Colour Analysis of Degraded Parchment

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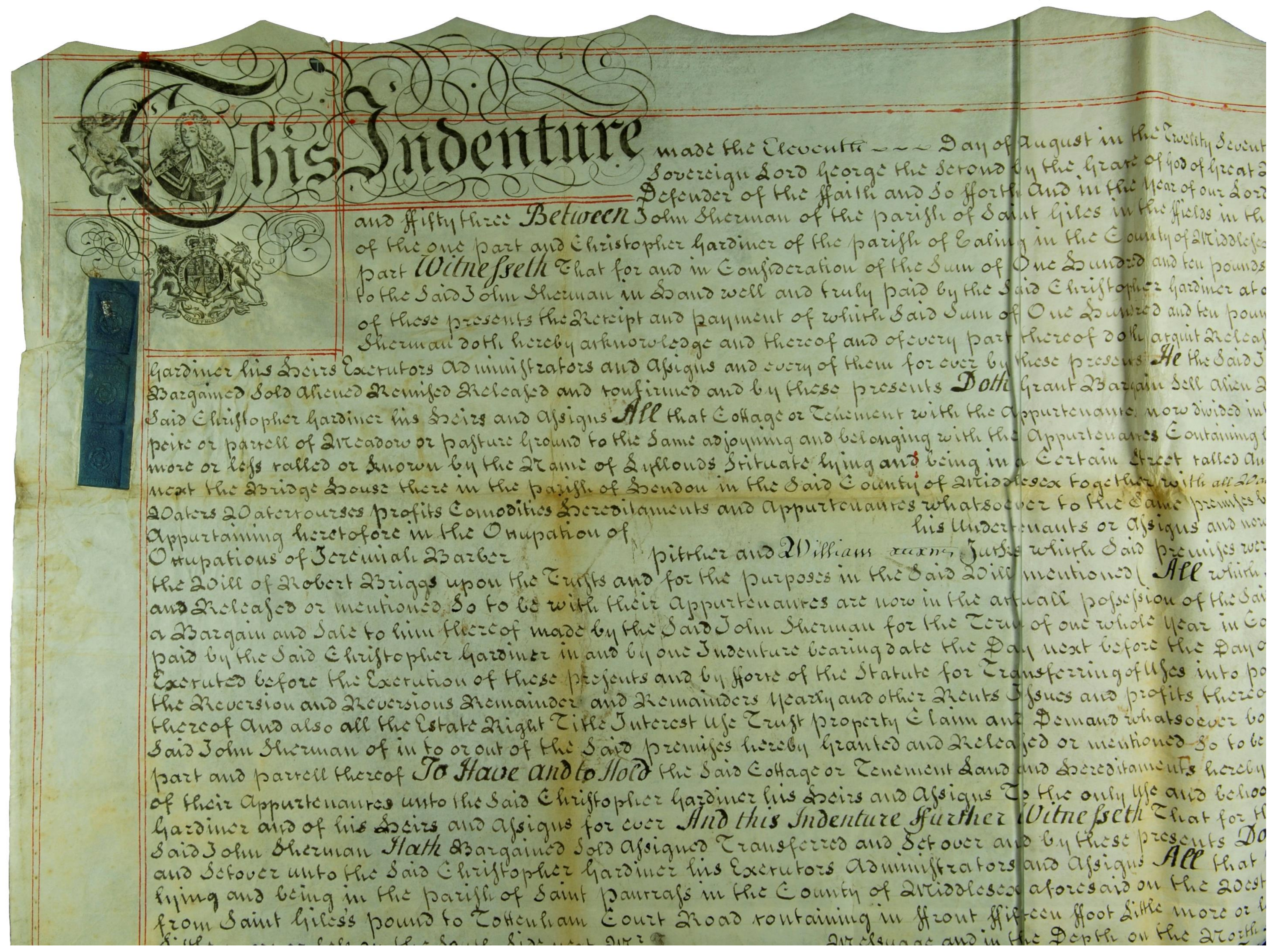
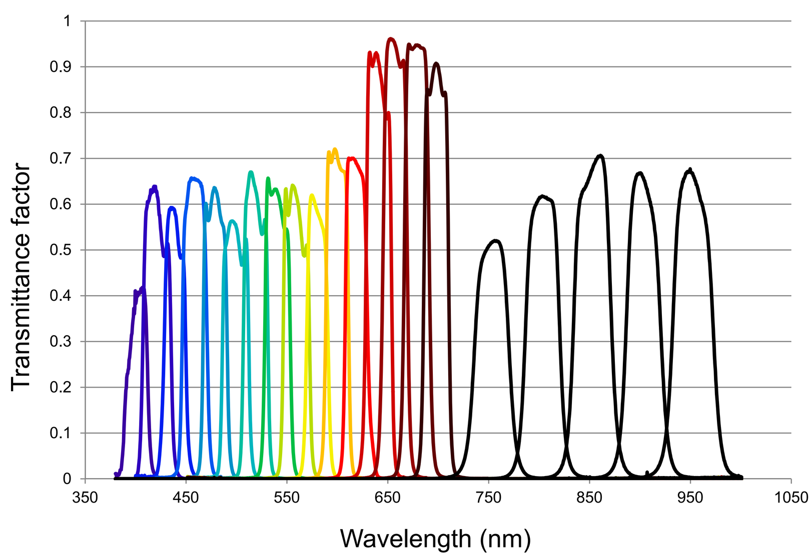
Multispectral Image Capture

