Short Note

Using the NTSC color space to double the quantity of information in an image

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INTRODUCTION

Geophysical images are, by their nature, intensity images: matrices of real numbers. Thus, representing an image in a color scale will only enlarge the visible dynamic color range without adding any information. But color can be used to encode information taken from a second geophysical image. The combination of the two images produces a meaningful image that can be understood better if two criteria are fulfilled: 1) The information used to create color (referred to from now on as the chrominance image) is entirely separated from the shading (black and white) information (referred to from now on as the luminance image). 2) The frequency content of the chrominance image must be different from that of the luminance image, preferably richer in lower frequencies, since the human eye is less sensitive to high spatial frequency color information. This short note will show how to combine two intensity images (i.e. a seismic section and a velocity model) into a single color image, using the NTSC (National Television Standards Committee) color space.

NTSC AND ITS PROPERTIES

The human eye has receptors for three primary colors - red, green and blue (Ruston, 1975). Thus, all color spaces have three dimensions. There are several color spaces available, the most widely known being RGB (Red-Green-Blue), HSV (Hue-Saturation-Value) and NTSC. NTSC is the color space used for television broadcast in the United States, and the only space among the above-mentioned ones that realizes a complete separation between the luminance and the chrominance information. NTSC has this property because when it was introduced, it had to separate the information used by the monochrome TV receivers from the supplementary one used by color receivers. (Blinn, 1993). The components of the NTSC color space are Y (the luminance component), I (the cyan-orange component), and Q (the green-purple component). There is a link between I and Q and the more intuitive hue and saturation: components I and Q have the property that, when modulated in quadrature in respect to each other by the 3.58

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MHz TV carrier wave and then summed, they form a signal (chrominance) whose magnitude represents the color saturation and whose phase represents the hue (Kuhn, 1996).

Saturation and hue are directly present as components of the HSV color space, and their meaning is more intuitive than that of the NTSC I and Q axes, so why not use HSV instead then? We must not not confuse between meaningfulness of the axes and meaningfulness of the object represented using these axes: because the separation between the luminance and chrominance information is not complete in HSV, those parts of the luminance image that are dark are not colored effectively and are rendered deep tones of gray, and ultimately a black pixel in the V component of HSV results in a black spot in a final image, thus not in the desired color. HSV images with the V component given by the luminance, and the H and S by the chrominance, will thus lack the ability to render fine detail, and the continuity of the color field will be broken by the dark pixels. The meaning of the dimensions of the HSV color space is easy to understand, but the final target, an image produced by taking the V component from one intensity image and the H and S components from the second intensity image, is harder to interpret than an image created in a similar manner using the NTSC color space. The exact way of constructing such an image using the NTSC color space is detailed in the next section.

CREATING THE COLOR IMAGE

The input data in this process consists of the luminance and the chrominance images. Both are stored in real-valued, normalized matrices (respectively L and C). The output will be a RGB image with three components: R,G and B, obtained by transforming a NTSC image composed of the matrices Y, I and Q. The first step is thus transforming L and C into the NTSC components Y, I and Q through a colormap operator (actually, a set of three related operators)

$$Y = M_1 L \tag{1}$$

$$I = M_2 C \tag{2}$$

$$Q = M_3 C \tag{3}$$

The next section will elaborate on the construction of the three operators. Once the Y, I and Q matrices are obtained, we basically have the color image, but since computer devices work with RGB, we usually need to transform to RGB with the equation

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.000 & 0.956 & 0.621 \\ 1.000 & -0.272 & -0.647 \\ 1.000 & -1.106 & 1.703 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix} \tag{4}$$

before writing the file to disk (Kuhn, 1996).

