Digital enhancement of pictographs from Baja California

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Abstract

Digital enhancement can make visible faded pictographs that have become nearly invisible to the human eye. This can be an aid to rock art researchers interested in documenting and studying faded pictographs. The DStretch program (www.DStretch.com) is designed specifically for this purpose. In this article I will explain how DStretch does its enhancement and present examples of its use from pictograph sites in Baja California.

Introduction

The advent of digital cameras has created a revolution in photography. The best digital cameras take pictures that equal or surpass film. Digital images can be manipulated and enhanced in ways that are impossible to reproduce with film in the darkroom. Rock art researchers were quick to use the digital image manipulation tools that appeared and achieved striking results (Mark and Billo 2002). The enhancements can bring out pictograph elements that are nearly invisible to the human eye.

Enhancement is possible because of peculiarities in the human visual system. Color is processed in a different part of the brain than luminance (grayscale), and human color acuity is much coarser than luminance acuity (Livingstone 2002:165). Moreover, we are more sensitive to color contrast changes than to broad swatches of color. As the color of a painted area fades over time, there is less contrast between it and the background. Eventually luminance differences in the background unrelated to the painting can dominate our visual perception. It becomes difficult to comprehend the totality of the composition, although faint traces of paint can be seen.

Digital images can hold much more color information than is necessary for our color perception system. This fact is used by image compression schemes (such as color TV or jpeg image compression) to reduce data size (Livingstone 2002:192). Thus the data recorded in a digital camera or a scan of a color photograph can hold “invisible” information that enhancement can bring out. Increasing the contrast of faint image data can make pictograph composition comprehensible. Caution: applying too much jpeg compression can destroy this color information.

The DStretch program is an image enhancement program written specifically for rock art research. It is based on a technique, decorrelation stretch, which was first developed for the enhancement of multispectral imagery from aerial photography (Gillespie et al. 1986). Robert Mark first suggested the technique to me in 2004. He had seen decorrelation stretch used by NASA to enhance photography from the Mars Rover mission (NASA press release, July 1, 2004) and felt it might work well on rock art.

One of my first successful enhancements, and one that convinced me of the usefulness of the technique for rock art, is shown in Figure 1. In December 2004, I visited Cueva San Borjita, a

Figure 1. Cueva San Borjita, near Mulege, B.C.S. Left: original photo; center: drawing by Campbell Grant 1974; right: DStretch YDS enhancement.

well-known Great Mural site near Mulege, Baja California Sur. I took the photograph in Figure 1 (left) because I felt there might be a faint *mono* there. (*Mono* is the word used to describe Great Mural anthropomorphic figures.) Decorrelation stretch (right) brings out the faint yellow *mono*. In 1974, Campbell Grant included a drawing of the entire ceiling in his book *Rock Art of Baja California* (Grant 1974). As a confirmation of the difficulty of seeing this yellow *mono*, Figure 1, center shows a portion of Campbell Grant's drawing of the cave paintings. Without DStretch, Grant missed the *mono*.

It was exciting for me to see the San Borjita *mono* suddenly appear in the enhanced image. That excitement has been repeated many times as I have applied DStretch to photos of rock art sites. Faint traces of paint barely visible on a wall will transform into complex designs (Figure 2). This has changed my experience of rock art and added to my appreciation of it.

DStretch is available as a plugin to the ImageJ program. Wayne Rasband has developed ImageJ at the United States National Institutes of Health. It is in the public domain and available on the Internet at http://rsb.info.nih.gov/ij/. DStretch is also freely available. For more information on how to get DStretch, visit http://www.dstretch.com/.

Explanation of decorrelation stretch

Decorrelation stretch is an enhancement technique based on the Karhunen-Loève transform from probability theory. Statistics are collected on the distribution of colors in the image and a transformation is calculated that decorrelates the colors. After transformation, the colors are stretched to equalize variances; then the inverse transformation is used to map the colors back to the original space. The result is a false color enhanced image. The application of the inverse transform results in more realistic colors. It also makes the enhancements more stable in the sense that similar images will give similar enhancements. However, there are cases in which not using the inverse transform produces superior results. In the DStretch program I allow the user to apply the inverse transform (which I call "mapping back"), or not.

