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DStretch® and Egyptian tomb paintings: A case study from Beni Hassan

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ABSTRACT

The advantage of using DStretch® – image enhancement software developed for rock art research – for the analysis and recording of ancient Egyptian wall paintings is demonstrated via its recent application at the cemetery site of Beni Hassan. DStretch® enhanced photographs of painted surfaces enable obscure or faded details to be viewed by artificially highlighting traces of remaining pigment. Trial use of DStretch® for the examination of wall paintings at Beni Hassan has revealed or confirmed new images of pigs and bats (animals that are rarely attested in Egyptian art), and a highly unusual depiction of a vulture, exposing features that were otherwise unavailable visually. When used in conjunction with digital epigraphy, DStretch® offers an invaluable tool for achieving a more complete record of Egypt's artistic legacy.

1. Introduction

Digital epigraphy has been a boon to archaeological practice in Egyptology. Prior to the introduction of computerised methods for recording Egyptian tomb paintings and reliefs in the 1990s, epigraphers could only rely on direct 1:1 tracing of wall imagery on-site (in which drawing paper or film is adhered to the walls) or tracing enlarged photographs. Both methods are time-consuming and, in the case of direct tracing, potentially damaging to fragile or poorly preserved wall surfaces.

Epigraphic practices began to change with the advent of vector-based image software (such as Adobe Photoshop), which, when used in conjunction with graphics tablets, allows epigraphers to trace scanned or digital photographs (Der Manuelian, 1998). This method produces high-quality, high-resolution, scalable line drawings that can also be collated digitally, avoiding misalignment problems that may be introduced with direct tracing (Vertés, 2014). Corrections are made quickly and efficiently, while the ability to magnify photographs on-screen enables minute details to be checked and traced.

Magnification is one of the primary advantages of digital epigraphy over 1:1 tracing (Der Manuelian, 1998), helping to reveal details that the human eye cannot detect. However, magnification cannot always clarify wall images that are damaged, faded or obscured by pollutants such as dirt, soot, or varnish. As many Egyptian monuments are poorly preserved, this problem is encountered frequently. If indistinct sections of wall scenes cannot be resolved visually, epigraphers must either omit them or indicate their uncertainty via dotted lines.

Indeed, the epigrapher's drawing rests ultimately on the ability to differentiate painted or carved lines and textures, and to make informed decisions about what can be seen. Egyptology training plays an important role in the latter, however the epigrapher's visual acuity and colour discrimination are highly important. Light levels and colour pigments in objects, as well as individual differences in vision, affect our ability to ascertain details (for example, age diminishes both contrast and colour perception; e.g., Greene and Madden, 1987). Thus, despite the advantages that digital epigraphy has afforded Egyptology, the accuracy of produced line drawings is still largely dependent on human vision.

Image enhancement software can be used to improve the appearance of indistinct digital photographs by sharpening or adjusting features (e.g., by manipulating lighting or contrast). Adobe Photoshop©, for example, is the industry standard for digital imaging. However, recent advances in graphic technology have resulted in the emergence of both cheaper and more specialised software to aid the interpretation of specific forms of digital media (e.g., CCTV footage) or for use in particular disciplines. One such example is DStretch®, which was developed in 2005 by rock art specialist Jon Harman to help define elements in faded rock paintings that are virtually invisible to the naked eye. The application of DStretch® has since broadened to include other research areas that similarly require the analysis of painted surfaces. Despite growing use of DStretch® in archaeology (see below), the Egyptology community is largely unaware of the software as, to date, few researchers have published findings based on its application. The potential for this simple tool to aid the analysis of Egyptian wall paintings is thus not generally known or appreciated. The following overview will therefore explain the technique, describe how it has been

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applied in archaeological contexts, and share epigraphic case studies from an Egyptian context that have benefitted from the use of DStretch®.

1.1. DStretch®

Colour Decorrelation Stretching or DStretch® is a plug-in for the free, open-source image processing and analysis program ImageJ©. Colour Decorrelation Stretching, which was developed by California's Jet-Propulsion Laboratory (Soha and Schwartz, 1979), was subsequently used in remote sensing to enhance multispectral images and, in 2004, it was employed by NASA to analyse photographs taken by the Mars Rover (NASA News Release, 2004). DStretch® was developed the following year and is now available online as a free download (a minimal fee of 50 USD is requested from professional researchers, however; see www.dstretch.com).

DStretch® analyses the three bands of RGB colour (red, green, and blue) embedded in an image, improving the intensity and saturation of each. The software applies a data transformation technique known as a 'Karhunen-Loeve transformation' to the colourspace, which derives its transformation vectors from the covariance or correlation matrix of the original data (Harman, 2005). In essence, the contrast for each colour is amplified to adjust colour variances (Harman, 2005). Lincoln provides the useful analogy of treating each of the three bands of RGB colour as a coordinate in a colourspace, the transformation process afterwards stretching these coordinates so that they are further apart, making it easier to see the differences between them (Lincoln, 2011). Once stretching has taken place, the program maps the colours back to their near-original form in RGB, enhancing their intensity and saturation and allowing for a greater distinction of colours in an image.

