Using Decorrelation Stretch to Enhance Rock Art Images

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Abstract

Decorrelation stretch, an image enhancement technique first used in remote sensing, can be usefully applied to rock art. In pictograph images from Baja California, California, and Nevada I demonstrate its ability to bring out elements nearly invisible to the eye and to improve visualization of difficult sites. A decorrelation stretch plugin to the imaging program ImageJ is available from the author, free for personal use.
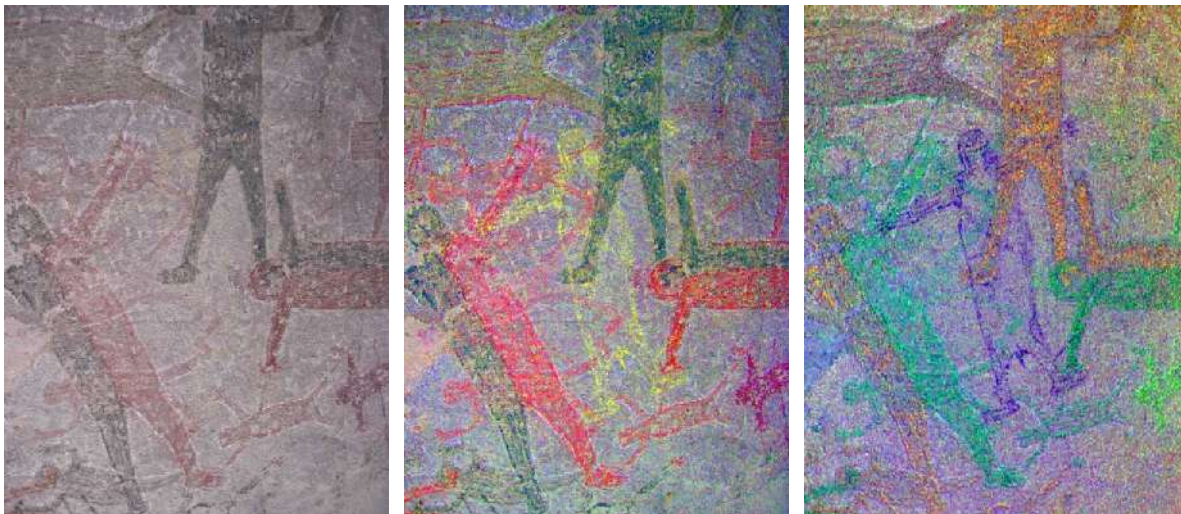
Figure 1 Cueva San Borjita, Baja California Sur. Left: original, Center: decorrelation stretch YDS mapped back, Right: decorrelation stretch RGB, not mapped back, hue shifted.

Introduction

Decorrelation stretch has been used in remote sensing to enhance multispectral images [2].   NASA has used it to enhance Mars Rover images.

I have implemented this technique in the DStretch plugin to ImageJ [1]. The plugin has options intended to be useful in rock art research.

DStretch is a useful tool for archaeologists involved in the study and documentation of rock art. Its enhancement techniques can bring out very faint pictographs almost invisible to the eye. Subtle differences in hue are enhanced which can give clues to superposition. Pictographs can be enhanced for publication or presentation to viewers not capable (or inclined) to puzzle out faint elements. Use of DStretch can be as simple as just hitting a button, but it also contains sophisticated tools for the manipulation of false color images. Because the enhancement works by increasing differences in hue, the technique gives better results

for pictographs than petroglyphs.

Theory

The technique consists of applying a Karhunen-Loeve transform to the colors of the image. This diagonalizes the covariance (or optionally the correlation) matrix of the colors. Next the contrast for each color is stretched to equalize the color variances. At this point the colors are uncorrelated and fill the colorspace. Finally the inverse transform is used to map the colors back to an approximation of the original. Other names for related techniques are Principal Components Analysis and Hotelling transformation [2] [3]. The decorrelation stretch calculation produces a 3x3 matrix that is then applied to the colors in the image. DStretch supports several different colorspaces (see below). The image is converted to the colorspace, the calculation and enhancement is performed, and then the colors are converted back to RGB before writing into a digital image.

Figure 2 Tule River Painted Rock. (TUL-19) Left: original, Center: decorrelation stretch YDS mapped back, Right: CRGB.