This process produces an enhancement that is different from typical image enhancements,

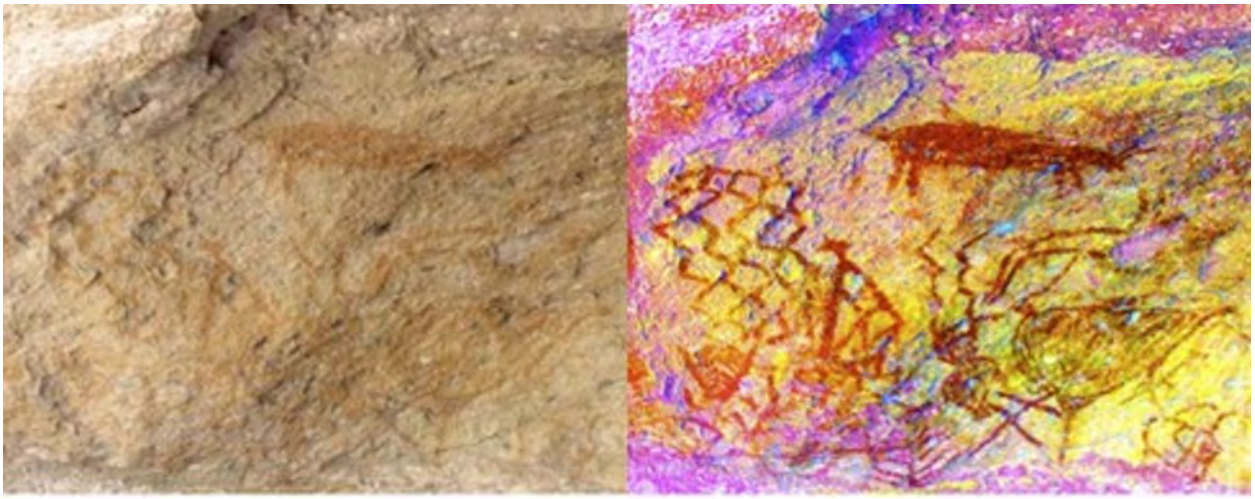

Figure 2. Las Tinajitas near Mission San Borja, Baja California. Right: original photo; left: DStretch CRGB enhancement.

as can be seen in Figure 3. The original photo and the conventional image enhancements of contrast increase and saturation increase are above. Compare them to the lower row of decorrelation stretch examples. One way to think of the decorrelation stretch process is that the image is transformed in such a way that stretching in the transformed space and then transforming back gives different results than an enhancement in the original space.

One advantage of decorrelation stretch is the nature of the algorithm. Other image enhancement techniques rely heavily on expertise in navigating the complexities of a photo manipulation program. Decorrelation stretch analysis is automatic. This is not to say that decorrelation stretch can give only one result. The colors of the resulting image can depend on the colorspace the decorrelation is done in and other factors. Expertise in manipulating the decorrelation stretch parameters can be rewarded by superior enhancements, but the basic technique is simple to use.

Because of the dependence of decorrelation stretch on colorspace and to explain some of the terms used to label enhancements, some background explanation of colorspace terminology is appropriate. A color image can be represented by different systems of primary colors, but always three primaries are needed. For instance the colors in a TV or computer monitor or in a digital camera are created using different intensities in tiny red, green or blue picture elements. This is the RGB colorspace. In printing, the primaries used are cyan, magenta, and yellow. This is the CMY colorspace. For transmission over the airwaves, the colors are transformed into a different colorspace, the YUV (or the similar YCbCr) system. Here the Y channel is luminance (red plus green plus blue) and the U (or Cb) and V (or Cr) channels encode color differences (blue-luminance and red-luminance respectively). The YUV colorspace was developed to minimize the bandwidth requirements of the TV signal and mimics the human visual system (Livingstone 2002). An even closer approximation to the human system is the LAB colorspace developed in 1931 by the Commission International de l'Eclairage (known as the CIE). The different decorrelation stretch enhancements in the lower row of Figure 3 use different colorspaces.

