COSCH STSM WG1: Elaboration of Hyperspectral Image Data from Round Robin Test Acquisition

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*Science & Engineering Arts Heritage & Archaeology (SEAHA) Centre for Doctoral Training*

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Host: Marcello Picollo

Instituto di Fisica Applicata “Nello Carrara”—Consiglio Nazionale delle Ricerche (IFAC-CNR)

Florence, Italy
Infrared (IR) Techniques & Technologies

Detector

Mercury Cadmium Telluride (MCT or HeCdTe) 1000-5500 nm

Indium Gallium Arsenide (InGaAs) 900 -1700 nm

Silicon 350-1100 nm
Charged-Couple Device (CCD) & Complementary Metal-Oxide Semiconductor (CMOS)

Mid-Infrared (MWIR)

Short-Wave Infrared (SWIR)

Near-Infrared (NIR)

Ultraviolet (UV) 400 nm
Visible (VIS) 700 nm

Technique

Visible Light Imaging (VIS)  Reflected Infrared Imaging  Infrared Reflectography (IRR) 2500 nm
Imaging Spectroscopy

• Combining digital imaging and spectroscopy¹
  – Expands point-based, or 1D, spectroscopic techniques
  – Ability to map spatial distribution of materials over entire object;
  – Extract reflectance spectra for identification of materials;
  – Enhance and reveal underdrawings;
  – Identify past conservation treatments; and
  – Measure colour (only in VIS).

Imaging Spectroscopy

Multispectral Imaging$^2$
   - Sequence of images with bandwidths of tens to hundreds of nanometers

Hyperspectral Imaging$^2$
   - Sequence of images with bandwidths of a few nanometers or less

Round Robin Test (RRT): Objectives

• To work towards standardised methodologies and best practices for spectral imaging in the CH field

• To better understand:
  – instrumentation
  – elements of data acquisition
  – the effects of the instruments and methodology to the accuracy and reliability of the data
COST is supported by the EU Framework Programme Horizon 2020

Round Robin Test (RRT): Materials

SphereOptics Zenith Polymer Wavelength Standard
X-Rite White Balance
X-Rite ColorChecker® CLASSIC
Painted test panel – medieval Tuscan technique
Antique Russian Icon (1899) on Copper plate

Figure from Vitorino
Round Robin Test (RRT): Materials

SphereOptics Zenith Polymer Wavelength Standard
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Painted test panel – medieval Tuscan technique
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Figure from Vitorino
STSM Objectives

• Process and compare RRT data from three institutions acquired in the short-wave infrared (SWIR) region (1000-2500 nm)

• Assess spatial and spectral resolution and how this influences the accuracy and reliability of the resulting data
  – Spatial Resolution—measure of a system’s ability to resolve the desired details in the image of an object
  – Spectral Resolution—how well the system can resolve the spectral details

• Inform the standardisation of methodologies and the development of best practices
Test Panel & Underdrawing Materials
Made by Elena Prandi & Marina Ginanni
(Restoration Laboratories of the Polo Museale Toscana)

<table>
<thead>
<tr>
<th>Material</th>
<th>Lead-based metalpoint</th>
<th>Lead and tin-based metalpoint</th>
<th>Graphite</th>
<th>Charcoal</th>
<th>Watercolour</th>
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<td>½ mm</td>
<td>½ mm</td>
<td>Spolvero (line) outlined with traces</td>
<td>½ mm</td>
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<tr>
<td>Sfumato</td>
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Figure from Vitorino
SphereOptics Zenith Polymer Wavelength Standard
Provided by András Jung (Leipzig University)

Wavelengths include:

1009.5 – 1013.5 nm
1134.1 – 1138.1 nm
1198.6 – 1202.6 nm
1230.5 – 1234.5 nm
1299.3 – 1303.3 nm
1470.0 – 1474.0 nm
1476.0 – 1478.0 nm
1682.0 – 1686.0 nm
1932.5 – 1936.5 nm

Data Acquisition: HSI Systems

**IFAC-CNR**—Instituto di Fisica Applicata “Nello Carrara”—Consiglio Nazionale delle Ricerche
- Custom-built HSI scanner with ImSpector N17E

**NM Krakow**—National Museum of Krakow
- Specim ImSpector N25E

**UCL-ISH**—University College London—Institute for Sustainable Heritage
- Gilden Photonics HSI system with Specim ImSpector N25E
# Data Acquisition: HSI Systems

<table>
<thead>
<tr>
<th></th>
<th>IFAC-CNR</th>
<th>NM Krakow &amp; UCL-ISH</th>
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<tbody>
<tr>
<td>Spectrophotometer</td>
<td>ImSpector N17E</td>
<td>ImSpector N25E</td>
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<tr>
<td>Sensor Type</td>
<td>InGaAs</td>
<td>MCT</td>
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<tr>
<td>Pixel Dimension (px)</td>
<td>512</td>
<td>320</td>
</tr>
<tr>
<td>Spectral Range</td>
<td>900-1700 nm</td>
<td>1000-2500 nm</td>
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<tr>
<td>Spectral Resolution</td>
<td>5 nm</td>
<td>8 nm</td>
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<tr>
<td>Number of Bands</td>
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<td>256</td>
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Assessing Spatial Resolution

• Visual comparison
• Plotting vertical profiles
• Calculating the sampling density
Spatial Resolution: Visual Comparison

IFAC-CNR

NM Krakow
Spatial Resolution: Vertical Profiles

IFAC-CNR

NM Krakow
### Spatial Resolution: Sampling Density

<table>
<thead>
<tr>
<th>Institution</th>
<th>Sampling Density</th>
<th>Spatial Resolution</th>
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</thead>
<tbody>
<tr>
<td>IFAC-CNR</td>
<td>55 x 55 pixels</td>
<td>9.12 px/mm</td>
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<tr>
<td>NM-Krakow</td>
<td>7 x 7 pixels</td>
<td>1.17 px/mm</td>
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<tr>
<td>UCL-ISH</td>
<td>6 x 6 pixels</td>
<td>1.05 px/mm</td>
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</table>
Assessing Spectral Resolution

SphereOptics Zenith Polymer Wavelength Standard

![Graph depicting spectral resolution analysis](image-url)
SphereOptics Zenith Polymer Wavelength Standard
Detail 1450 – 1500 nm

Reflectance (%) vs. Wavelength (nm)
Comparing Sampling Densities

- IFAC-CNR
- NM Krakow
- UCL-ISH

1050 1055 1060 1065 1070 1075 1080 1085 1090 1095 1100
Gypsum

Azurite 1

Lead White

Malachite 1

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Conclusions

• Spectral and spatial resolution needs of system determined by object and use of resulting data

• Accuracy and reliability of the data improved by understanding the systems, elements of data acquisition, and the affects of the instruments and methodology

• Value of scientific investigations increased by standardising and defining best practices
  • Reproducibility and comparability

• Collaborative endeavor and an interdisciplinary team required for imaging spectroscopy of paintings
Acknowledgements

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  – University College London (UCL)
  – Analytik Ltd.
• National Museum of Krakow
• UCL Institute for Sustainable Heritage