Future Directions

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What about the Future trends?

- Recent trend towards multi-analytical and multi-instrumental approaches
- Mapping and Imaging
- Non-invasive techniques are increasingly being used intelligently to answer key questions in preventive and practical conservation

5I's: General trends

- Instrumental Advances
- Integrated Approaches
- Intelligent Applications
- Interpretation and Assessment
- International Publications & Dissemination

Instrumental Advances

- Lasers are becoming cheaper and smaller
- Sensors are developing for some applications (X-ray detection, FTIR)
- Motorisation is being combined to allow scanning and 3-d imaging/sensing
- There will always be new instrumentation
  - NMR Mouse
  - ATR devices
  - Atmospheric MALDI
Instrumental Advances: Example X-ray fluorescence scanning

- Combine XRF with a scanning instrument
- For the moment this has been limited to paintings - but this could be extended to 3-d objects
- Use rapid Si-drift detectors to acquire spectra and scan an area

XRF maps of Lapis Lazuli

The pattern of Ca-rich and K-rich phases, detected with high lateral resolution, together with the presence of traces of Ba and inclusions of Fe (Pyrite) constitute a fingerprint for the Siberia source. DOI: 10.1021/acs.analchem
Instrumental Advances: FTIR Imaging

Antilllean folk art painting (8×8 cm²), of assumed 20th Century origin. A) Visual image; MA-FTIR chemical distribution images: B) cadmium lithopone (1173–1260 cm⁻¹), C) chrome yellow (980–990 cm⁻¹), D) phthalocyanine blue (729–740 cm⁻¹) and E) phthalocyanine green (747–762 cm⁻¹); MA-XRF elemental distribution maps of F) cadmium, G) chromium, H) copper and I) chlorine: lighter tones indicate higher levels of net pseudo absorbance or X-ray fluorescence intensity; J) Photograph of MA-FTIR device in front of a large canvas, scanned area: 76×76 mm², step size: 1 mm in both directions, dwell time: 8 s/pixel.

Instrumental Advances: Fluorescence Lifetime Imaging

Umberto Boccioni: Modern Idol (1911)
25 images @ 355 and 532 nm Estorick Museum London

Lifetime Imaging
Maps of Pigments

FTIR “Hyperspectral” Imaging

Angewandte Chemie International Edition 52(20) May 2013, DOI:10.1002/anie.201209929
Integrated Approaches

- Combine instrumentation to gain more complete assessment
  - Laser Scanning + Photogrammetry
  - OCT + Spectral Imaging
- Use more than one technique
- Many examples including XRF-Raman have been produced
- Scanning: IR+VIS
- The same setup for XRF+XRD

Interpretation and Assessment

- Free Access to databases
- Free Software
- Better networks and user working groups (IRUG)
- User interfaces make operating instruments easier
- Increase in the number of publications suggesting interpretation for spectra in conservation
- Use statistical methods to assess data and images

Intelligent Applications

- Research driven investigations
- In depth studies to examine materials and their ageing
- Assess treatments in real time
- Understand and prevent deterioration

Laser-based analytical techniques

Assessing the effect of RH on works of art: paintings on wood
**Context: RH on works of paintings on wood**

- Many paintings are on wood – crucifixes, fayum, sarcophagi, panels, icons, etc.
- Wood is a hygroscopic material:
  1. Wood support and paint Absorbs humidity and changes shape
  2. Changes in RH and T can cause significant damage or dimensional change
  3. Few methods for monitoring of effect on paintings

**Assess the effect of RH on works of art: paintings on wood**

- **Questions**
  1. Is it possible to measure variations in the moisture content of wood using non-contact laser-based spectroscopic techniques?
  2. Can real-time movement of paintings as a function of changes in ambient conditions be measured?
  3. What degree of change can be measured how fast is dimensional change?

