Perception of Visual Information: What are you Interpreting from your seismic?

Authors: Barbara Froner*, Steve J. Purves, James Lowell, Jonathan Henderson
ffA, Generator Studios, Trafalgar Street, Newcastle upon Tyne, NE1 2LA, United Kingdom

Introduction

Advances in the quality of computer visualisation over last 15 years have significantly improved the ability of geoscientists to interpret seismic data. However, the increasing trend to simultaneously interpret multiple attributes has been supported by significant improvements in the levels of quality being achieved in colour data visualisation in the past 5 years [Henderson, 2007]. Such effective use of colour is making composite, chromatic attributes such as RGB blended volumes a mainstay of seismic exploration workflows.

Using colour to represent data has proven to be a powerful tool but one whose subtleties can lead the unaware into potential pitfalls. These stem from the non-linear behaviour of our own visual systems and subtle visual effects that can affect how objects appear to us and potentially bias an interpretive decision.

In this paper we discuss a number of visual effects, namely *luminance and hue sensitivity*, *false colour contours*, *chromostereopsis*, *induced atmospheric perspective* and *simultaneous contrast*. Through visual examples we illustrate how these effects may impact on interpretation.

Human Colour Perception: If You Know It You *Don't* Avoid It

Colour is the visual 'percept' that derives from the way our visual system responds to and elaborates light. In the natural world, more than a trillion levels of light can be registered [Pokorny and Smith 2003], ranging from a dark night scene in the forest to the bright scene of snow in full sunshine.

The visible spectrum includes wavelengths between 400 nm and 700 nm and defines the spectral range that humans can see. Due to the nature of the photoreceptors, our colour discrimination is best in the regions around 480 nm (blue-green hues) and 580 nm (green-yellow hues) [Pokorny and Smith 2003] and we can perceive more variations in the upper part of the visible spectrum (green to red). These physiological parameters affect the way we perceive colour.

Generally, the human brain is remarkably good at distinguishing colours and a trained human eye can distinguish about ten million colours [Judd and Kelly, 1939], as compared to a mere 500 shades of grey [Aidan, 2006]. However, we perceive colour in a non-linear fashion as our visual system adopts a number of compensating mechanisms in order to adapt to different stimuli and visual scenes, resulting in a number of somewhat unexpected visual effects.

What Are We Interpreting? Our Data or Our Colour Bars?

As we continue to use colour in more sophisticated ways within seismic analysis, we need to become more aware of its impact on our interpretive decisions, as visual effects do have a significant impact in the simplest of situations.

The first effect that we discuss is *luminance sensitivity* sometimes also called *intensity sensitivity*. Figure 1 (left) shows a typical grey-scale colour bar found in any interpretation software package. Luminosity increases linearly from left to right. When examining the colour bar and attempting to interpret the position of a middle (50%) grey level, the apparent middle point is often placed well to the right of the centre line; a second obvious effect is that the transition from dark grey to black is more abrupt than is reflected in the profile. The result is that when such a grey-scale colour bar is used to display reflectivity data, seismic sections may appear darker than they actually are giving the impression of lower amplitudes or a dominance toward troughs. The transitions to peaks and troughs is exaggerated and manual interpretation of zero crossing events or other low amplitude features is likely to be error prone.

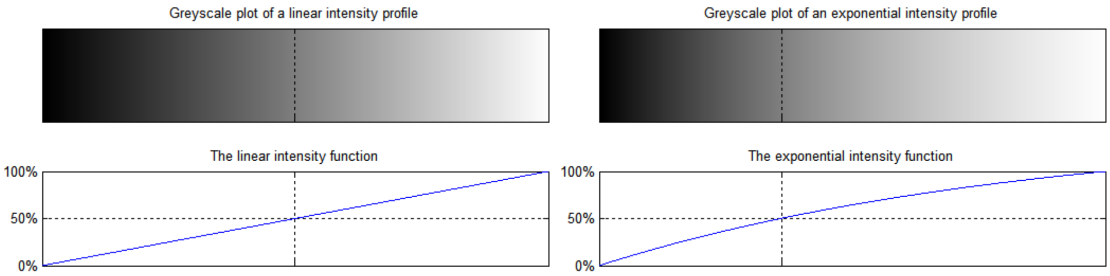

Figure 1 *Linear intensity profile image and corresponding value plot with 50% intensity highlighted (left) versus exponential* $(1\text{-}e^{(1-\alpha x)/\beta})$ *intensity profile that better aligns the apparent middle grey level in the centre of the scale (right).*

On the right of Figure 1, the profile has been modified to better align the middle grey value in the centre of the scale. In this example, we have made a highly subjective adjustment to compensate for the effect. More rigorous studies on the subject have been performed by Welland et al. [2006] and Donnelly et al. [2006].

