IIC-ITCC 2016 Programme
Non-destructive Analysis in the Conservation of Cultural Heritage
Teaching Topics and References

Current State of Non-Destructive Analysis of Cultural Properties

This session will make a brief survey of the types of method that are available for non-destructive analysis and introduce some of the techniques that will be covered in greater detail throughout the course of the week.

It will begin by addressing the issue of why we conduct scientific analysis of cultural properties and what type of question we are seeking to answer in so doing.

The non-destructive methods will be grouped according to the extent of information they provide, from point analyses to whole object examination, and according to the type of analytical information that they generate. Each group and method will be illustrated with case studies.

An assessment will be made of how representative the information gained is, and of the accessibility, cost and complexity of equipment and technique.

Finally, the results provided by non-destructive techniques will be compared with those that can be obtained from methods that require sampling; a brief risk benefit analysis for decision making regarding sampling will be presented.

Analytical Imaging

Teaching topics:

1. Visible imaging
2. Infrared imaging
3. Ultraviolet imaging
4. Image analysis and interpretation (False colour and UV-induced luminescence imaging corrections)
5. X-ray and neutron radiography
6. Case studies

Readings:

1. G. Verri and D. Saunders, 'Xenon flash for reflectance and luminescence (multispectral) imaging in cultural heritage applications', The British Museum Technical Bulletin, 8 2014 83-92
2. http://www.britishmuseum.org/pdf/BMTRB_8_Verri_and_Saunders.pdf
3. J. Dyer, G. Verri and J. Cupitt, 'Multispectral Imaging in Reflectance and Photo-induced Luminescence modes: a User Manual', European CHARISMA Project, published online
4. https://www.britishmuseum.org/pdf/charisma-multispectral-imaging-manual-2013.pdf

Microscopy

Teaching topics:

1. USB microscopy
2. PLM (cross sections, thin sections and dispersions)
3. Fluorescence and Confocal microscopy
4. SEM-EDX
5. Case studies

Readings:

1. http://olympus.magnet.fsu.edu/primer/techniques/fluorescence/fluorhome.html
2. http://serc.carleton.edu/research_education/geochemsheets/techniques/SEM.html

Colour and Gloss

Teaching topics:

- Definition of colour and gloss
- Origins of colour and gloss in objects – specular and non-specular reflection
- Standard methods of defining colour, colour difference and gloss
- Classifying, mapping, measuring and comparing colour
- Instrumental methods for colorimetry and spectrophotometry
- Reference standards
- Long-term monitoring of colour
- Case studies of colour measurement of cultural heritage
- Techniques for gloss assessment and measurement
- Case studies of gloss measurement

References:

1. Bacci, M., Baronti, S., Casini, A., Lotti, F., Picollo, M., and Casazza. O. (1992). Non-destructive spectroscopic investigations on paintings using optical fibers. *Materials Research Society Symposium Proceedings*, 267, 265–283.

2. Bullock, L. (1978). Reflectance spectrophotometry for measurement of colour change. *National Gallery Technical Bulletin*, 2, 49–55.

3. Ford, B. L. (1992). Monitoring colour change in textiles on display. *Studies in Conservation*, 37(1), 1–11.

4. Hunt, R. W. G., & Pointer, M. (2011). *Measuring Colour. Wiley-IS&T Series in Imaging Science and Technology* (4th ed.). Chichester, West Sussex, U.K.: Wiley.

5. Martinez, K., Cupitt, J., Saunders, D., and Pillay, R. (2002). 10 years of Art imaging research. *Proceedings of the IEEE*, 90(1), 28–41.

6. Nadal, M. E., Early, E. A., & Thompson, E. A. (2006). *Specular Gloss. NIST Special Publication 250-70*. Gaithersburg, MD: U.S. Dept of Commerce, Technology Administration, National Institute of Standards and Technology, Physics Laboratory, Optical Technology Division.

7. Ricciardi, P., Delaney, J. K., Facini, M., and Glinsman, L. (2013). Use of Imaging Spectroscopy and in situ Analytical Methods for the Characterization of the Materials and Techniques of 15th Century Illuminated Manuscripts. *Journal of the American Institute for Conservation*, 52(1), 13–29.

8. Schanda, J. (2007). *Colorimetry: Understanding the CIE System*. Vienna: International Commission on Illumination; Hoboken, NJ: Wiley-Interscience.

