

Multi-modal imaging spectroscopy of paintings and illuminated manuscripts

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The use of non-invasive point measurements with multiple modalities has been shown to yield more complete identification of artist materials' in situ. For example, the combination of x-ray fluorescence elemental analysis combined with molecular reflectance and fluorescence spectroscopy can provide information on colorants (both inorganic and organic lake pigments) as well as paint binders. Extending this to collect 2-D spatial maps with each modality offers unique opportunities to mathematically combine, or fuse, the information derived from all the image cubes to yield material maps with higher confidence, as well as provide new image products. In this talk we will describe the instrumentation used to acquire such 3-D data sets and show examples of information that can be derived from them. The multi-modal imaging system is able to provide XRF image cubes, diffuse reflectance image cubes (400 to 2500 nm), as well as molecular luminescence image cubes (400 to 1000 nm). Using a novel image registration program developed with George Washington University, these image cubes can be spatially aligned with the color image, x-ray radiograph, etc. The case studies will highlight the potential to mine these data sets for new information. For example, an improved model for 'virtual removal of aged varnish' will be presented, which was derived from visible reflectance image cubes collected before and after the removal of an aged varnish on a painting by Georges Seurat titled *Haymakers at Montfermeil*, c. 1882. Other examples will include improved visualization of prior paintings which have been painted over, such as the Spanish woman beneath Pablo Picasso's Blue Period painting *Le Gourmet*, c. 1901, and earlier drawn and painted features found in Andrea del Sarto's painting *Charity*, c. 1528 or 1529 that relate to another of his paintings. Improved material maps obtained by fusion of XRF elemental maps with pigment maps obtained from reflectance imaging spectroscopy of Pacino di Bonaguida's illuminated manuscript titled *Christ in Majesty with Twelve Apostles*, c. 1320 will also be shown. Finally, all three imaging modalities were used to understand the artist's materials and methods used to create an encaustic Greco-Roman portrait painting from the 2nd century AD Egypt. The increasing availability of such image cubes collected in several modalities offers new opportunities for the development of new processing algorithms which will be expected to yield new information about important cultural objects.