18th century manuscript de-accessioned from the London Metropolitan Archives, comprising two large sheets of parchment written in iron gall ink and highlighted in red ink.



23 square sections of 8×8 cm were cut from manuscript. Each sample was treated by an external degrading agent, including mechanical damage, heat, humidity, abrasion, and chemical substances such as acid, alkaline, bleach, tea, black ink, red wine and human blood.



Spectral transmittance of 21 optical bandpass filters in the visible and NIR spectrum.

Each sample was imaged before and after treatment, through a series of bandpass filters by a Kodak Megaplus 1.6i scientific camera with Nikkor 50mm f/2 lens. 21 monochrome images of 1536x1024 pixels span the range 400–1100 nm.

The spectral transmittance of each filter was measured with an Ocean Optics HR2000+ spectrometer. Samples were illuminated by four tungsten-halogen lamps on a photographic document copystand under a 3 mm glass plate.

Registration of Images

The images of all wavebands were registered, using four 1mm holes drilled in each parchment sample as anchor points for a projective geometric transform.

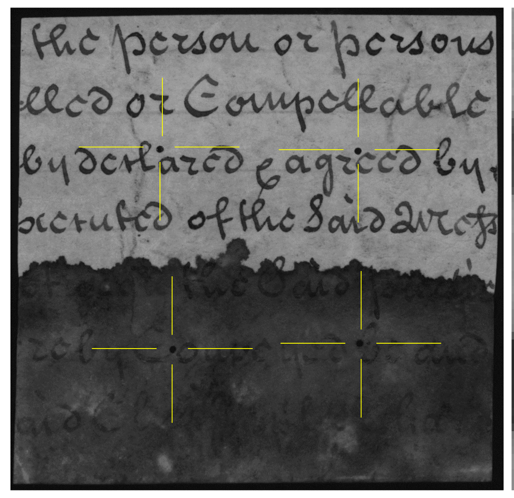
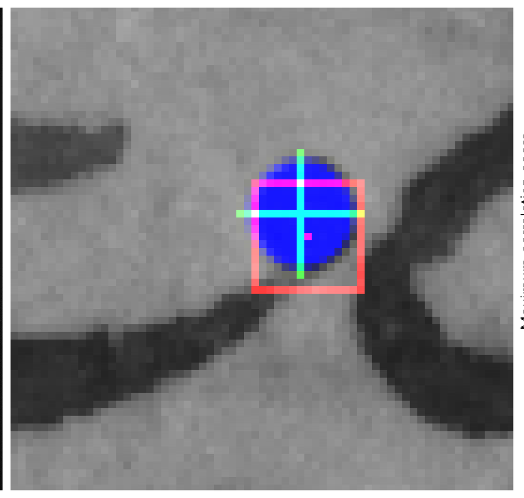
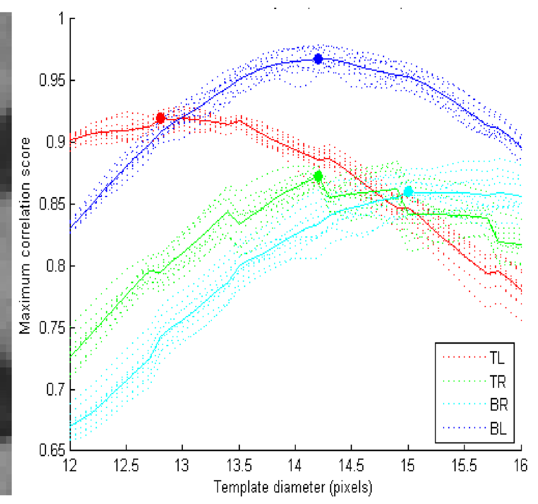


Image through 600nm filter of parchment sample half-covered by blood. Yellow lines indicate the positions of registration holes.



Centroid (cyan cross) of template position (blue) over image of neighbourhood of lower left hole. Red square is range of correlation region.



Maximum correlation score for each hole as a function of the template diameter in pixels.

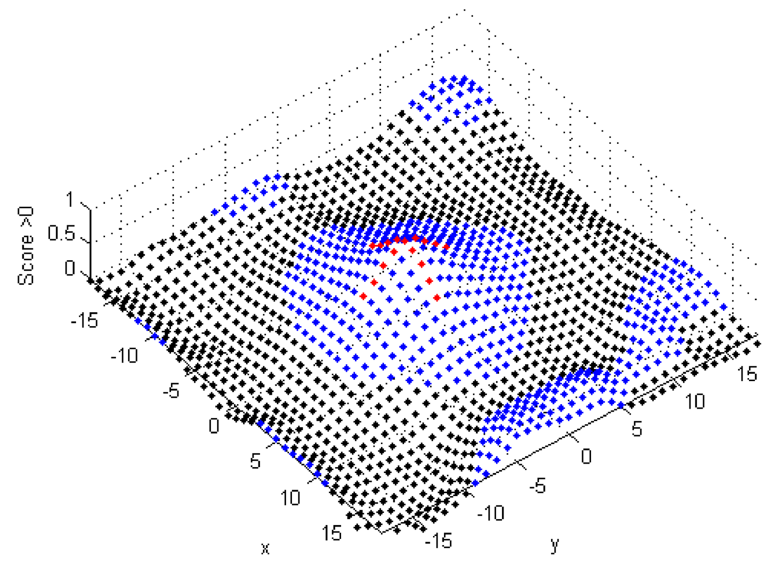
Cross-correlation was performed between circular template and corresponding image region, using Matlab function `corr2` to calculate correlation coefficient r. Advantage of being independent of brightness and contrast of image.

$$r = \frac{\sum_i \sum_j (a_{ij} - \bar{a})(b_{ij} - \bar{b})}{\sqrt{\left(\sum_i \sum_j (a_{ij} - \bar{a})^2\right)\left(\sum_i \sum_j (b_{ij} - \bar{b})^2\right)}}$$

Projective mapping of each image to reference image by Matlab functions `maketform`, `imtransform`. Quadrilaterals map to quadrilaterals; straight lines remain straight.