Optical Coherence Tomography (OCT)

Outline:

- What is OCT?
- How does it work?
- Different types of OCT
    - Time-domain OCT
    - Spectral domain OCT
    - Other classifications - Raster scan and parallel or full field OCT
    - Functional OCT
        - Doppler OCT
        - Spectroscopic OCT
- How to interpret an OCT image?
- What can OCT measure?
- Which OCT is right for your application?
- Example applications of OCT to different conservation, art history and archaeology problems and different types of objects

Pre-course recommended reading:

1. LIANG, H., PERIC, B., HUGHES, M., PODOLEANU, A., SPRING, M. and ROEHRS, S., 2008. Optical coherence tomography in archaeological and conservation science - a new emerging field., *Proceedings of SPIE 2008*, 713971. http://irep.ntu.ac.uk/24480/
2. P. Targowski, M. Iwanicka, "Optical Coherence Tomography: its role in the non-invasive structural examination and conservation of cultural heritage objects—a review", Applied Physics A **106**(2), Special Issue on *"Optical Technologies in Art and Archaeology"*, 265-277 (2012) http://link.springer.com/article/10.1007%2Fs00339-011-6687-3
3. CHEUNG, C.S., SPRING, M. and LIANG, H., 2015. Ultra-high resolution Fourier domain optical coherence tomography for old master paintings., Optics Express. *Optics Express*, 23 (8), pp. 10145-10157. ISSN 1094-4087. http://irep.ntu.ac.uk/22486/ [just read section 3]

Reality Based 3D Models for the Documentation of Cultural Heritage

Outline:

1. Survey definitions and Cultural Heritage subject matter
2. Non invasive 3D survey techniques: 1) long range scanner, 2) structured light scanner and 3) photogrammetry
3. Survey results outcome: point cloud and/or mesh
4. Use and processing of the data
5. Web sharing of the data
6. Conclusion/Bibliography

References:

1. Dellepiane, M.; Callieri, M.; Fondersmith M.; Cignoni, P.; Scopigno, R. (2007); Using 3D scanning to analyze a proposal for the attribution of a bronze horse to Leonardo da Vinci. *The 8th International Symposium on Virtual Reality, Archaeology and Cultural Heritage*, November, Sacramento CA, USA, pp. 117–124.

2. De Luca, L. (2011); Methods, formalisms and tools for the semantic-based surveying and representation of architectural heritage. *Applied Geomatics*, June 2014, Vol. 6, Issue 2, Springer, pp. 115–139, DOI: 10.1007/s12518-011-0076-7.

3. Fassi, F.; Achille, C.; Fregonese, L. (2011); Surveying and modelling the Main Spire of Milan Cathedral using multiple data sources. *The Photogrammetric Record*, *26*, pp. 462-487.

4. Remondino, F. (2011); Heritage Recording and 3D Modeling with Photogrammetry and 3D Scanning. *Remote Sens.*, *3*, 1104 – 1138, DOI: 10.3390/rs3061104.

5. Russo, M.; Guidi, G. (2011); Reality-based and reconstructive models: digital media for cultural heritage valorization. *SCIentific RESearch and Information Technology*, *1*, pp. 71–86, ISSN 2239-4303, DOI:10.2423/i22394303v4n2p87.

6. Fassi F.; Parri, S. (2012); Complex architecture in 3D: from survey to web. *International Journal of Heritage in the digital era*, *1*, pp. 379–398, ISSN: 2047-4970.

7. Dore, C.; Murphy, M. (2012); Integration of Historic Building Information Modeling (HBIM) and 3D GIS for Recording and Managing Cultural Heritage Sites. *Proceeding of 18th International*

Conference on Virtual Systems and Multimedia, Virtual Systems in the Information Society, 2 – 5 September, Milan, Italy, pp. 369–376, IEEE 978-1-4673-2565-3/12.

8. Fassi, F.; Achille, C.; Mandelli, A.; Rechichi, F.; Parri, S. (2015); A new idea of BIM system for visualization, web sharing and using huge complex 3d models for facility management. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.*; Volume XL-5/W4, *Proceedings of the 3D Virtual Reconstruction and Visualization of Complex Architectures*, 25 – 27 February, Avila, Spain, DOI: 10.5194/isprsarchives-XL-5-W4-359-2015.