BUILDING THE THREE COLORMAP OPERATORS

In simple cases M_1, from eq. (1), is a histogram equalization operator (for contrast adjustment) or only the identity matrix, and M_2 and M_3 represent raising each point in the matrix to a
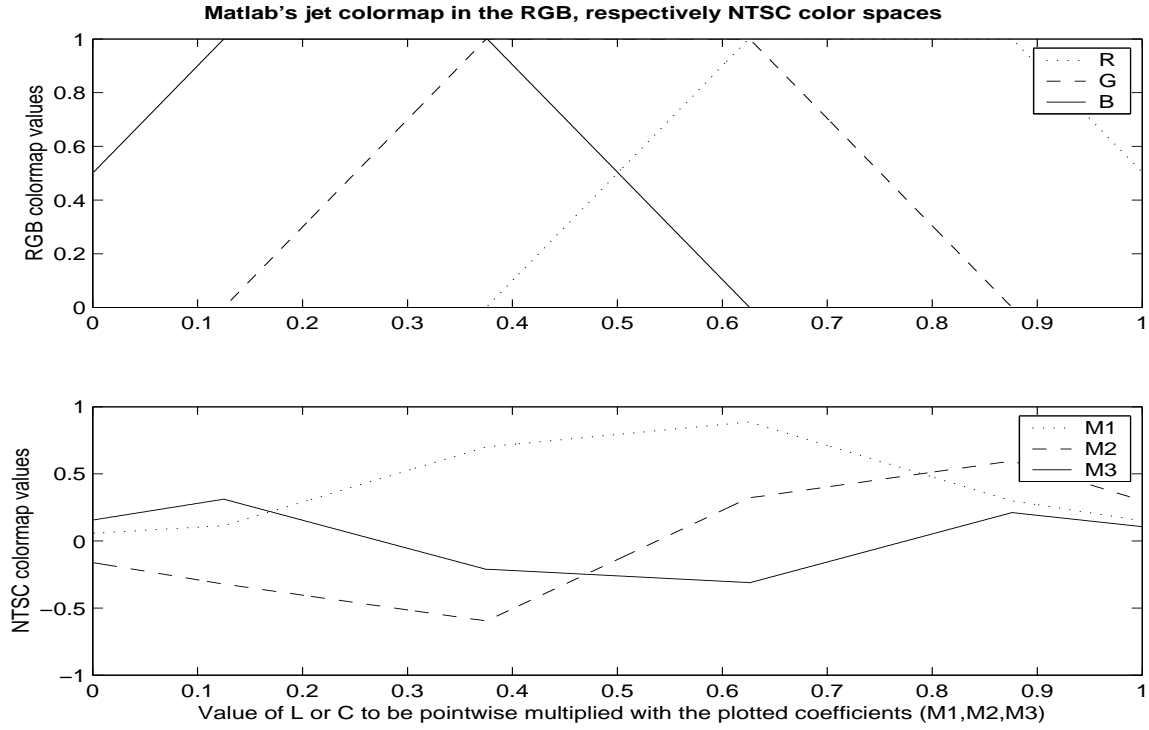
Matlab's jet colormap in the RGB, respectively NTSC color spaces

Figure 1: The main part of the operators M_1, M_2 and M_3 consists of the transformation from RGB to NTSC of a common colormap $\boxed{\text{nick1-jetcolormap}}$ [CR]

power. Several variations that would result in monochrome colormaps suitable especially for highlighting linear, coherent shapes (fig. 6) can be imagined. If a more complex colormap is desired, the three operators must be constructed by transforming common RGB colormaps to NTSC, with the equation:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & 0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{5}$$

An example is provided in Figure 1 for Matlab's jet colormap.

APPLICATIONS

The use of color for highlighting linear objects is illustrated by figure 6. (All the color images were grouped at the end of the paper due to printing necessities). Luminance is given by a simple synthetic reflectivity model, and the result of applying a local monoplane anihilator to the luminance image constitutes the chrominance (fig 2). The two images were generated with code from Claerbout (2001). It must be noticed that the colored pixels do not obscure the local features of the image (the highlighting is not "drawn over" the luminance image), but they have the shading given by the synthetic model itself.
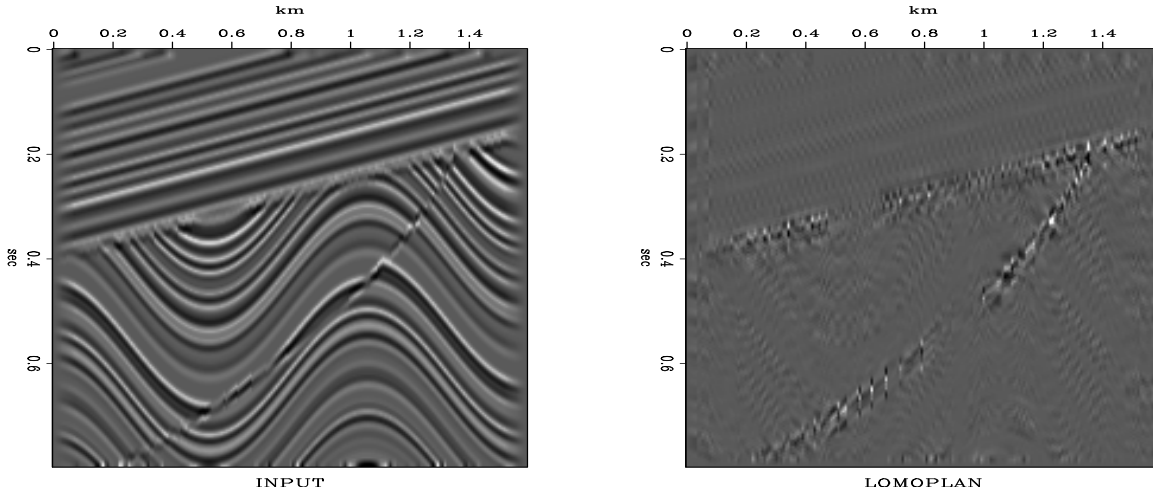
Figure 2: Luminance (left) and chrominance (right) for Fig. 6 nick1-lomoplan [ER]