The application and effectiveness of DStretch® may vary according to the quality of the original photograph (e.g., its resolution, perspective or whether it was taken in uneven illumination), its distribution of colours, and the colourspace chosen for analysis (Harman, 2005). Consequently, DStretch® will enhance each image differently. Colours that are particularly well enhanced by the plug-in are red, yellow, black, and white. However, rather than cycling through several filters and modifications in image enhancing programs such as Adobe Photoshop©, DStretch® provides a number of custom colourspaces or presettings that can be used to bring out or suppress different colours and shades. The resulting enhancements produce artificial colours. This is because they are intended to show specific hues in great intensity and saturation. Further modifications are often required to increase contrast between elements, boost sharpness, or select particular colours for emphasis by greying out surrounding noise. These can easily be accomplished using DStretch®'s expert mode and Adobe Photoshop© (see Le Quellec et al., 2015). The software also includes the option to save a transformation matrix calculated on one image for later application on others. This allows for quick, efficient and easily reproducible results that can be applied consistently to images of a particular detail, scene or room.

Unlike other image enhancement protocols, very little training is required to use DStretch®. Furthermore, an inexpensive DStretch® app for tablets and mobile phones is now available, enabling the software to be used on-site to immediately clarify ambiguous painted details, while tablet and desktop applications can be used for later recording, tracing, and interpretation.

1.2. Archaeological applications

DStretch® has been widely utilised for the analysis of rock art in many parts of the world, including Africa, Europe, North America, and Australia. The software has sharpened and made more visible the features of faded, eroded and/or overlapping painted images, as well as pictographs (e.g., Cassen et al., 2014; Defrasne, 2014; Defrasne and Bailly, 2014; Gunn et al., 2014; Harman, 2014; Le Quellec et al., 2013, 2015; Tomášková, 2015). It has frequently uncovered previously undocumented images and has also allowed painted features to be differentiated from natural rock stains (Dodd, 2013) or imperfections (Le Quellec et al., 2013, 2015). DStretch® has been especially beneficial for the analysis of problematic paintings. For example, a curious figure, one of many painted images at the World Heritage site of Tassili-n'Ajjer in Algeria, appears to have a drum-like head. However, after a photograph of the image was processed via DStretch® (Le Quellec et al., 2013, 2015), the figure's actual head could be seen inside the drum, the arrangement of the lines also revealing clearly that it was painted after the circular feature, but with the pigment failing to adhere properly inside the sphere.

Although designed primarily for rock art research, DStretch® applications have begun to vary recently, with archaeologists now utilising the plug-in to evaluate a range of painted surfaces. For example, it has been used to study faded wall paintings in the temple of Angkor Wat in Cambodia (Tan et al., 2014) and frescoes in an early seventeenth century church in Bulgaria (Raykovska et al., 2016), soot-obscured imagery (Miller and Thompson, 2015) and paint layers on ancient pottery from the southwestern United States (Shepard and Wright, 2016), as well as crackle patterns on Chinese ceramics (Lahlil et al., 2013).

We are aware of only two published reports in which DStretch® has been applied to ancient Egyptian material. It has aided the interpretation of faded inscriptions at the quarry site of Hatnub, where it has helped to reveal many previously unknown images and texts (Enmarch, 2015), while at Gebelein the technique has been combined with Reflectance Transformation Imaging to yield clear images of otherwise invisible painted and inscribed graffiti and dipinti (Witkowski et al., 2016; see also Witkowski, 2015). To our knowledge, however, the benefits of DStretch® for the analysis of pharaonic wall paintings is not yet widely known among Egyptologists, despite Gebelein scholars noting that '*It would appear that the same approach can provide good results during research on the decoration of temple walls*' (Witkowski et al., 2016: 944). We therefore offer the following case study as a practical demonstration of the software's feasibility and potential use with digital epigraphy.

2. Method

2.1. The site

The Middle Kingdom cemetery at Beni Hassan (c. 2050–1650 BC) is well known for the exceptional quality of its artwork (Kanawati and Evans, 2014, 2016; Kanawati and Woods, 2010; Shedid, 1994). Each of the 12 decorated rock-cut tombs at the site display highly detailed scenes of daily life (e.g., agricultural tasks, hunting and fishing, workshop activities, funerary rites, etc.), painted directly onto the wall surfaces in a range of vivid colours. First recorded by Percy Newberry in the 1890s (Newberry, 1893, 1894; Griffith, 1896; Carter et al., 1900), re-assessment of these unique images is currently underway as part of a federally funded project by the Australian Centre for Egyptology, Macquarie University, which has the long-term goal of publishing all of the decorated tombs at the site.

During fieldwork, wall scenes are photographed and traced using a combination of 1:1 tracing and digital epigraphy. While the paintings are largely well preserved, some sections are damaged. That is, the combined effects of age, human intervention, pollutants, and exposure to the elements have resulted in faded or eroded scenes that are difficult to reconstruct and thus trace, either manually or digitally. DStretch® was consequently employed to check the validity of tracings following their production on site.

2.2. Approach

The procedure implemented was largely based on Gary Hein's