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Visualising Our Cultural Heritage: Why Science Shouldn't Get Lost in Digitisation

Introduction

When preparing a piece of work it is often expected (nay, demanded!) that one should include an image to support the primary content. But what if the image *is* the primary content? For imaging scientists, this is often the case. Images and data visualisations are becoming increasingly more accepted as scientific objects in their own right, without the need for caption or explanation. As cultural heritage institutions (galleries, libraries, archives, and museums) seek new ways to explore their collections, there is a growing appetite to integrate science and technology into all aspects of mission and vision statements. This year alone has welcomed science at the fore of several major London exhibitions including those at the British Museum (*Ancient lives, new discoveries*, 22 May – 30 November 2014) and the National Gallery (*Making Colour*, 18 June – 7 September 2014) where images are used to convey new methods of thinking and to reveal new discoveries. The British Museum claims to use "the latest scientific techniques to shed new light on ancient cultures", while the National Gallery "invites you on an artistic scientific voyage of discovery." Positively tantalising!

In this piece, scientific imaging techniques adapted to suit cultural heritage needs are described, some examples of imaging science at the British Library are shared, and the consequences of replacing physical book and manuscript consultation with digital examination are considered.

The Evolution of Imaging Science

Imaging science is an evolving multidisciplinary field encompassing image capture, analysis, processing, and visualisation. The field is largely associated with scientists and researchers of physics, medical physics, computer science, mathematics, engineering, and computer science, but is more recently finding application in other research areas. Imaging science is regarded as an independent discipline based on a conceptual model known as the "imaging chain". The chain describes the factors to consider when developing a system for image creation. The primary chain links include the human visual system, the subject of the image, the capture device, the processor, and the display, while other factors such as illumination source, or storage and/or transmission systems are sometimes relevant. The successful application of any imaging technique relies on the stability and repeatability of these links, and for an image to be considered an object of science; the documentation of these links is critical.

Imaging Techniques and Cultural Heritage Applications

1. X-ray Imaging

The importance of the imaging chain, and the inter-dependence of chain links, was well illustrated during the development stages of X-ray imaging. In X-ray imaging, the images can be considered as both the data and the final visual product. There was worldwide acclamation in 1895 when Wilhelm Röntgen first published his discovery that X-rays could be used to identify bone structures. Less than a month later X-rays were being used for medical diagnoses, and since then billions of X-ray examinations have been conducted.

The use of X-ray imaging on cultural heritage artefacts has rapidly increased since the inception and development of Computed Tomography (CT). CT scanning is a powerful and non-destructive X-ray based imaging technique for full-volume investigation of an object. Physical and morphological information of scanned objects provide information on the inner structures of investigated objects. Entire mummies at the British Museum's *Ancient lives, new discoveries* exhibition were "virtually unwrapped" allowing every feature and amulet of the bodies to be visualised without having to disturb the original wrappings. The British Library has conducted a micro-CT scan (a higher resolution variant of CT scanning) of the oldest intact European book, the early 8th century St Cuthbert Gospel (Add. MS 89000), at the Natural History Museum, London. This Anglo-Saxon pocket gospel was found in the coffin of St Cuthbert in Durham in 1104. Our understanding of the internal structure of this binding provides the starting point for the history of bookbinding in Europe.

2. Digital Microscopy

Microscopy allows samples to be viewed at magnifications that are beyond the normal resolution of the human eye. Optical (or light) microscopy illuminates a sample with visible light. Passing the transmitted or reflected light from the sample through a single or multiple lenses creates a magnified view. Digital microscopes use a CCD (charge-coupled device) camera to focus on the object, an advancement that has replaced stereomicroscope eyepieces with digital monitors.

High-resolution digital microscopy has found applications to both conservators and researchers at the British Library. Images ranging from 20x - 200x magnification illustrate the condition of adhesives, paper, ink, and pigments. These images can inform conservators on how to best treat objects. Early detection of degradation features facilitates the monitoring of collection environments, ensuring that correct temperature and relative humidity controls are in place. The quality of a potential new acquisition can be quickly assessed with digital microscopy, and items going on loan can be imaged in the same location, at the same magnification, before and after their display on exhibition. This practise evaluates whether protocol loan measures are sufficient to protect the item or not.

Figure 1 (left) shows an image captured at 50x magnification by a digital microscope during the condition assessment of one of the British Library's greatest treasures: the Lindisfarne Gospels (MS Cotton Nero DIV). The Lindisfarne Gospels is a magnificent manuscript from the late 7th century containing five major decorated openings, cross-carpet pages, canon tables and the text of the four gospels. The Latin text contains an interlinear Old English gloss translation by Aldred, Provost of Chester-le-Street, in the mid-10th century.