One of the best uses of the tool described in this paper is representing both the velocity model and the seismic section in the image. Fig. 3 represents the velocity model (chrominance), Fig. 4 the seismic section, and Fig. 7 the result of applying the above described algorithm to the two images. Operator M consisted in this case of a histogram equalization for the luminance, then of a transformation to Y, I and Q through the components of the jet colormap (fig. 1).

Figure 3: The velocity model (chrominance for Fig. 7) nick1-chrominance_VEL [CR]

Dip fields, described in Fomel (2000) can be helpful in interpreting seismic data. Fig. 5 shows the value of the strongest dip in the corresponding point of Fig. 4, computed with the programs accompanying Fomel (2000). It is not easy to visually correlate the features in the two images. But when the dip field is used for chrominance, and the seismic image for luminance (with the operator M containing a 97 percent clip before applying jet colormap), the unconformities, as well as the areas with conflicting dips, become highly visible. (Fig. 8)
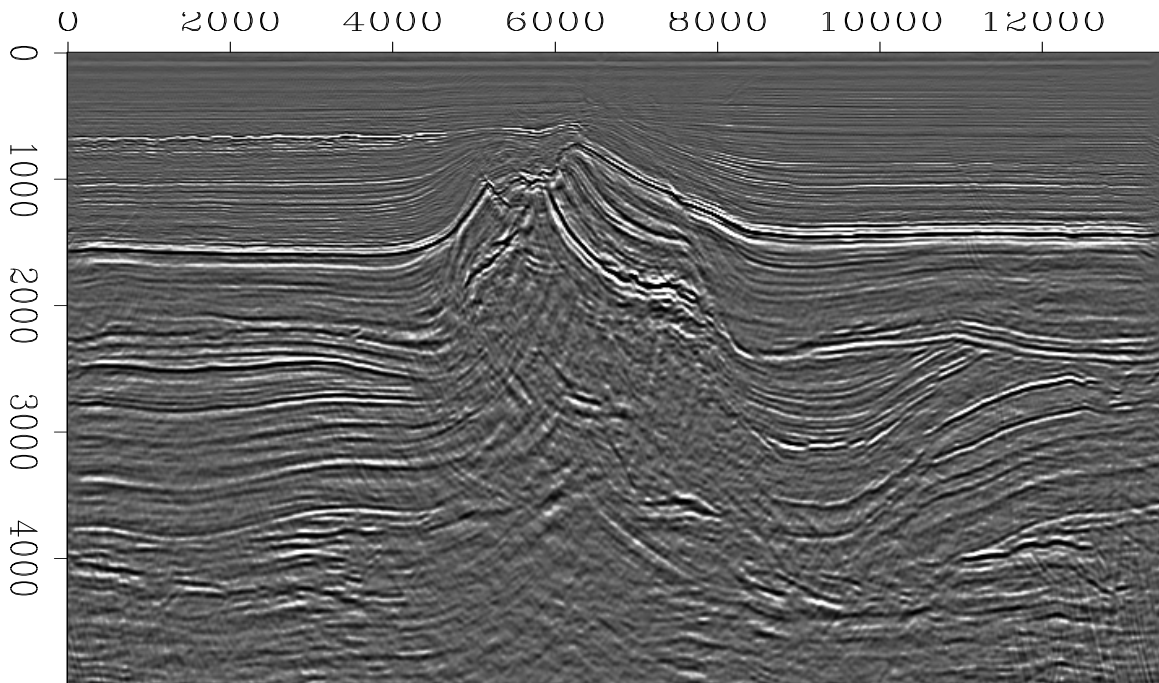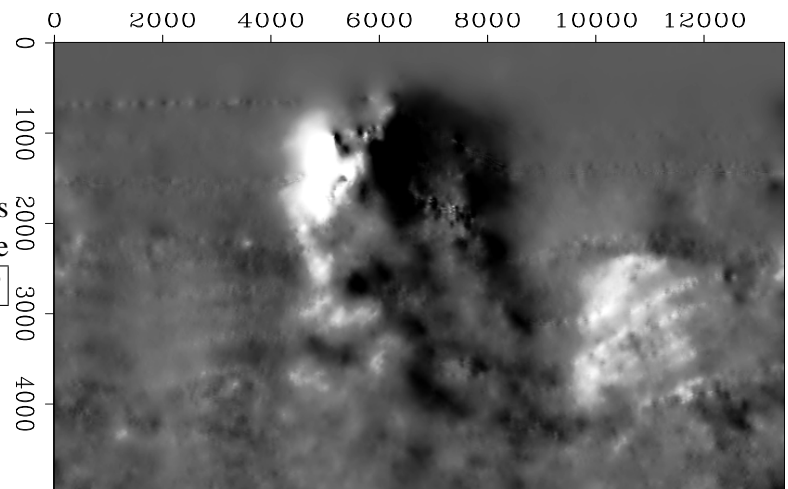
Figure 4: Luminance for Fig. 7 ⟨nick1-luminance_VEL⟩ [CR]

