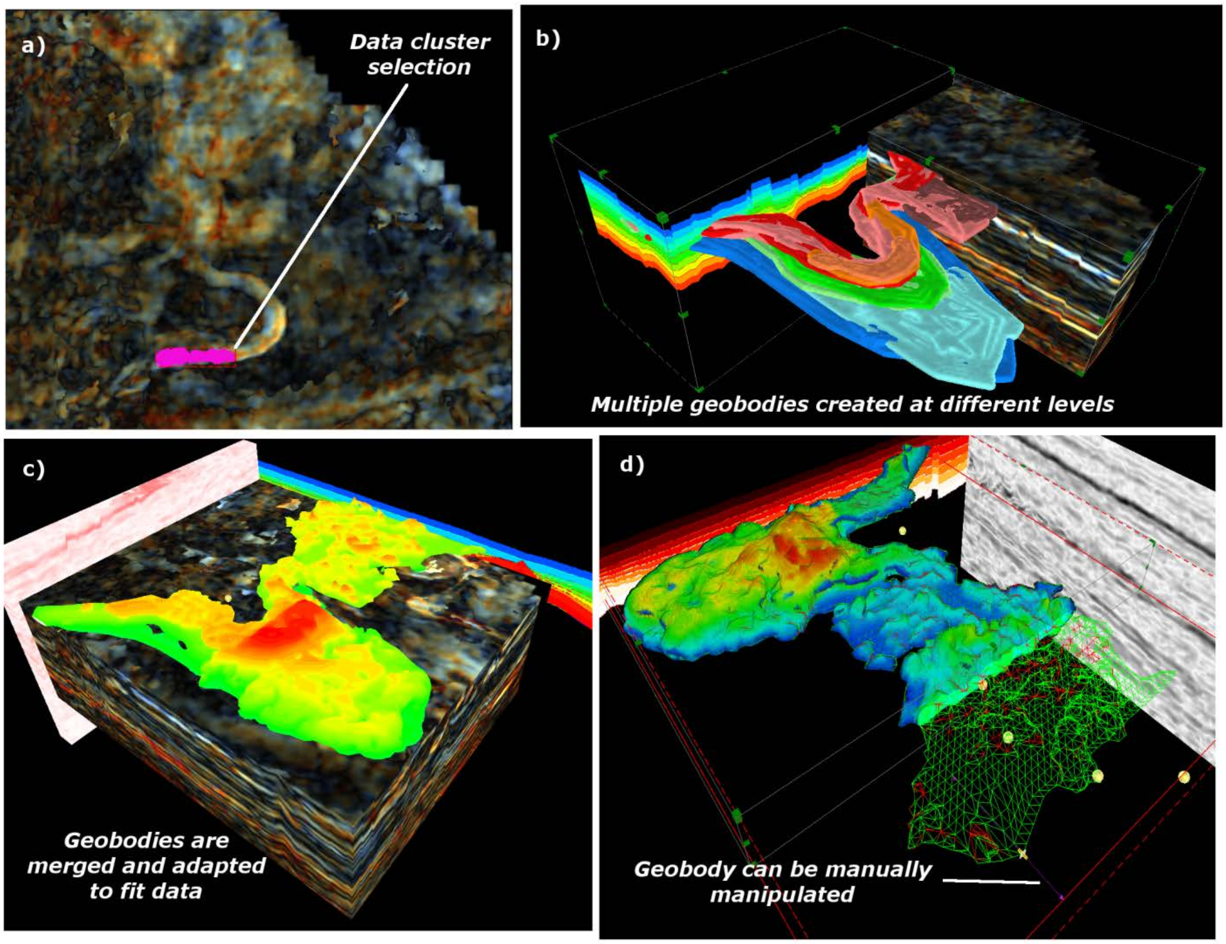

Figure 3: An example workflow demonstrating the use of adaptive geobody technology in the interpretation of a Cretaceous submarine fan system from a HD Frequency Decomposition RGB blend, Barrow sub-basin. a) The adaptive geobody is seeded with a data cluster that gives a statistical representation of the channel and fan system. b) In this example several geobodies have been interpreted at different levels to give a sense of migration of the channel. c) The geobody is adapted to fit the data therefore reducing interpretation bias. d) Ultimately the interpreter has full control over the geobody surface and can manually manipulate to the geobody. When stable the geobody surface is converted to a volume for further computation such as the thickness attribute shown here.