9. Fassi, F.; Rossi, C.; Mandelli, A. (2015); Emergency survey of remote and endangered archaeological sites. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.*; Volume XL-5/W4, *Proceedings of the 3D Virtual Reconstruction and Visualization of Complex Architectures*, 25 – 27 February, Avila, Spain, DOI: 10.5194/isprsarchives-XL-5-W4-85-2015.

10. Tommasi, C., Achille, C., Fassi, F., From point cloud to bim: a modelling challenge in the cultural heritage field, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLI-B5, 2016, XXIII ISPRS Congress, 12–19 July 2016, Prague, Czech Republic

11. Stylianidis, E., Remondino, F., 3D Recording, Documentation and Management of Cultural Heritage, Whittles Publishing, Anno edizione: 2016, ISBN: 1849951683

Spectral Imaging

Outline:

- What is spectral imaging?
- What can we learn from spectral imaging?
- Different types of spectral imaging devices
    - Different capturing methods
    - Different spectral range
    - From close range imaging of small objects to remote imaging of large wall paintings at standoff distances at the same high resolution
- How to select the right instrument for your application?
- Calibration & post-processing – an important step in quantitative spectral imaging
- Material identification using spectral reflectance
- The Big Data challenge & modern statistical methods for information extraction – automated uncovering of the unknown unknown
- A systematic multi-modal approach to non-invasive investigation – a case study

Pre-course recommended reading:

LIANG, H., 2012. Advances in multispectral and hyperspectral imaging for archaeology and art conservation., Applied Physics A: Materials Science & Processing. *Applied Physics A: Materials Science & Processing*, 106 (2), pp. 309-323. http://irep.ntu.ac.uk/25520/

CT

Teaching topics:

1. Basic concepts of CT
2. 2-D X-radiography vs. CT
3. CT scan example: JPGM Red shroud mummy
4. Getty Home built CT scan
    a. Concept of system
    b. Various parts of system
5. Tips and Tricks
6. Case studies
    a. Horse model
    b. Roman statuette of Eros
    c. Roman silver statuette of Mercury
    d. Other case studies

Reading Material and Key References:

1. F. Casali, “Chapter 2. X-ray and neutron digital radiography and computed tomography,” in Physical Techniques in the Study of Art, Archaeology and Cultural Heritage. New York: Elsevier, May 2006, vol. 1: 41–123
2. Bettuzzi, M., Casali, F., et al. (2015). “Computed tomography of a medium size Roman bronze statue of Cupid”, Applied Physics A 118 (4): 1161-1169.
3. Re, A., Albertin, F., et al. (2014). “X-ray tomography of large wooden artworks: the case study of “Doppio corpo” by Pietro Piffetti”, Heritage Science 2(19)

XRF

Teaching topics:

1. Basic concepts of X-ray fluorescence spectrometry
2. Qualitative analysis of EDXRF
3. XRF applied to cultural heritage
    a. Advantages and limitations
    b. Handheld vs. micro-XRF vs. macro-XRF scanner
4. Tips and Tricks
5. Case studies
    a. Paintings
    b. Objects
    c. Manuscripts, photography

Reading Material and Key References:

1. C. McGlinchey. “Handheld XRF for the examination of paintings: proper use and limitations.” in XRF for art and archaeology. A. N. Shugar and J. L. Mass. Leuven, Leuven University Press: 131-158
2. Namowicz, C., K. Trentelman, et al. (2009). "XRF of cultural heritage materials: Round-robin IV- paint on canvas." Powder Diffraction 24(2): 124-129
3. Hahn, O., B. Kanngiesser, et al. (2005). "X-ray Fluorescence Analysis of Iron Gall Inks, Pencils and Coloured Crayons." Studies in Conservation 50(1): 23-3
4. Alfeld, M., J. V. Pedroso, et al. (2013). "A mobile instrument for in situ scanning macro-XRF investigation of historical paintings." Journal of Analytical Atomic Spectrometry 28(5): 760-767

FTIR and Raman

Teaching topics:

1. Molecular Spectroscopy: Theory, Electromagnetic Spectrum Vibrational Energy Levels, Fluorescence and Phosphorescence
2. Vibrational Spectroscopy: Phenomena of Raman Scattering and Infrared Absorbtion, Overtones and Combinations
3. Instrumentation: Michelson Interfermoter (Fourier Transform Infrared Spectroscopy) and Raman set-ups, Integration of Microscopy and Spectroscopy
4. Applications of Infrared Spectroscopy and Micro-FTIR: Different set-ups, Analysis of Minerals, Degradation and Organic materials
5. Applications of Raman Spectroscopy: Analysis of Pigments, Surface Enhanced Raman Spectroscopy
6. Applications of Near Infrared Spectroscopy: Analysis of Cellulose and Polymers
7. Introduction to Fluorescence Spectroscopy: Jablonskii Diagramme
8. Applications of Fluorescence Spectroscopy for Cultural Heritage: Dyes, Binding media and Semiconductor materials