Digital microscopy not only allows us to monitor pigments, but the resulting images can be appreciated as independent works of art. In the case of the Lindisfarne Gospels, high magnification has revealed spectacular examples of medieval artistry suggesting the involvement of a highly skilled craftsman. Remarkably, it is thought that the entire manuscript is the work of one man: a monk named Eadfrith who was the bishop of Lindisfarne between 698 and 721.

Figure 1. Left: A decorated intial from folio 51v of the Lindisfarne Gospels (MS Cotton Nero DIV). Right: 50x magnificaiton of the decorated intial in the Latin text of folio 51v. The intial is coloured with yellow pigment (orpiment), and displays a network of cracks formed by pigment shrinking due to age (craquelure). The intial is surrounded by a decorative border of red lead dots.

3. Multispectral Imaging

Multispectral imaging is the capture of image data at specific frequencies across the electromagnetic spectrum, which encompasses the range of all possible frequencies of light energy, or radiation. Human vision has adapted to detection of the visible region of this spectrum, which forms just a small percentage of all radiation present. We cannot see radio waves or X-rays, but we know they exist by detecting them by other means. Imaging under ultraviolet or infrared light can extract information the human eye fails to detect. The technique of spectral imaging was originally developed for space science, but has rapidly found applications in other fields including that of cultural heritage. Multispectral imaging can assist in the interpretation of ancient materials which have become faded due to natural degradation, or been purposefully erased. It is a key technique in the scientific analysis of palimpsests (a page from a scroll or book where the text has been scraped away and written over) and pentimenti (traces of previous work and alterations in paintings).

Multispectral imaging is used at the British Library to recover and discover unseen or illegible text. The technique has played a key role in the examination of manuscripts from the Cotton Library; an important collection of manuscripts assembled by Sir Robert Bruce Cotton (1571-1631). The collection was bequeathed to the nation in 1702 forming the foundation collection of the British Museum. The collection contains some of the greatest treasures of British literature and history including the Lindisfarne Gospels, Magna Carta, and Beowulf. In 1731 disaster struck: a great fire broke out at Ashburnham House, Westminster, where the Cotton manuscripts were temporarily being stored. Some volumes were completely destroyed while others were damaged to varying degrees. Fragments of charred manuscript, in a state beyond any conservation treatment at the time, were prudently retained in the hopes of being revived by future technologies. Recent multispectral imaging has recovered lost text allowing the material to be transcribed and fragments to be matched and reunited. Figure 2 shows an indecipherable original colour image compared to the now legible ultra-violet image of a fragment on MS Cotton Otho BX folio 55r.