The end result of the decorrelation stretch analysis is a 3-x-3 matrix of numbers that determines how to transform input values of the three primary colors of the colorspace (a 3-dimensional vector) into output values (also a 3-dimensional vector). Once calculated for one

Figure 3. Rockshelter near Cataviña, Baja California. Upper row: original photo, increased contrast, increased saturation; lower row: decorrelation stretch YDS, LAB, CRGB.

image, the matrix can be used on others and sometimes can produce interesting enhancements. The CRGB enhancement in the lower right of Figure 3 was produced using a matrix calculated for another image.

The DStretch program

DStretch provides enhancement tools for rock art researchers based on the decorrelation stretch algorithm. It can perform decorrelation stretch in a variety of colorspaces, including RGB, LAB and YCbCr. Modifications of standard colorspaces are also available and have been found to be very useful. The YDS colorspace is a modification of the YUV colorspace that emphasizes yellows. The LAX colorspace is a modification of the LAB colorspace that emphasizes reds.

Figure 4 gives an indication of the enhancement differences resulting from the use of different colorspaces. In the upper right is a YDS enhancement that does a good job of bringing out the yellow anthropomorph on the left and the yellow circle at center left. The LAB enhancement in the lower left does less well on yellows and reds, but does better in preserving whites and blacks, especially the white element at lower center. Finally, the lower right is the

Figure 4. Vallecitos Indio rockshelter near Mexicali, Baja California. Upper left: original photo; upper right: DStretch YDS; lower left: DStretch LAB; lower right: DStretch CRGB.

CRGB enhancement that was derived from a decorrelation stretch in the RGB colorspace. It performs excellently on red pigments. This figure demonstrates a truth about image enhancement. Often the enhancement of one range of colors comes at the expense of others. A technique that does well on yellows or reds may not do well on whites and blacks. For this reason, DStretch offers a number of colorspace possibilities and other tools for optimizing enhancement.

Figure 5 from Cueva Boca de San Julio near Cueva Pintada in the Sierra de San Francisco illustrates one of the tools available in DStretch: the hue shift tool. This tool allows all the colors in an image to be shifted in hue, while keeping saturation and luminance the same. In the original image, a *mono* can be faintly seen behind the large deer. The CRGB enhancement does not help with the *mono*; however, the YDS enhancement does bring it out. By shifting the red hues to green, there is better contrast and the black *mono* is much more visible. The decorrelation stretch algorithm does not know what colors contrast well for humans, and sometimes the enhancement colors do not contrast well or are not pleasing to the eye. Using the

Figure 5. Cueva Boca de San Julio, Baja California Sur. Upper left: original photo; upper right: CRGB; lower left: YDS; lower right: YDS hue shifted 123 degrees.

hue shift tool can help with these problems.

My goal in developing DStretch has been to find novel ways of enhancing rock art, and I have experimented with colorspaces and the decorrelation stretch algorithm with this in mind. I noticed early on that the RGB colorspace could sometimes give striking enhancements of red pictographs if the inverse transform in the decorrelation stretch was not applied. This led me to add two features to DStretch. First, I added a checkbox to the interface that can disable the use of the inverse transform, called “mapping back” in the program. Second, the matrix that defines a particular enhancement can be stored for later use.

I found a particular matrix from an RGB enhancement (without the transform back) that performed very well on red pigments. It works so well and red pigments are such a common element at pictograph sites that I added a special CRGB button to the program that uses that matrix for enhancement. This matrix is used in most of the figures in this paper because of the excellent contrast it provides for red pigments. Figure 6 Illustrates the difference between using the automatic RGB transforms on an image and the stored CRGB matrix. Notice the three *monos* at right with overlapping arms. We will see another example of this composition in the next section.