Reading Material and Key References:

1. Infrared Spectroscopy:
    a. Dei, L., A. Ahle, P. Baglioni, D. Dini, and E. Ferroni, "Green degradation products of azurite in wall paintings: identification and conservation treatment", Studies in conservation, vol. 43, no. 2, pp. 80-88, 1998.
    b. Infrared Spectroscopy in Conservation Science, Michele R. Derrick, Dusan C. Stulik, and James M. Landry, 1999, http://www.getty.edu/publications/virtuallibrary/0892364696.html
2. Raman Spectroscopy:
    a. G. Smith, R. Clark, Reviews in Conservation, Volume 2, p.92-106 (2001)
    b. S. Best et al, Identification by Raman microscopy and visible reflectance spectroscopy of pigments on an Icelandic manuscript. Studies in Conservation, Volume 40, pp 31-40, 1995
3. Near Infrared Spectroscopy:
    a. L. Cséfalvayová, et al, Use of genetic algorithms with multivariate regression for determination of gelatine in historic papers based on FT-IR and NIR spectral data, Talanta, 2010
    b. Vignani et al FT-NIR spectroscopy for non-invasive identification of natural polymers and resins in easel paintings, Analytical and Bioanalytical Chemistry 2009
4. Fluorescence Spectroscopy:
    a. Lackowicz, Principles of Fluorescence Spectroscopy, 2006 (http://kemia.unideb.com/pr/Principles%20of%20Fluorescence%20Spectroscopy.pdf)
    b. De la Rie, Fluorescence of paint and varnish layers (Part I) Studies in Conservation, 1982

    Nevin, et al, Total Synchronous Fluorescence Spectroscopy Combined with Multivariate Analysis:

Method for the Classification of Selected Resins, Oils, and Protein-Based Media Used in Paintings, Analytical Chemistry 2009

Non-Destructive Analysis in the Palace Museum

The conservation department in the Palace Museum (PM) is among the most important and largest in the world. As an important part of the department, the scientific lab has a number of responsibilities, such as environmental control & monitoring, materials selection for treatments, material analysis, etc. Recently, the non-destructive analysis in the lab has developed quickly. The lecture given by Dr Lei will demonstrate non-destructive analysis in the Palace Museum in three fields: image analysis, elemental analysis and molecular structure analysis.

Imaging analysis at the Palace Museum has been carried out by soft and hard X-rays, ultraviolet light, infrared photography, multispectral imaging, hyperspectral imaging (HSI), terahertz devices, and optical coherence tomography (OCT). Their application to the examination of bronzes, polychromed or lacquered wooden sculptures, furniture, mural paintings, oil paintings, Chinese paper or silk-net paintings, and ceramics will be demonstrated. Macro mapping is stressed recently in the lab and a new 2D hyperspectral scanning system will also be presented with some new fresh case studies of Chinese painting.

For non-destructive or in situ materials analysis, two methods, XRF and laser induced breakdown spectroscopy (LIBS), will be presented. Some light elements, as low as boron, have been identified in Chinese cloisonné objects by LIBS, which has advanced the development of Chinese enamel technology research. Macro-element scanning using the Bruker M6 equipment greatly improves the scanning speed for paintings in PM, and the method has also been used successfully on some cases of Chinese paper-net painting

A new open confocal Raman microscope was installed at the Palace Museum last year, which has allowed the scientists in PM to study some large scale paintings more conveniently than before. Some portable equipment, such as handheld Raman, FTIR, near infrared, and fiber optic spectrometers, also provide easy methods to discover the properties of relics generally, which might help find significant clues and point to new options for further analysis.

The use of synchrotron radiation is a novel, fast-developing technique for material sciences globally. Scientists in Palace Museum have collaborated with the Shanghai Synchrotron Radiation Facility (SSRF) to study the manufacturing techniques of Chinese cloisonné objects, architectural painting, glass beads and ceramics.

In summary, Palace Museum is building up a collaborative relationship with more other institutes, colleges and museums, which will contribute to the development of the scientific lab.