Figure 5: Dip field of Fig. 4. This image will be used as chrominance for Fig. 8 ⟨nick1-chrominance_DIP⟩ [CR]
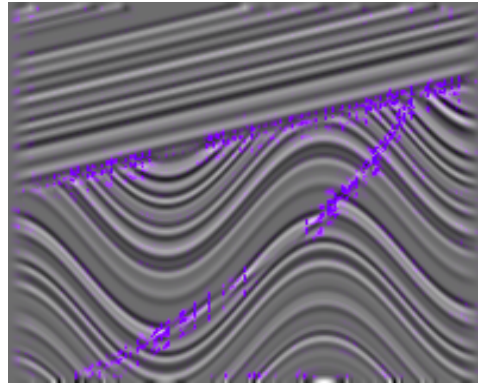
CONCLUSIONS

NTSC is the color space with the best separation between the luminance and the chrominance information. It is useful for enhancing the interpretability of geophysical images in a simple, intuitive way, easy to implement into software and computationally inexpensive. Several other examples can be found at http://sepwww.stanford.edu/sep/nick/research/NTSC/ . Future work include implementation of this feature into SEPlib.

REFERENCES

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Kuhn,   K.   J.,   1996,   Conventional   analog   television   -   an   introduction: http://www.ee.washington.edu/conselec/CE/kuhn/ntsc/95x4.htm.

Ruston, W., 1975, Visual pigments and color blindnes: Scientific American, pages 64–74.

