Perception of Visual Information: What Are You Interpreting from your Seismic?

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The Problem

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 five 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.

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.

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.

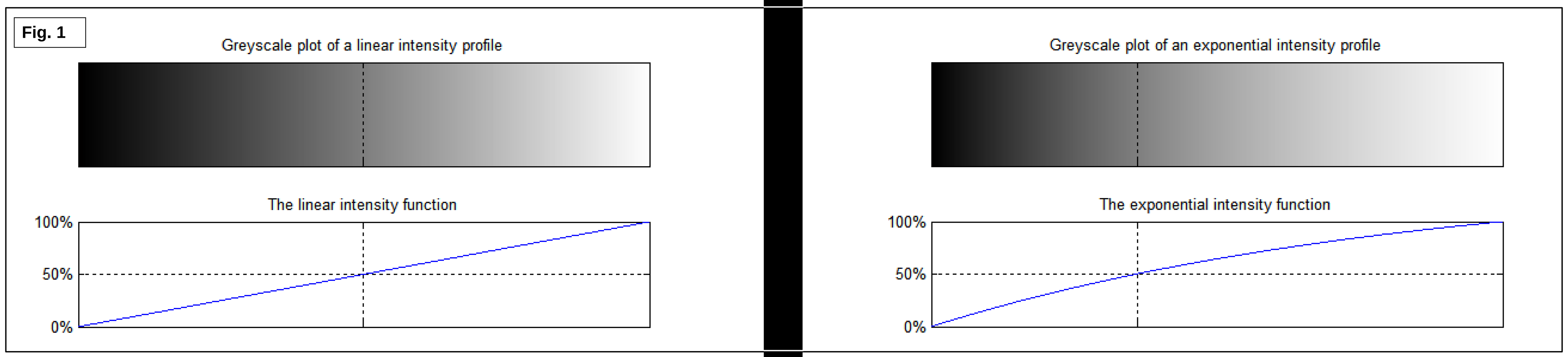
Generally, the human brain is remarkably good at distinguishing colours and a trained human eye can distinguish about ten million colours [Judd and Kelly, 1939], as compared to a mere 500 shades of grey [Aidan, 2006]. However, we perceive colour in a non-linear fashion as our visual system adopts a number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

Luminance Sensitivity

The left side of Figure 1 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.

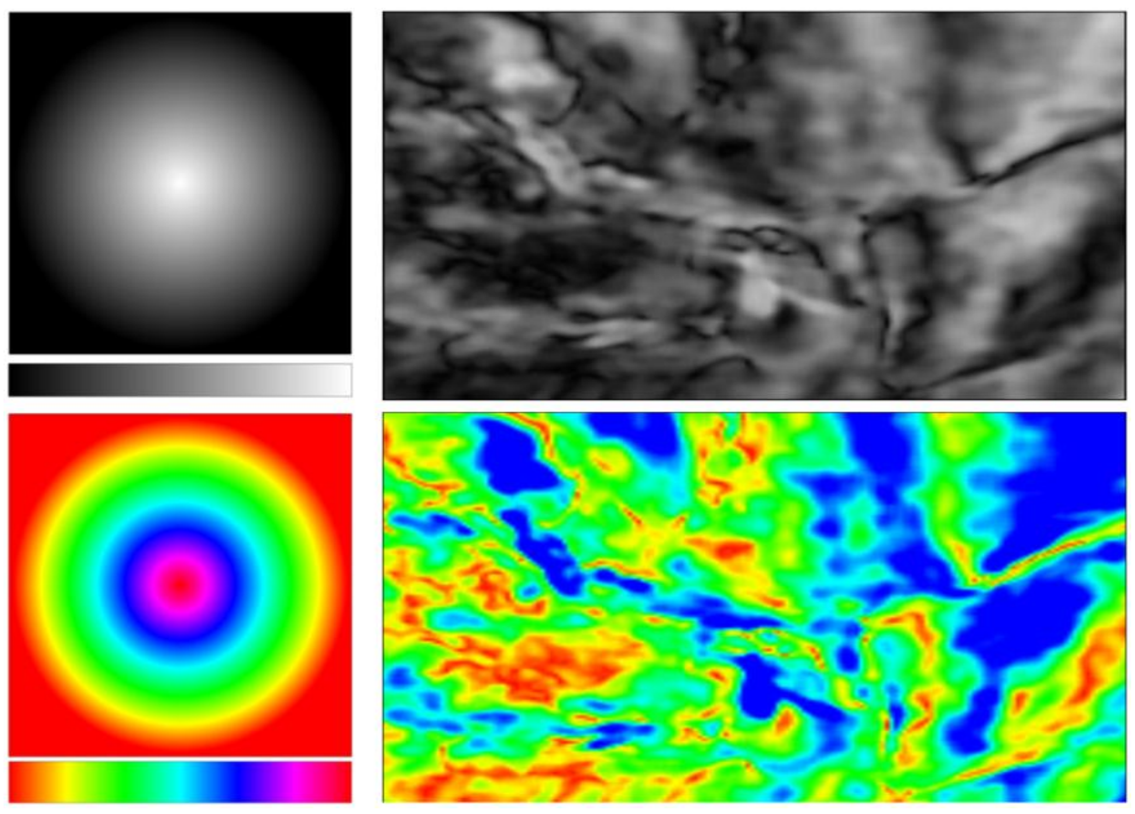
On the right of Figure 1, the profile has been modified to better align the middle grey value in the centre of the scale. In this example, we have made a highly subjective adjustment to compensate for the effect. More rigorous studies on the subject have been performed by Welland et al. [2006] and Donnelly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