**Analytical Techniques:**

1. **Time-resolved diffuse reflectance spectroscopy**
2. **Digital Holographic Speckle Pattern Interferometry (DHSPI)**

**Wood and RH: Basics of time-resolved absorption spectroscopy**

1. ps laser Ti (465-1750 nm)
2. spectral density > 1 mw for all A
3. Laser is focused into a 50 μm core graded index fibre and into the wood sample.
4. Detect transmitted (diffuse) irradiation using a 1 mm plastic-glass optical fibre
5. Detect micro-channel plate photomultiplier
6. Time-correlated single photon counting (TCSPC) PC board to record time-resolved curves.
7. Mathematical modelling to separate absorption and scattering coefficients

**Absorption spectrum (μa)** ► concentration of constituents (lignin, cellulose, and H₂O) by Beer’s law

**Scattering spectrum (μs) » structure of wood**

Spectra change depending on RH (MC), Resolve spectrum into μa and μs
Wood and RH: Time-resolved spectroscopy

- Coniferous European Silver Fir (*Abies alba*) (cut into samples of: 5 cm x 5 cm x 5 cm)
- Static differences in moisture content
- Blocks of wood were conditioned in sealed plexiglass boxes with saturated solutions
- RH varied between 12% to 94% at 25 °C
- Moisture contents of wood were achieved ranging from 4.7-17.8%.

Wood and RH: Consider Dynamic Time-resolved spectroscopy of wood with ΔRH


Wood and RH: Basics behind the assessment of movement using Holographic Interferometry

V. Tornari, Analytical and Biomedical Chemistry, 2007


Detection of movement following change in conditions (change in T)

1. Even very small differences (1%) in MC → differences in absorption spectra
2. Particularly advantageous for the monitoring of samples during humidity changes
Nd:YAG: 250 mW at 532 nm, a coherent length of 30 m.

CCD detector 1392 x 1040, pixel size 6.45 μm x 6.45 μm.

Change environmental conditions (RH) and record interference patterns in real time (every 6 seconds following change).

Wood and RH: Digital Holographic Speckle Pattern Interferometry

Displacement from the centre of the panel to the right edge/time for an isothermal humidity change from RH 23-58%.

0-11 minutes after change

Movement continues after 30 minutes with a total displacement of ~ 20 micrometers

18-27 minutes after change
Analysis of wooden materials

Research Questions
1. Is it possible to measure variations in the moisture content of wood using non-contact laser-based spectroscopic techniques?
   1. Time resolved absorption spectroscopy may provide means but relies on light coloured materials (darker materials will absorb more radiation)
   2. Alternative methods may require use of electrode/sensors
2. Can real-time movement of paintings as a function of changes in ambient conditions be measured?
   1. DHSPI provides a unique non-contact method
3. What degree of change can be measured how fast is dimensional change?
   1. Micrometer-level changes (~2 micrometers depending on S/N)
   2. Very rapid dimensional changes occur with change in RH
      1. Movement begins within seconds (detected within 6 seconds with DHSPI)
      2. Movement continues for many minutes

Articles in Studies in Conservation@ IIC

User of imaging spectroscopy, fiber optic reflectance spectroscopy, and trypt fluorescence to map and identify pigments in illuminated manuscripts

John E. Nemecek, Konn Bicakci, Linda Darley-Scheuber, Arthoara Hata, Matthew Novak, Abdal-Halim L., and A. A. El Khoefi


Distribution of moisture in reconstructed oil paintings on canvas during absorption and drying: A neutron radiography and NMR study


Articles in Studies in Conservation@ IIC
International Dissemination and Publications

- IIC Studies in Conservation*
- Special Issues in Studies in Conservation
  - LACONA
  - LACQUER
- National Gallery Technical Bulletin
- British Museum Journals
- Getty Conservation Institute Publications
- Dedicated scientific publications from other journals and publishers
  - Pigment Compendium

International Dissemination and Access to knowledge

- Conferences
  - IIC Biennial Congresses
  - See IIC Website for events and other congresses
  - Consdistlist
  - Dedicated scientific conferences but most are not with or for conservators
    - XSA
    - IRUG (very small)
    - TECHNART 2017