Similar non-linear effects occur when perceiving different hues on a linear chromatic colour bar; here the impact of the effects can be more striking and misleading. This is due to the non-linear sensitivity of our visual system to different parts of the spectrum and to our visual ability to infer apparent structure from variation in colour [Dejoie and Truelove, 2000].

On the left of Figure 2, the two images have been generated using the same dataset, i.e. a radial pattern decreasing linearly with distance from the centre. When displayed in grey scale the smooth radial variation is clear, in the colour image a number of steps appear. The image has been created using a colour table where hue varies uniformly, similar in nature to the rainbow or spectrum colour bars found in seismic interpretation software packages.

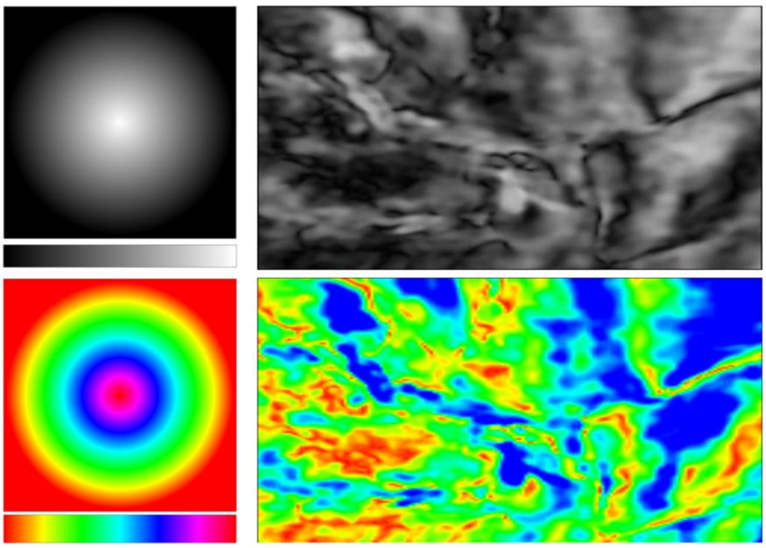

Figure 2 *Left: radial grey-scale pattern uniformly decreasing in amplitude away from the centre (top) and the same image data displayed with a varying hue colour bar (bottom). Right: envelope volume time slice displayed in greyscale (top) and with a spectrum colour bar (bottom).*

Here the effects of using hue variation to visualise attribute data is clear, as a number of *false contours* are now apparent on the radial profile, most prominently around the yellow and cyan hues. This effect becomes more dangerous when the structure of the data is not known in advance as we risk interpreting these false contours as actual data features.

A further effect is also apparent in the hue colour bar of Figure 2, where 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 3, where an RGB image has been created using three of the radial profiles from Figure 2 mapped to the red, green and blue channels of the image. 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.

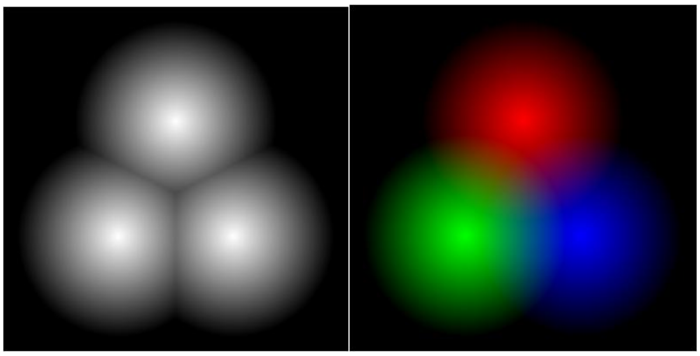

Figure 3 *Left: composite image of three radial profiles viewed with a grey-scale colour bar: the three profiles are clearly symmetrical and of the same size. Right: an RGB image of the same data: the green hue is clearly the most prominent, followed by red and finally blue.*

So far the effects we have highlighted have been related to how colour affects our perception of the underlying image intensity values. However, colour can have a significant impact on depth perception and therefore on how we perceive the position of different objects within 3D scenes [Froner 2011]. Two notable effects are *chromostereopsis* [Allen and Rubin, 1981] and *induced atmospheric perspective* [Guibal and Dresp, 2004]. Figure 4 illustrates these effects. In the left image, the red circle appears to be at a different depth to the blue ring as an effect of the difference in wavelength of the red and blue colours and the chromatic aberrations occurring in the eye; most people perceive the red circle as nearer but the opposite can also occur. Red-green stimuli may also cause this effect. On the right of Figure 4 the brightness of the object affects our perception of its depth with the dimmer circle appearing further away.