Fig. 1



The Non-Linearity of Colour Perception

Fig. 2

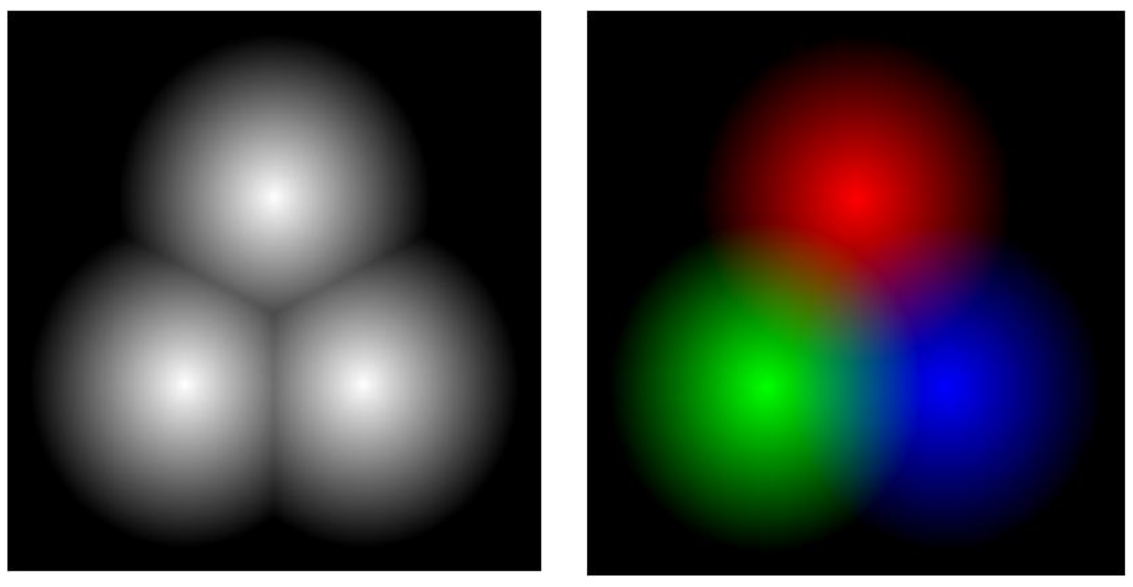


When perceiving different hues on a linear chromatic colour bar, the impact of non-linear visual effects can be more striking and misleading. This is due to the non-linear sensitivity of our visual system to different parts of the spectrum and to our visual ability to infer apparent structure from variation 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.

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.

