Automatic registration and mosaicking of conservation images

Damon M. Conover[1], John K. Delaney[1,2], Murray H. Loew[1]

[1] The George Washington University, Department of Electrical and Computer Engineering, Washington, D.C.

[2] National Gallery of Art, Scientific Research Department, Washington, D.C.

Samuel H. Kress Foundation

Introduction

…cess of bringing into alignment two images … image registration is particularly useful when … a scene captured with different imaging modalities, such as … infrared (IR) imaging, because each modality can potentially … something different about the scene. By aligning the …ties, registration makes it possible to either merge the …ation contained within the images or to observe differences between them.

Hyperspectral reflectance imaging spectroscopy is a non-destructive method that allows for the construction of a reflectance spectrum at each point in an image. In the field of paintings conservation, the spectrum can be used to gain knowledge of artists' materials, such as pigments and binders [1].

Our registration and mosaicking algorithm allows for hyperspectral data to be captured at high spatial and high spectral sampling rates. The registered dataset can then be utilized to produce accurate pixel-level maps of the locations of materials used in the construction of a painting.

RGB color image (left), 1200-nm band (center) and 1680-nm band (right) from the registered and mosaicked hyperspectral image cube
Le Gourmet, Pablo Picasso (1901), Chester Dale Collection, National Gallery of Art, Washington, D.C.

Results

The resulting registered and mosaicked data sets are used to: 1) identify and emphasize information not visible at the surface of the paintings and 2) separate, map, and identify artists' materials in situ.

To date, the algorithm has been used to register and produce more than ten mosaicked large-scale hyperspectral image cubes, each consisting of 10 to 40 image cube captures (each 640 by 640 by 256 spectral bands).

The registration of the hyperspectral image cubes to an RGB color reference image is used to correct for differences in the properties of the imaging systems and their positions relative to the artwork. By registering those modalities, conservators are better able to identify and follow compositional changes, identify original sketches, and pinpoint damage and prior conservation treatments, such as inpainting. To produce the registered hyperspectral image cube, shown below, eight overlapping infrared sub-images were registered independently to an RGB color image. One large cube was then created by forming a mosaic from the registered cubes.

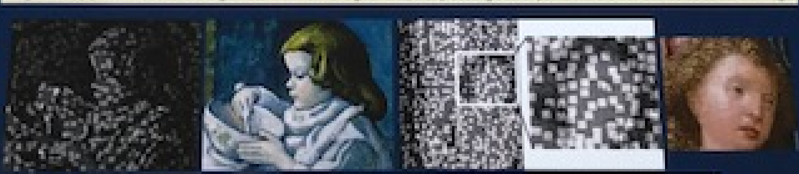
The images to the left are the RGB color image, the 1200-nm band from the resulting registered cube, and the 1680-nm band. The two example bands illustrate that the paint is becoming more transparent as the imaged bands move farther into the infrared. The image of the woman in the infrared is evidence of a previous painting that has since been painted over.

Method

Point-based image registration approaches usually consist of two fundamental steps: 1) control-point selection, and 2) control-point matching.

Automatic control-point selection

Selecting a good set of control points is an important first step when registering two images, particularly when those two images are acquired using different modalities. We start by computing the modulus maxima of the wavelet transform of the template image (one band from the hyperspectral image cubes) [2]. Then we select the largest local maximum for a given area, thus producing a set of points that are well-distributed across the image.



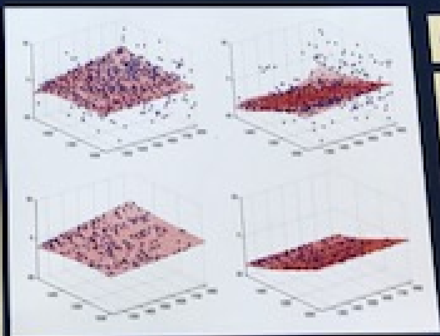
Candidate control points identified in the template images and the corresponding color reference images
Detail from *Le Gourmet*, Pablo Picasso (1901), Chester Dale Collection, National Gallery of Art, Washington, D.C.
Detail from *Christ Among the Doctors*, Bernard van Orley (1513), Samuel H. Kress Collection, National Gallery of Art, Washington, D.C.

…pping hyperspectral image cubes (960 – 1680 nm, 215 bands)
…Pablo Picasso (1901), Chester Dale Collection, National Gallery of Art, Washington, D.C.

Registered and mosaicked hyperspectral image cube (960 – 1680 nm, …
Le Gourmet, Pablo Picasso (1901), Chester Dale Collection, National G…
Washington, D.C.

Control-point matching between template and reference images

The set of points identified in the template image are matched with the corresponding points in the reference image (RGB color image) by finding the maximum of the normalized cross-correlation between the reference and template phase images. This produces an initial matched set of control points from each image, i.e., the same point in space. The sets may, however, contain false pairs and inaccurate matches. This can be seen in the horizontal- and vertical-disparity plots. The blue points represent the differences in the x- and y-coordinates (x- and y-disparity) between the two sets of points. The disparity plots also show a distortion in the image cubes due to the imaging spectrometer's scan mirror. The least-squares 4th-order function that best fit the disparity data are shown in red. The 4th-order function approximates the scan-mirror distortion. The bad pairs are identified by finding those that are far from the fit function. After the bad pairs have been iteratively removed, the remaining pairs are used to produce an accurate spatial transform that will correct for the scan-mirror distortion and bring the template image into alignment with the reference image.



Initial horizontal (top, left) and vertical (top, right) disparity maps
Final horizontal (bottom, left) and vertical (bottom, right) disparity maps

References

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