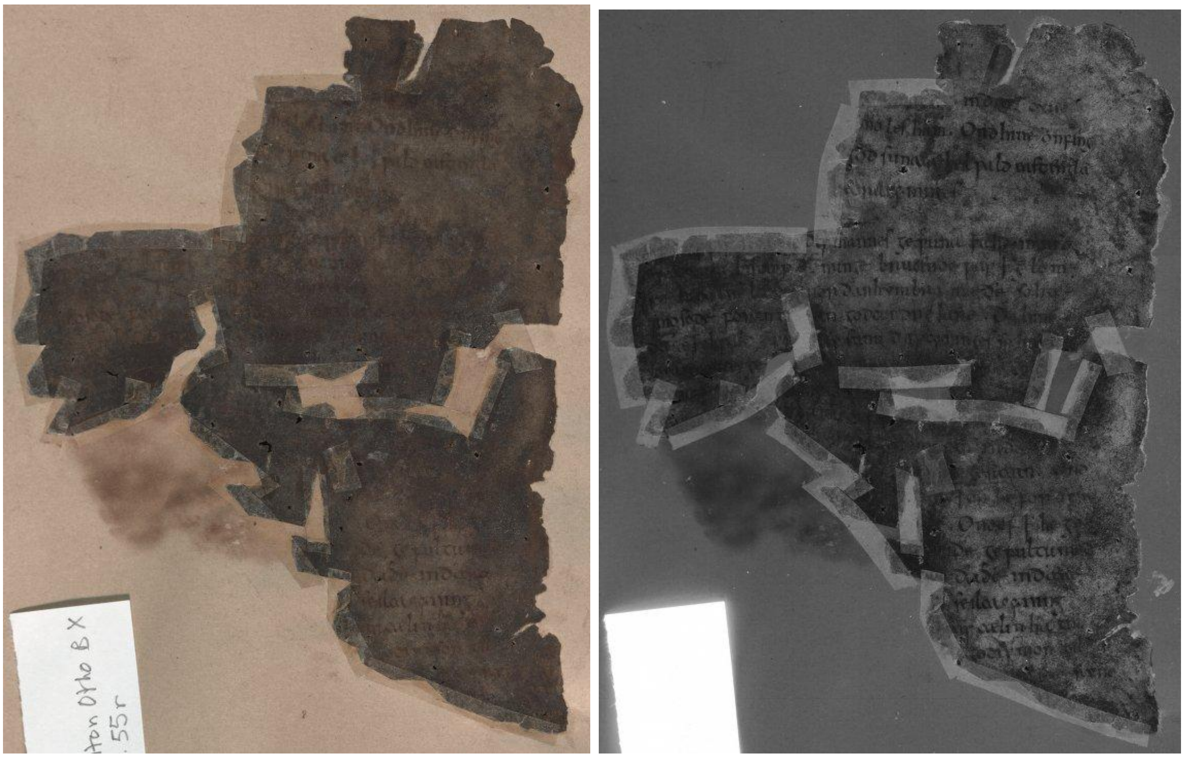

Figure 2: Left: Original colour image of MS Cotton Otho BX folio 55r. Right: Enhanced multispectral image of the same folio taken under ultra-violet light.

Multispectral imaging has also proven successful in exposing underdrawings (guidelines or practice drawings done before paint or pigment is applied) of illuminations in another Cotton manuscript, MS Cotton Nero AX, which contains the story of Sir Gawain and the Green Knight. This 14^{th} century manuscript is of one of the most famous romances in medieval English literature describing the adventures of Sir Gawain, a knight of King Arthur's Round Table, and his encounters with the mysterious "Green Knight". While the poetic quality of the manuscript has been well-lauded, the handwriting and drawings have been widely criticised for their simplistic execution, suggesting to some that the manuscript is a provincial or unprofessional production. Images captured under infrared light revealed previously unseen details in the drawings. Figure 3 compares the original colour image of the Green Knight on folio 129v with the corresponding infrared image. The infrared version allows us to see through the green pigment exposing a striped pattern underneath. Infrared imaging has also proven successful in revealing watermarks and penetrating through stains and regions of corroded iron gall ink.

Figure 3: Left: Original colour image of the Green Knight from MS Cotton Nero AX folio 129v. Right: Underdrawings in the clothing of the Green Knight are revealed in the infrared image, which penetrates through surface layers.

4. Image Processing

While the advantages of scientific imaging techniques such as CT scanning, microscopy and multispectral imaging are innumerable, the expense and expertise required to setup and maintain such systems is often prohibitive. Thankfully, much research can be done without excessive cost. Mass digitisation projects generate huge datasets comprised of high-resolution images that are usually freely available online. These images are invaluable digital assets from which much information can be extracted through a series of manipulations. Manipulating images in such a way as to alter their original state is known as image processing. Image processing software is available both commercially and for free as open source packages. ImageJ, paint.net and GIMP are freeware packages that have most, if not all, of the functionality of those commercially available. The majority of image processing problems can be solved using the Java-based package ImageJ due to the use of recordable macros, user-written plugins and support from a large online user community. Two plugins that have been used extensively for colour space analysis for cultural heritage applications are “Colour Transformer”, and “Colour Space Converter”.

Colour space analysis is an image processing technique that can be used to enhance faded designs on bindings, disclose watermarks and expose hidden inscriptions. Colour can be specified by three parameters in a colour space and there are mathematical relationships that enable the parameters of one colour space to be transformed into another. Most images are described by the percentage of red, green and blue components combined, and therefore exist in RGB colour space. A transformation from the RGB colour space into another, such as one that describes colour in terms of the hue, saturation and luminance, can reveal information unseen in the former.

A watermark of a post-horn surrounded by a shield was discovered in this way on the rear pastedown of the St Cuthbert Gospel (Add. MS 89000). Watermarks were first introduced in the thirteenth century and are used as a means of establishing the provenance and origin of paper, as well as helping to identify the mills from which the paper came. Motifs, place names or initials are embedded in the paper by placing appropriate wire shapes in the paper mould. Paper thickness is reduced in these areas resulting in the appearance of the wire shape when held up to a light source. The watermark on the St Cuthbert Gospel pastedown had not be observed before due to it being adhered to the right (back) board of the binding, i.e. a location which prevented light transmission.

The entire St Cuthbert Gospel volume (Figure 4, left) was digitised in 2012 and images are available to view on the British Library’s Digitised Manuscripts website. The image showing the right board inner pastedown (Figure 4, centre) was processed using colour space analysis in ImageJ.

Figure 4: Left: The St Cuthbert Gospel (Add. MS 89000). Centre: The inner paste down on the right (back) board records the donation of the volume to the British Province of the Society of Jesus in 1769. Right: The location of the watermark.

The watermark as shown in Figure 5 (right) is most prominent in the luminance-chrominance colour space AC1C2, in the C1 colour channel. A full description of the methods employed in this case study can be found in a 2014 publication of the Electronic British Library Journal.