Observations

Each image enhances differently depending on the distribution of colors, colorspace chosen, and whether the inverse transform is used to map the decorrelated colors back. After some experience with the algorithm I am beginning to see some trends, but my observations must be considered preliminary at this point. The most common color found in pictographs at sites I have seen is red, followed by black, then white, then rarely other hues. Often the rock shelter or cave wall is reddish or blackened. Thus there are common types in the color distributions of pictograph images and so also in the types of enhancement.

If the transform is mapped back the enhancements more closely match the original colors. This is sometimes good, but sometimes not mapping back can give excellent enhancements, albeit in false color. The YDS colorspace is my modification of the YUV colorspace used in analog television. YDS gives good results over many different imput images. LAB is less subject to noise and jpeg artifacts. YCbCr tends to produce reds with higher saturation than RGB or YDS. RGB suppresses the background more. Not mapping back gives larger color differences.

When using RGB, not mapped back, I noticed similar, very striking, enhancements in several red pictograph images. I created an enhancement matrix that reproduced those striking results and made it accessible from the plugin (CRGB button). This enhancement is not dependent on the particular image color distribution and so gives consistent results over many different images. It works well to enhance red pigment but suppresses

white and blacks. By bringing out the red painting and suppressing the background shades it can help clarify image composition.

Figure 3 Burham Canyon (KER-273). Left: original. Right: CRGB. Note small creature at left center brought out by enhancement.

Program Features

ImageJ is a full-featured imaging program. It is written in Java and can run on PC's, Mac's and Linux computers.   Information on its capabilities can be found at [1]. This section will focus on the DStretch plugin features.

When the 'DStretch' button is pressed the plugin calculates the covariance or correlation matrix of the image colors. If an area selection is made within the image the calculation will be restricted to the colors inside the area. The enhancement will be applied to the entire image. This allows the exclusion of parts of the image that may have little to do with the area of interest, say a green bush at the side of a pictograph panel. Different decorrelation results are possible by selecting different parts of the image.

Mapping back is optional. Not mapping back can create more colorful enhancements, but the colors will have less resemblance to the original. When mapped back the enhancement is usually stable, repeating the decorrelation usually makes little difference. When not mapped back repeating the decorrelation can switch colors and sometimes create better contrasts. It is possible to reset the image to the original colors before trying a different enhancement combination.

Different colorspaces give different results, especially when not mapped back, so I have implemented the algorithm in RGB, YCbCr, YDS and LAB colorspaces. I have also experimented with what I call "LAX" colorspace. This is a modification of the LAB colorspace to give more enhancement to colors. Image noise and artifacts from JPEG compression can be a problem; using LAB or YCbCr colorspace lessens the noise and artifacts. The reds in YCbCr can be a bright neon color (i.e. very highly saturated); choosing YDS colorspace can sometimes improve the colors. The RGB colorspace, not mapped back, can sometimes give very good enhancement of red pictographs. I have saved a particularly useful enhancement matrix that can be accessed by the CRGB button.

The enhanced image is false color, i.e. the colors in it can be radically different from the original, especially if not mapped back. The contrast between different hues can vary a great deal and sometimes the enhanced image has poor contrast between desired elements. DStretch has the ability to shift the hues in the enhanced image to increase contrast.

Each image enhances differently, depending on its own unique distribution of colors. For consistency it is

possible to save an enhancement matrix that was calculated on one image and apply it to others. I have saved one matrix that I have found useful for each colorspace. Choosing custom in the matrix chooser can access these matrices. A dialogue pops up and allows for user modification of the default matrices.

Another useful enhancement technique, not related to decorrelation stretch, is the manipulation of the hue and saturation of the image. DStretch can do hue histogram equalization and saturation stretching.

DStretch also contains a tool that allows a region of the enhanced image to be isolated by hue and then added back to the original image. This can be used to isolate an enhanced element then return it to the original image.

References

[1] ImageJ web site: http://rsb.info.nih.gov/ij/index.html

[2] Gillespie, et al. 1986: Color enhancement of highly correlated images. I. Decorrelation and HSI contrast stretches. Rem. Sens. Environ., 20, 209-235.

[3] Gonzalez and Wintz, 1977: "Digital Image Processing", Addison-Wesley, Reading, MA.

Acknowledgements

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