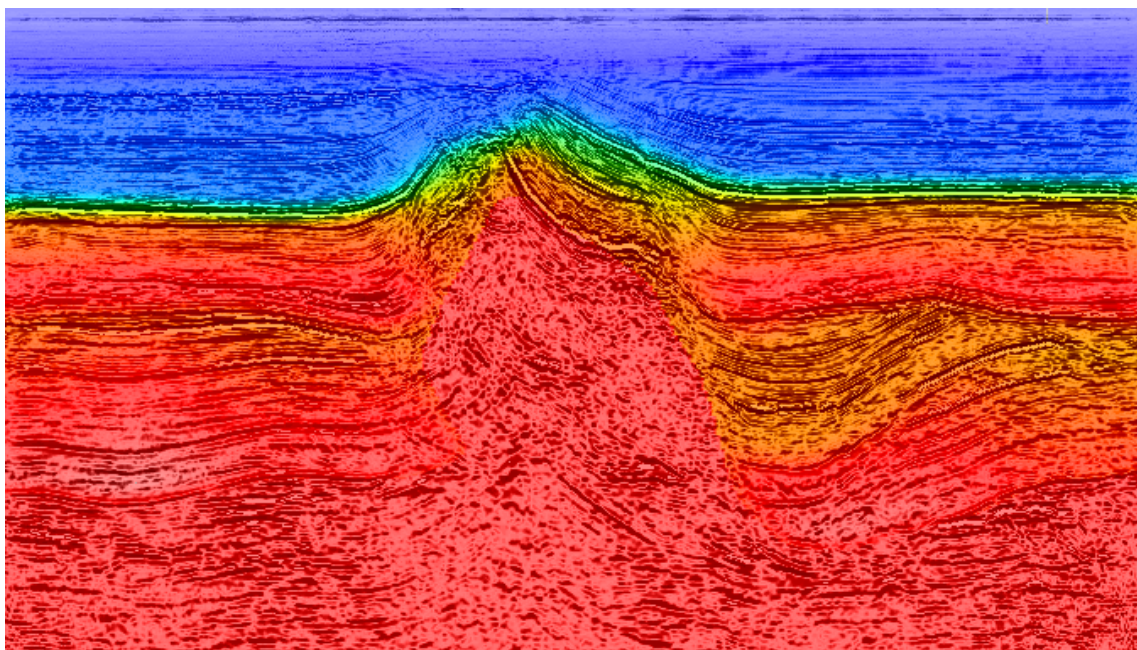Figure 6: Image built using NTSC, the color highlights the discontinuity in the seismic section nick1-lomocolor [CR]

Figure 7: Composite image with shading taken from fig. 4 and color from Fig. 3. Electronic viewing of the image is highly recomended in order to show the full power of the technique described in this paper. nick1-color_VEL [CR]
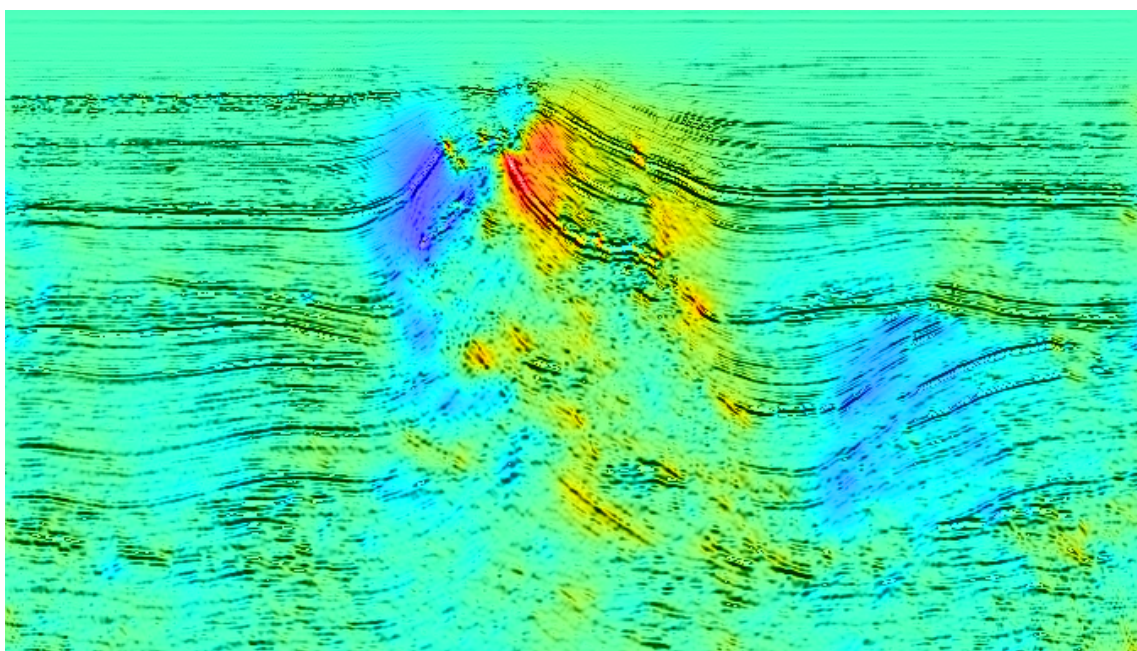

Figure 8: Coloring the dips on the seismic section: composite image with shading taken from Fig. 4 and color from fig. 5. Electronic viewing of the image is highly recomended in order to show the full power of the technique described in this paper. nick1-color_DIP [CR]