TWT Spectrum Lab – Technical Information

**Conservation** is about preserving cultural heritage for the future and conservation activities include examining, documenting, and preventative care of an object and this is supported by research and education. A conservator is someone whose primary job is to protect and preserve art, objects, and historic sites that tell the story of our lives, history, and society. Conservators use their specialized knowledge and expertise to perform treatment and prevent damage from occurring to objects and sites.

- More information about conservation can be found on the American Institute for Conservation website: https://www.culturalheritage.org/about-conservation/what-is-conservation

**Conservation science**, also referred to as heritage science, is the interdisciplinary scientific study of cultural or natural heritage that draws on many disciplines from the humanities, sciences, and engineering. It can include aspects of material science, chemistry, physics, engineering, and biology. It focuses on increasing our understanding, care, and sustainable use of heritage so that the heritage objects and sites can enrich people's lives today and in the future. There are three main areas of conservation science:

- The first focuses on questions like: what is the object made of? When was it made? Where was it made? And how was it made?
- The second area focuses on how objects change and studies deterioration and degradation with the goal of slowing or stopping the degradation.
- The third area focuses on the development or modification of methods and techniques for examining and treating objects. Sometimes this is adopting tools and techniques from different fields.

**Imaging Techniques Information**

Imaging techniques, as non-destructive and sometimes portable tools, can aid in investigating documents, materials, manufacture, and condition to support research and conservation of heritage objects. Imaging can be used to investigate and record the condition of an object, increase the understanding of materials and how objects are made, and to inform additional analysis and care of an object.

Imaging does not require sampling or other types of destructive or invasive analysis and is often a good option when starting to look at and understand an object and its materials. The imaging results may help to inform additional scientific analysis and where sampling might be most informative. Many (but not all) imaging techniques are portable which means that the equipment can be taken to the museum or conservation lab instead of the object needing to travel to the equipment. This is important to reduce the risk and handling of valuable and fragile objects.

**Visible light imaging (VIS)** records an object under normal illumination and creates an image similar to one the human eye would see. The technique is used to record the condition of an object and to act as a reference for the other imaging techniques. The visible light image is particularly useful if the object is not available when analyzing and interpreting the image data or other analytical results. Visible light images were acquired to correspond with the other imaging modalities as well as document the condition of the objects. Visible light images are acquired using a standard digital camera and a light source that outputs visible light. No filters are required.

**Ultraviolet (UV)-induced visible luminescence imaging (UVL)** records low-energy radiation that materials reemit in the visible range, called luminescence, during exposure to UV radiation. UVL has been widely used in art conservation as a non-destructive examination technique for characterizing and differentiating materials, assessing the condition, and showing alterations and past conservation treatments. Using UV radiation may help a conservator reveal or differentiate materials, features, or conditions that may not be observed in visible light. UVL is used for a variety of cultural heritage objects, but for paintings it is useful to characterize and differentiate varnishes and pigments. It is particularly useful in the cases of organic materials such as coatings and adhesives and can be used to characterize varnish coatings on paintings. Some pigments have characteristic luminescence that can provide information about the material. For example, three white pigments respond differently to UV radiation: lead white luminesces white, zinc white luminesces pale yellow, and titanium white does not luminesce. Another example, two yellows respond differently to UV radiation: Indian yellow luminesces yellow and orpiment does not luminesce.

UVL is also used to identify past conservation treatments because these treatments include non-original materials that may respond differently to UV radiation, allowing these details to be revealed with documenting the object with UVL. Conservation treatments of paintings are often separated from the paint surface with a varnish layer. When examining the painting under UV radiation, the varnish will likely luminesce while the overlying treatment will likely absorb the UV radiation appearing darker and not luminescing.

UVL images are acquired with a standard digital camera using a UV radiation source and some filters on the camera lens to ensure only visible light is being recorded.

Resource that may be interesting for students that further describes UVL (also referred to as UV-induced visible fluorescence): https://www.webexhibits.org/pigments/intro/uv.html

**Reflected Infrared (IR) imaging** records the variable absorption, transmission, and reflection of IR radiation by the materials that make up an object. The IR wavelengths may penetrate materials below the surface, unlike visible light, revealing preparatory drawings and information about the artist process when documenting materials like paper objects and paintings. Materials may absorb and reflect IR radiation differently from visible light, which can help with material characterization and enhancing the visibility of obscured or faded details. In the case of paint and charcoal or carbon-based inks on paper, the contrast can be dramatic. Reflected IR imaging is also used to further investigate the condition, materials, and manufacture of the objects.

