Seeing Colors Beyond the Naked Eye: Spectral RTI, a New Tool for Imaging Artifacts

By: Todd R. Hanneken

Photography has long been an essential tool for archaeology. But photographers often struggled to capture texture, such as cuneiform writing, or a stone inscription, or a stamped coin. In these cases, the primary meaning is not conveyed through contrast of light and dark materials or between different colors, which are the strengths of photography. A photograph of an inscription with diffuse lighting would show only stone. The best photographs relied on light raking from a low angle to show the texture through highlights and shadows. This could work well for at least part of the image, but often not the whole image. As a result, it was common for editors to offer line drawings that attempted to express in black and white the shapes expressed as texture in the original artifact. In this era there was no need to argue that a photographic edition was no substitute for first-hand inspection.

In the past decade a new technology revolutionized archaeological photography. Texture imaging was originally developed at Hewlett Packard Labs for use in 3D environments. This technology, called Reflectance Transformation Imaging (RTI), captures the texture of every pixel in the image. The texture maps are derived from measuring the light reflected from forty or so different angles. Once the texture is digitized, the technology can predict how light coming from any angle would be reflected. Furthermore, the RTI images can be enhanced to show texture more dramatically.

This technology has been brought to the study of material culture by Cultural Heritage Imaging and especially by the West Semitic Research Project (WSRP) at the University of Southern California. Led by Bruce Zuckerman, WSRP, created a massive library of images of coins, cuneiform writings, and inscriptions in stone and other materials. The InscriptiFact Digital Image Library is free with registration, certain requirements for ports open through the firewall, and the ability to download and install Java applications. For more casual users, the Institute of Science and Information Technology at the National Research Council of Italy created a way to embed interactive RTI images in any webpage. RTI alone is not 3D, but describing the texture of a plane and how it responds to light is an essential part of 3D imaging. Together these technologies have revolutionized archaeological study and publication.

Recently the National Endowment for the Humanities has funded the Jubilees Palimpsest Project at St. Mary's University to take RTI to the next level through the integration of spectral imaging. This integrated Spectral RTI has all the advantages of RTI, but also adds the key advantages of spectral imaging. First, spectral imaging uses higher resolution sensors without the distorting filters that plague even the most expensive DSLR cameras by Canon and Nikon. The fifty-megapixel sensor of a MegaVision E7 allows capture of a frame as large as 14.5 by 9.7 inches at 600 dots per inch (or a smaller area at higher resolution). The result is that we can see texture much finer than the surface of cuneiform and coins, down to paint strokes, the grain of the parchment, and even the outline of a letter where now-missing ink once corroded the surface. The second key advantage of spectral imaging is that it utilizes a wider range of the electromagnetic spectrum, including ultraviolet and infrared light that human eyes cannot see. The third advantage is that it resolves color more finely than the human eye. Browns that are indistinguishable to the eye can be easily differentiated by spectral imaging because it resolves eleven to sixteen wavelengths, far more than the three color receptors of the eye.

All these data can be processed to render color more accurately than conventional photography (which uses red, green, and blue sensors that only roughly approximate the receptors in the eye). Color accuracy without subjective color matching also means that images can be compared reliably across time and space. Extended Spectrum processing squeezes the wider color range into the human visible range, such that ultraviolet light looks blue and infrared light looks red (rather than invisible). A third technique uses a statistical technique called Principal Component Analysis to find the greatest contrasts and render them into colors we easily distinguish. This process least resembles reality but successfully makes the brown blob of an erased manuscript readable in bright reds, greens, and blues.
The 2013–2014 startup phase developed the technology using test objects of varying depths of texture. The deepest texture was a terracotta figurine from the USC Archaeological Research Collection. The figurine found in Egypt is believed to celebrate the victory of Hadrian over Jewish militants (note the curved knife or sicar definitive of the Sicarii described by Josephus, see further). The image above has zoom controls to utilize the high resolution images. By clicking the “light bulb” icon and clicking or dragging in the frame users can change the light position. The interactivity and the various light positions make clear the texture of the artifact, both the deliberate form and the imperfections in manufacture. The enhanced color images make it easier to see traces of paint and other materials.

Spectral RTI images of the encaustic mummy mask from Roman period Egypt (USC Archaeological Research Collection) can be similarly manipulated to show the brush stroke of the original artist and the conservation concerns of chipped paint. Although the Extended Spectrum (not shown, see here) cannot be called more accurate as a representation of the artifact today, it may be suggestive of the original appearance by sunlight two millennia ago (note the white of the eye). In the Pseudocolor it is easy to notice a slight error in the artist's technique. The painted background and the wood surface are rendered yellow and light blue, respectively. Zooming in on the light blue streak along the left chin shows that...
the artist missed a spot and did not paint the background all the way to the face. In the accurate color image, the shortcut is understandable as there is almost no natural color contrast. However, in Pseudocolor materials do not look the same unless they are the same.

The startup phase also experimented with the very fine texture of an erased manuscript, or palimpsest. The writing is illegible in real life and in accurate color. In the Pseudocolor some contrasts are visible thanks to principal component analysis of all captured bands. Other portions are still not legible, however, unless one utilizes the moving light of RTI. At very high resolution it is possible to read the outline of letters in the texture as one moves the light. Note that there is no one magic angle that makes the entire page legible. It is the variability and interactivity that allows us to recover the text.

The next phase of the project will take us to Milan, Italy to work at the Biblioteca Ambrosiana. In particular, we will work on the Jubilees Palimpsest, which includes the only copy of the book of Jubilees in Latin (the Dead Sea Scroll fragments are in Hebrew and the nearly complete copies are in Ethiopic), along with the only copies of the Testament of Moses and the Arian Commentary on Luke. In the following year we will introduce the open image repository to scholars and build scholarly content. In the third year we will offer manuals, training, and free software to institutions considering adopting Spectral RTI technology for their own projects. It is our hope that these tools will serve many projects when conventional digitization does not suffice. Not only will new excavations benefit from the technology, but artifacts already studied by the human eye in museums and libraries can be rediscovered by the global community of scholars and enthusiasts.

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