Images of archival material are useful to both conservators for monitoring changes, and to researchers for detailed analysis and permanent access to collection items. Image processing allows historical documents and other collection items to be studied without the risk of damage to the primary source. The increase in digitisation projects is generating large volumes of image files that can be processed to enhance the understanding of our collections without physically handling fragile material.

ImageJ is a powerful public domain Java-based image processing package. The nature of open source software allows for the constant update and availability of new plugins and recordable macros designed for specific tasks. ImageJ’s built-in editor and a Java compiler allow for the development of custom acquisition, analysis and processing plugins. In this study the applications of image processing to archival material are described.

**DIGITAL IMAGE ENHANCEMENT**, brightness/contrast adjust.

Important features in a collection item are often obscured due to poor environment lighting during image capture. ImageJ supports 8-bit, 16-bit and 32-bit grayscale images, and 8-bit and 32-bit colour images. The brightness and contrast of an image can be interactively altered serving to optimise features and enhance regions which are shrouded in darkness (Fig. 1).

**ARTIFACT INTERPRETATION**, merging and splitting channels.

Pseudocolour images are used to enhance features such as deterioration artifacts so that they are easier to interpret. Pseudocolour or false colour images are single channel grayscale images of 8, 16 or 32 bit pixel depth that have colour assigned to them via a look-up table (LUT). They reflect differences in image intensity rather than differences in image colour. This type of processing has applications for multispectral imaging where three bands reveal different information are chosen and assigned to the colours red, green or blue. These images can be merged to create a pseudocolour image highlighting important features (Fig. 2).

Sometimes image information can be observed more readily in single channel view than in RGB combination. An RGB image can be deconstructed in ImageJ using the Split Channels tool. The RGB original image separates into three grayscale images, in three different windows representing red, green and blue colour channels.

**SCHOLARLY UNDERSTANDING**, rotation and transformation.

Captured images are often at an unsuitable orientation for publication. It is also useful to compare writing on one side of a page with that on the reverse to determine if faded text is obscured by ink overlay.

Within the ImageJ Transform menu are options "Flip Horizontally" (replaces the image or selection with a mirror image of the original), "Flip Vertically" (turns the image or selection upside down), "Flip Z", "Transform", and three related to rotation which contains commands that rotate the active image or stack.

Slight rotations are achieved without apparent visible effect on the image, but a large rotation results in the reordering of colour values and slight blurring of boundaries (Fig. 3, B). For cultural heritage collections, the boundaries of letters and artefacts are crucial to defining context.

**PROVENANCE DETERMINATION**, colour space converter.

Converting images from the RGB to other colour spaces can reveal hidden text and help determine the provenance of archival material. The colour of an image is most often described in terms of the percentage of red, green and blue hues combined. Images such as these exist in RGB colour space, but there are other ways to describe the colour of a pixel using different colour spaces. Alternative ways of describing colour numerically are useful for making certain calculations easier and making colour identification more intuitive such as by describing colours by their hue, saturation and luminance. Describing colour numerically are useful for making certain calculations easier and making colour identification more intuitive such as by describing colours by their hue, saturation and luminance.

ImageJ has plug-ins for the conversion of a standard RGB image into another colour space called 'Colour Transformer' (Barilla 2012) and 'Colour Space Converter' (Schwartzwald 2007). ImageJ can generate as many as fifty-two combinations of the original image in different colour spaces.

**IMAGEJ**

ImageJ was originally designed for the purpose of medical imaging by the National Institutes for Health by Wayne Rasband, but has since found applications in many fields. It can be run on any computer with a Java 5 or later virtual machine, as an online applet or as a downloadable application (Microsoft Windows, Mac OS, Mac OSX, Linux, Sharp Zaurus PDA). ImageJ offers features similar to commercially available image processing software packages such as brightness/contrast adjustment, frequency domain filtering, binarisation and particle analysis.

**DIGITAL IMAGE ENHANCEMENT**

- Brightness and contrast adjust.
- Frequency domain filtering.
- Unsharp mask command.

**DEGRADATION MONITORING**, stacks.

Degradation features in a collection item can be monitored over time by comparing sequential images. An image stack is a collection of images of the same size and bit depth usually taken over the same region of interest where the scene is not changing due to motion. ImageJ can display these spatially or temporally related images in a single window allowing the user to scroll between images and monitor changes in the region of interest. Individual images within a stack are called slices.

Cameras can be positioned locally to collect images to determine the rate of dust collection or mould growth in a cultural heritage site. Placing images into a stack allows for immediate identification of changes. Multispectral images can be opened as a stack in ImageJ to compare the behaviour of pantochr and pigments across the electromagnetic spectrum.

**WATERMARK EXTRACTION**, bandpass filter.

The subject of interest of an image for a particular user can sometimes be obscured by other features such as a watermark hidden under lines of text. Bandpass filters can be used in ImageJ to filter out unwanted pixel structures. An upper size limit filters out large structures (shading correction) and a lower limit filters out small structures (smoothing).

ImageJ uses a Gaussian filter in Fourier space allowing isolation of important features for research. There is an extra option to suppress horizontal or vertical stripes, which is similar to subtracting an image that is only blurred in the horizontal or vertical direction in the original.

**BOUNDARY DEFINITION**, unsharp mask.

Unsharp Mask is applied to compensate for poor focus during image capture either because the user failed to focus the camera tightly enough, or because the camera was too far away from the subject (a possible restriction due to limited gutter opening space for bound collection items). Unsharp mask is a command in the ImageJ Process menu which subtracts a blurred duplicate of the image followed by a rescaling of the image to obtain the same contrast of large low frequency structures as in the original. The image is sharpened as this process is equivalent to adding a high pass filtered image to the input image.

Unsharp mask is the final operation which should be applied during image processing. It is a destructive process. Unsharp mask changes colour values and is especially destructive in the fine gradations of colour which form part of the image that is most vital in enhancement processes. Smooth backgrounds become grainy and lose subtle colour definition crucial to restoration, while boundaries become more well-defined (Fig. 4).

**DIGITAL IMAGE ENHANCEMENT**

- Brightness and contrast adjust.
- Frequency domain filtering.
- Unsharp mask command.

**SCHOLARLY UNDERSTANDING**

- Rotation and transformation.

**DIGITAL IMAGE ENHANCEMENT**

- Brightness and contrast adjust.
- Frequency domain filtering.
- Unsharp mask command.

**DEGRADATION MONITORING**

- Stacks.

**WATERMARK EXTRACTION**

- Bandpass filter.

**BOUNDARY DEFINITION**

- Unsharp mask.