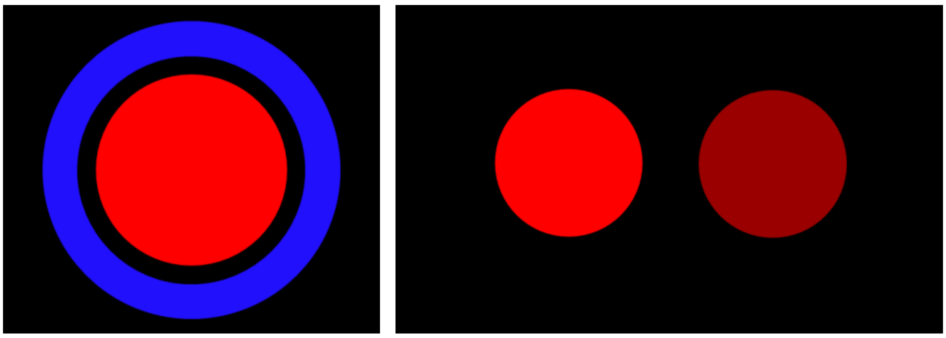

Figure 4 *Chromostereopsis (left) and induced atmospheric perspective effect (right).*

The last phenomenon that we will show is called the *simultaneous contrast* effect, i.e. the tendency of the appearance of an object to be influenced by the visual characteristics of adjacent or intersecting objects. In Figure 5, the two pink central squares are exactly the same colour but appear to be different due to the surrounding colours. Similarly, the grey inner squares in the lower part of the figure are of the same grey shade despite the fact that they appear to be different: the darker the surround the lighter the square.

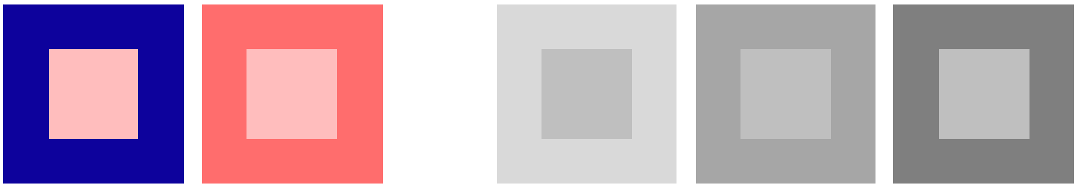

Figure 5 *- Simultaneous contrast effect in chromatic stimuli (left) and black and white stimuli (right). In both cases the inner square appears of different colour depending on the colour of the surrounding square.*

Simultaneous contrast effects can cause significant problems when attempting to visually compare seismic attribute responses in different parts of a large seismic section or extracted map; those responses may in fact be the same, even though they appear to be different because of the colour of the surrounding data.

Conclusions

Colour plays a primary role in seismic interpretation. Improvements in colour visualisation have contributed greatly to simultaneous interpretation of seismic attribute. In this paper we presented a number of phenomena related to colour perception and discussed the effects that these may have on seismic interpretation. Although research has been carried out in this field [Donnelly et al., 2006] [Welland and Donnelly, 2006] current interpretation or visualisation software does little to acknowledge or compensate for these effects. Practically, maintaining an awareness of these effects during interpretation is currently the best an interpreter can do towards compensating for any bias they introduce. However, more investigative work is needed in order to fully understand how to get the best out of our visual system in the context of scientific visualisation and ensure our visualisation systems are designed to eliminate visual bias.

References

R.C. Allen and M.L. Rubin. Chromostereopsis. Survey of Ophthalmology, 26(1), 22-27,1981.
J. Dejoie and E. Truelove, What is meant by “false color”, 2000, From the StartChild website: http://starchild.gsfc.nasa.gov/docs/StarChild/questions/question20.html, Last Accessed: 12th January 2012.
N. Donnelly, K.R. Cave, M. Welland and T.Menneer. Breast screening, chicken sexing and the search for oil: challenges for visual cognition. Geological Society, London, Special Publications 2006, 254:1-5
B. Froner, Stereoscopic 3D Technologies for Accurate Depth Tasks: A Theoretical and Empirical Study, PhD Thesis, Durham University, UK, 2011.
C.R.C. Guibal and B. Dresp. Interaction of color and geometric cues in depth perception:
When does red mean near? Psychological Research, 69(1-2), 30-40, 2004.
J. Henderson, S.J. Purves and C. Leppard. Automated delineation of geological elements from 3D seismic data through analysis of multi-channel, volumetric spectral decomposition data. First Break, 25, 87-93, March 2007.

D.B. Judd and K.L. Kelly. Method of designating colors. Journal of Research of the National Bureau of Standards, 23, 355-366, 1939.

J. Pokorny and V.C. Smith. The visual neurosciences, 2, Chapter 58 – Chromatic discrimination, MIT Press, November 2003.

J. Aidan, Eye Facts: Some amazing facts about your eyes!, 2006, From the Convery Optometrists website: http://converyoptometrists.com/facts.aspx, Last Accessed: 11th January 2012.

M. Welland, N. Donnelly and T. Menneer, Are we properly using our brains in seismic interpretation?, The Leading Edge, 142-144, February 2006.