I began a search for other matrices that might provide useful enhancements. I have built

Figure 6. Panel near Rancho Campo Monte, Baja California. Upper left: original photo; upper right: RGB not mapped back; lower left: RGB mapped back: lower right: CRGB.

into DStretch one such matrix for each colorspace. Figure 7 shows the built-in LAX matrix used on an image from a Great Mural site near Mission Santa Gertrudis, Baja California. This once-spectacular site has faded greatly, but DStretch can bring back some of the beauty in the ancient images.

The large number of choices available in DStretch can be intimidating, but in practice there are only three enhancements that I suggest should be tried first: the YDS and LAB colorspaces and the CRGB matrix. I have made separate menu items for these enhancements so the complications of the DStretch user interface can be skipped. Each of these enhancements can be applied to an image in a couple of mouse clicks.

Great Mural overpainting: using DStretch to clarify composition

Harry Crosby has remarked on the common occurrence of overpainting in Great Mural art. He feels this indicates the painters valued the act of painting in certain places more than they valued the show that resulted (Crosby 1997:70). However certain patterns of overpainting are repeated in Great Mural art and this suggests that some overpainting may have been intentional

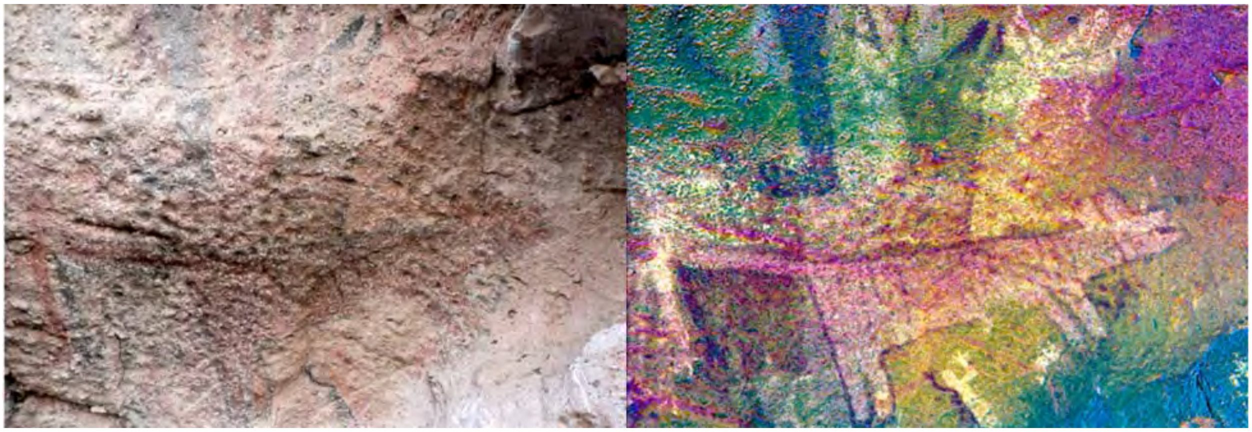

Figure 7. Rockshelter near Mission Santa Gertrudis, Baja California. Left: original photo; right: enhancement using LAX built-in matrix.

Figure 8. Panel near Rancho Campo Monte, Baja California. Left: original image; center DStretch YDS; right: DStretch CRGB.

and have had meaning to the painters. Additionally, the extremely conventionalized portrayal of animals and humans in Great Mural art (Crosby 1997:211) suggests that conventions may also have governed the overpainting. DStretch can be useful in the study of this question.

We have already seen several examples of Great Mural overpainting. In Figure 1, the yellow *mono* brought out by DStretch was carefully placed so that its body did not overlap the bodies of the surrounding *monos*, but arms and legs may overlap. In Figure 5, a small *mono* is placed behind a larger deer. A very similar composition will be shown in Figure 8. *Monos* with overlapping arms appear in Figure 6.