Fig. 3

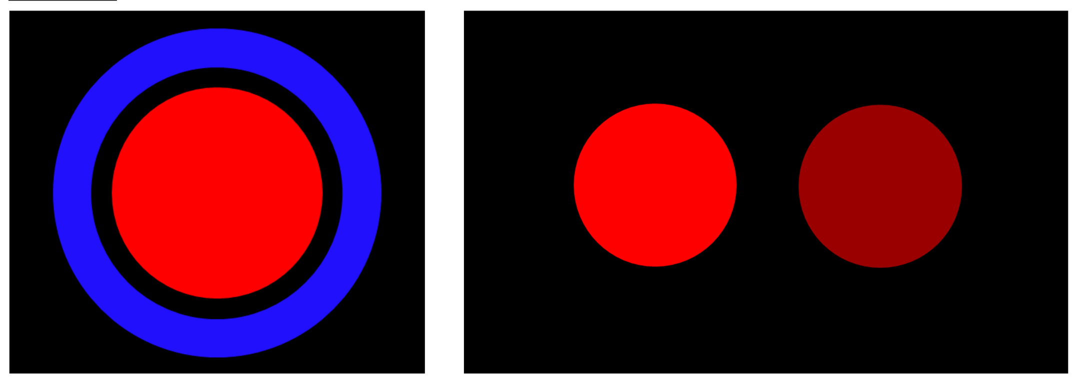


A further effect is apparent in the hue colour bar of Figure 2, where different hues appear more prominent than others (most notable with the green hue) although the colour bar has been constructed uniformly.

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 (right). 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. On the other hand, the same radial profiles viewed with a grey-scale colour bar (left) appear symmetrical and of the same size.

Colour, Position and Depth

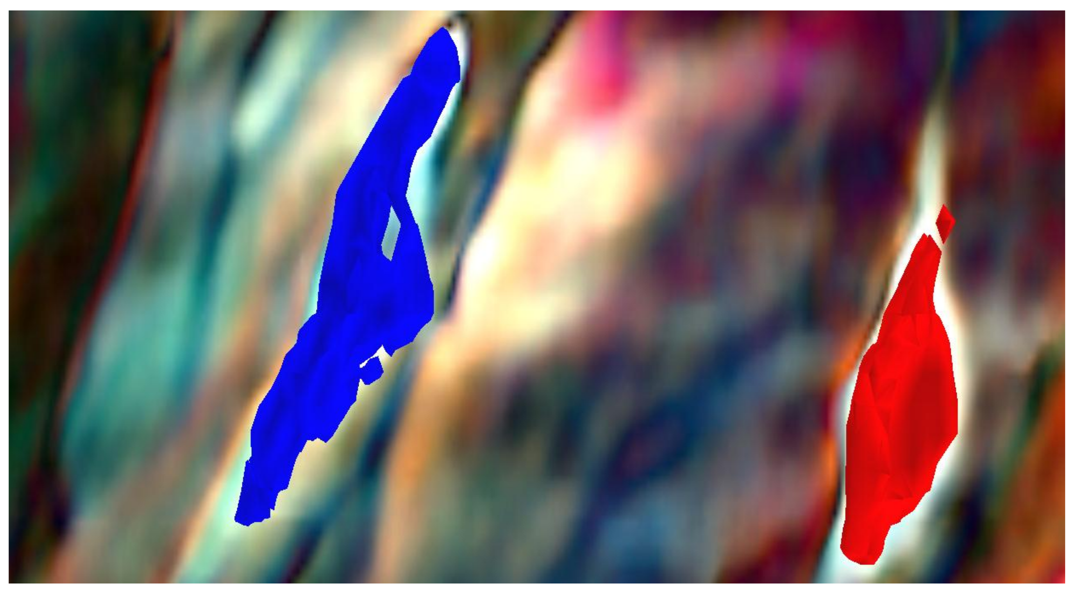
Fig. 4



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. The same effect can be perceived by looking at Figure 5: the two delineated geobodies appear at a different distance from the observer.

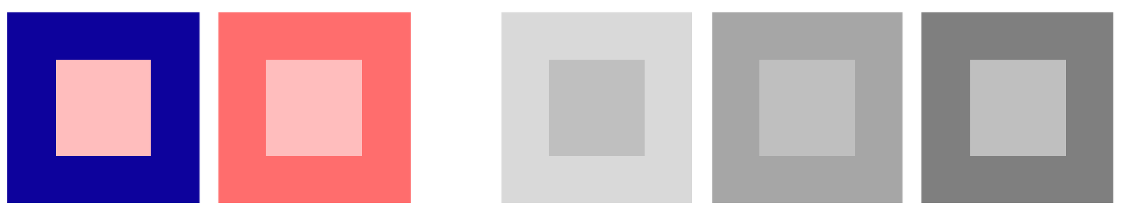
Fig. 5



Simultaneous Contrast

Simultaneous contrast is a visual effect that occurs when the chromatic appearance of an object is influenced by the visual characteristics of adjacent or intersecting objects. On the left of 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 right 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.

Fig. 5



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 attributes. Here 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

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