Reflected IR imaging requires the use of a camera that is sensitive to IR radiation. The sensors at the heart of consumer digital cameras are inherently sensitive to near UV and near IR radiation; however, these cameras are optimized for color, visible light photography. A standard consumer digital camera includes a color filter array on the sensor in order to produce a color image and a UV and IR block filter over the sensor to only pass visible light and provide the highest image quality. By removing these filters, a consumer digital camera can be used to record in the near UV and near IR ranges (up to about 1000 nm). For reflected IR imaging, we used a modified digital camera with different filters on the camera lens that block UV and visible light and pass IR wavelengths. IR imaging also requires a light source that has output in the near infrared range.

**Reflectance Imaging Spectroscopy – Multispectral Imaging (MSI) and Hyperspectral Imaging (HSI)**

Multispectral and hyperspectral imaging are both reflectance imaging spectroscopy techniques. These techniques extend spot-based reflectance spectroscopy, and they involve the collection of high-quality images with spectral information associated with each pixel. These image sets are called image cubes and can help with identifying artists' materials and mapping their spatial distribution of these materials over the object surface. These techniques are also used to identify past conservation treatments and can be used to visualize underdrawings if the included range extends into the infrared.

Multispectral imaging tends to involve tens of images, or bands, while hyperspectral imaging involves hundreds of bands that tend to be narrower with bandwidths of a few nanometers or less. Both techniques were initially developed for remote sensing but have been adapted and developed for conservation science and the recording of heritage objects. An important feature for both MSI and HSI is that they do not require samples for analysis; they are non-invasive and non-destructive tools to investigate heritage objects.

**Multispectral Imaging (MSI)** is used to differentiate materials, enhance or recover hidden or obscured features, and provide information about the condition of an objection. With systems that go into the IR, there is also the opportunity to visualize underdrawings.

**Hyperspectral Imaging (HSI)** requires specialized camera equipment that can be quite expensive. Often the ranges are separated with cameras that acquired visible and near IR also known as a VNIR system and cameras that acquire in the shortwave infrared (SWIR) range, known as SWIR systems. Depending on the SWIR systems, the wavelength range may be from about 900 or 1000 nm up to 2500 nm.

HSI can be used for identifying some pigments and artists' materials. Multivariate statistical analysis is used to reduce the large number of reflectance spectra for analysis and interpretation including the identification of pigments and artists' materials. Some pigments have specific spectral features that can aid in characterization and identification. The image cube can also be explored by looking at the individual images that make up the image cube. This could include exploring traces of an earlier painting beneath the surface and changes in the final composition. In some cases, this can lead to discovering paintings that have been painted over. Looking at the images that make up the image cube can also allow the visualization of underdrawings since infrared radiation can penetrate many paint layers. Underdrawings are the sketches made by artists as they plan the composition of the painting. Sometimes the painting we see follows the underdrawings and other times we can see changes in the composition between the underdrawings and what we see on the painting's surface.

**False Color Image Processing and False Color Infrared (FCIR)**

A false color image is created by using a combination of images in the different color channels combining the features from all the images into one image. We use the red, green and blue channels to create a false color image. These images can help to visualize the spectral differences between materials and can be useful for differentiating materials and mapping the distribution of a material across the surface of an object.

False Color Infrared (FCIR) is a processing method using a visible light image and a reflected IR image of the same view of an object to characterize and differentiate materials. FCIR has been successfully used for inks, dyes, and pigments for conservation documentation. The processing involves channel substitution to result in an image with “distinctive ‘false’ colors” that facilitates the characterization of different materials. The channel substitution can be done in an image processing program like Adobe Photoshop where the green channel is moved to the blue channel, the red to green, and the IR to red. Conservators often use FCIR using visible light and reflected IR images, but conservation scientists also use this process with MSI and HSI image sets.

False color image processing is not just restricted to false color Infrared processing. With MSI and HSI, any band combination can be used to create the false color using the red, green, and blue channels, and the combination of bands may be selected to further differentiate materials.