Figure 9 from the justly famous south gallery of Cueva Pintada in the Sierra de San Francisco provides another overpainting example. The detail in Figure 10 is a confusing jumble of overpainted figures. DStretch CRGB helps to decipher the overpainted figures. This enhancement emphasizes red pigments and makes the black painting nearly invisible. This brings out details of the painting of the deer and the *monos*. In the enhancement one can see a line of

Figure 9. South gallery of Cueva Pintada, Sierra de San Francisco, Baja California Sur.

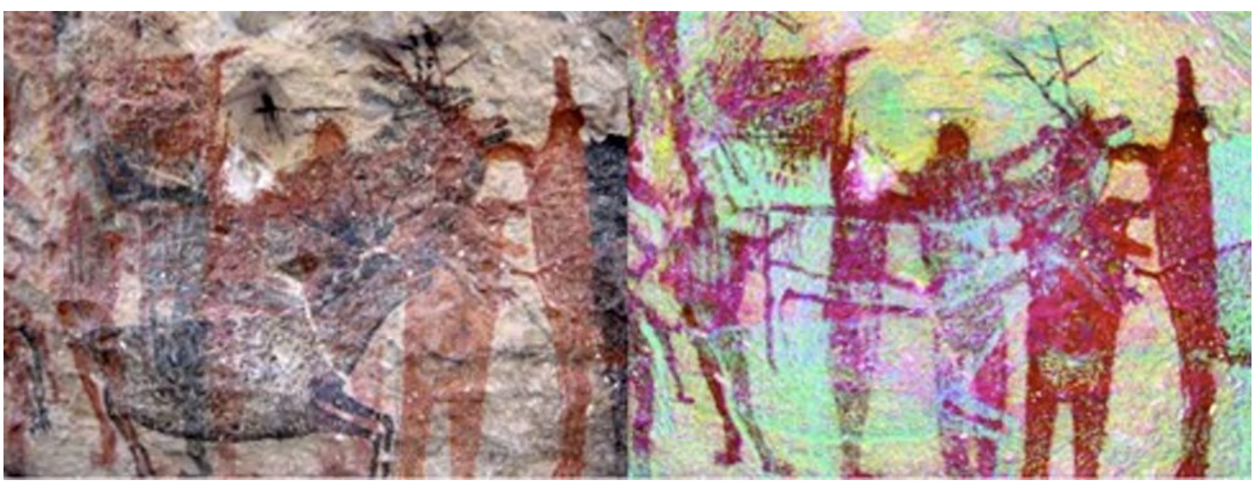

Figure 10. Detail of south gallery. Left: original photo; right: DStretch CRGB enhancement.

monos behind the deer each with arms overlapping the others. This line is a continuation of one crossing much of the gallery as can be seen in Figure 9. This pattern suggests that some sort of intention was involved in the placement of the figures.

Figure 8, from a panel near Rancho Campo Monte, Baja California gives another DStretch enhancement example. In this detail from a larger panel is a very faint deer figure with superimposed *mono*, very similar to Boca de San Julio. Interestingly, the style of the deer and *mono* seem similar to Great Mural sites far to the south, whereas Campo Monte is near the northern limits of Great Mural art. The placement of the *mono* inside the deer is clearly intentional.

Summary

As pictographs fade with age, it becomes harder for our brains to make out the original composition. Even though the pigment is faintly visible, our minds require a certain threshold of contrast before we can appreciate the composition. This effect can be seen in many of the figures in this paper, Figure 2 is a good example. Increasing the contrast with DStretch causes compositions to become comprehensible, as if by magic.

Poor preservation and overpainting can present a challenge for those attempting to study or document rock art sites. DStretch is designed to help. DStretch is the first image enhancement program specifically designed for the needs of rock art research. Its automatic use of the decorrelation stretch algorithm can give excellent results even when used by researchers who are not experts in image enhancement software.

Over the years I have developed a great love and appreciation of the Baja California peninsula. The people, the landscape and the rock art are exceptional. I hope DStretch can make a contribution to the understanding of the human history there.

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