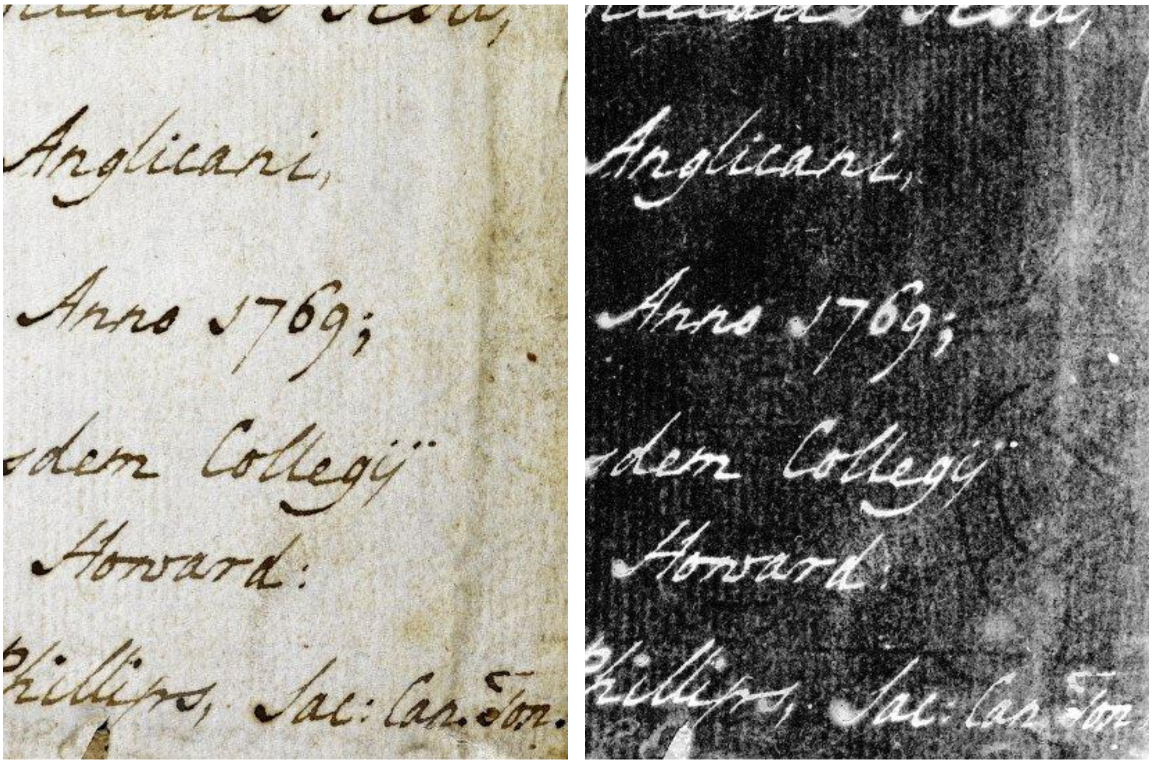

Figure 5: Left: Original RGB colour space image of the right (back) board pastedown from the digitised manuscripts website of the St Cuthbert Gospel. Right: AC1C2 C1 colour channel revealing a watermark in the lower right hand corner.

The Value of Physical Objects and their Digital Images

Digitisation has benefited cultural heritage institutions by enabling access to a wider community, encouraging education and research, supporting preservation, and increasing an institution's profile. However, awareness must be generated of the risks associated with presenting works in a format not intended as the original. Image misinterpretation can have serious consequences for researchers claiming to see dots of gold pigment where in reality pests have eaten away holes in the pages, or citing evidence of palimpsests where instead ink is showing through from the verso. An understanding of the process of image capture is often overlooked as an important aid to online viewers. This is especially the case for scientific images – notes on image capture and processing (i.e. the links in the "imaging chain" must be incorporated as part of the image's meta-data.

It is not surprising that we lose some of the essence of a book or manuscript (produced to be held and cherished) by viewing it as a series of pixels on a screen. Folios become isolated entities and lose their material connection to each other. They become separate parts, rather than parts of a whole. Establishing the context allows us to distinguish between the value of an item and the value of its digital image. We must accept that while digitisation and scientific imaging allows the real environment to be replaced by a virtual one, it is not meant as a permanent substitute for the real world. Looking is a transforming act and grows our understanding. It is often the case that the human desire for conclusions is stronger than the desire to observe. For interpreting digital collections, including scientific images, this desire can be fatal; observation is more important. With this in mind, imaging science is becoming a powerful and welcome force in the future study of our cultural heritage collections.

This article is part of *Looking at Images: A Researcher's Guide*:
http://blog.soton.ac.uk/wsapgr/looking-at-images/