$$[u' \quad v' \quad w'] = [x \quad y \quad z]\,\mathbf{T}^{-1}$$

where $u = u'/w'$ and $v = v'/w'$ and $\mathbf{T}^{-1} = \begin{bmatrix} A & D & G \\ B & E & H \\ C & F & I \end{bmatrix}$, $u = \frac{Ax+By+C}{Gx+Hy+I}$, $v = \frac{Dx+Ey+F}{Gx+Hy+I}$

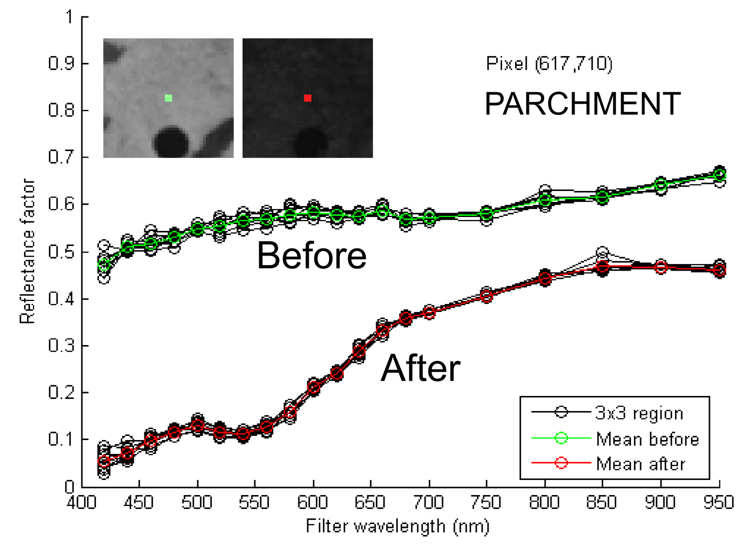


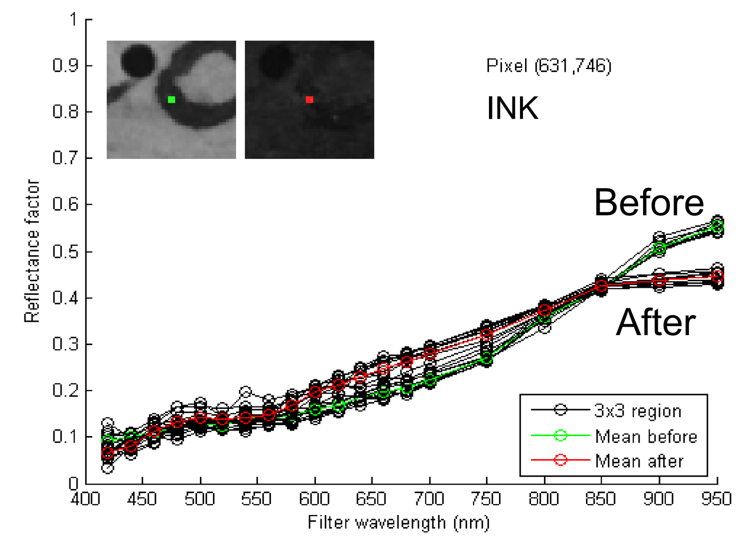
Correlation scores from template matching on one registration hole, visualised as a surface on a pixel grid, showing peak score at hole centre, and secondary peaks caused by ink strokes. Blue dots are scores >0.

False-colour composite of reference 600 nm channel of sample before treatment (blue), 850 nm channel of sample after treatment (green), and the latter after registration (red).

Colour Analysis

Reflectance spectrum reconstructed for any pixel region. Blood affected the parchment colour, reducing reflectance factor from 0.5 to less than 0.1 in the short wavelengths, rising to about 0.4 at long and NIR wavelengths, producing a dark red. Spectrum of iron gall ink was not much changed except at wavelengths >850 nm.





When the reflectance spectrum is known, then the colour appearance of the parchment under any illumination source of known spectral power distribution can also be predicted. Result is converted from *XYZ* tristimulus values to sRGB.