Art and Science of High-End Digital Color Print-Making

Imaging and printing old master paintings at the National Gallery, London

Joseph Padfield (Principal Scientist, The National Gallery, London)
• The National Gallery was founded in 1824.
• The main collection ranges from the 13\textsuperscript{th} to the early 20\textsuperscript{th} century.
• 5 - 6m physical visitors every year and over 6m virtual visitors.
• Over 2,300 works of art in the European Style.
• Including many famous works, by artists such as van Eyck, Velázquez, Turner and Van Gogh.
The need for a chemist to study the collection was discussed as early as 1845.

Faraday’s opinion was sought on the question of the effects of air pollution in 1850.

The first Scientific Advisor, Ian Rawlins, was appointed in 1934.
National Gallery Scientific Department

• Preventive conservation
  – lighting, environmental conditions, pollution and vibration.

• Scientific analysis and technical research on the collection
  – in support of conservation
  – for historical research (incl. scholarly cataloguing projects, exhibitions, history of materials etc)

• Documentation and the study of the condition of the collection
  – Photography, technical imaging and printing
  – Improved storage care and organisation of our records

• Development of new analytical and imaging methods and new instrumentation.
• This talk will briefly present some of the history of the department’s digital imaging and printing research
• Before moving on to outline its current imaging and printing research
The VASARI project FP2-ESPRIT 2 project (1989 – 92)

• Developed a colorimetric multi-spectral scanner system for direct digital imaging of paintings.
• Produced images of paintings at resolution of 20 pixels per millimetre.
• Initially with seven colour bands spanning the visible spectrum.
• Producing images of around 1GByte each.
• Used for publishing, scientific analysis and conservation. This includes studies of surface texture and colour change.
• Supported the development of: https://github.com/libvips
• Development continued after the funding ended, including improvements in lighting, software, calibration and colour targets.

Grant agreement ID: 2649
Further improvements continued to be made with an improved camera and filter set within the CRISATEL FP5-IST project (2001-05) Grant agreement ID: IST-1999-20163
The MARC FP3-ESPRIT 3 project (1992-95)

- Integrated system for the digital acquisition, storage and handling of colorimetric high-definition images of paintings for printing purposes.
- “Portable” digital camera providing up to 20k x 20k pixel images, high colour accuracy.
- Colour calibration achieved using a 24 patch Macbeth ColourChecker chart
- Files produced > 1 GB.
- Long exposure time ~40 minutes.

Grant agreement ID: 6937
The MARC II Camera

• Higher quality hardware suitable for heavy continuous work.
  – First used in the Library of Congress.
• Improved sensor, Peltier cool, producing D65 CIELab 12-bit images.
• Decreased resolution, 10k x 10k, but much faster image acquisition, about 2 min 40 secs.
• Improved HMI lighting.
• Average mathematical colour error of around 3-4 ∆E
• Used (2000-02) to image the entire National Gallery Collection to provide a complete set of digital images for printing and digital presentations.
  – Supported by HP.
Print on Demand – NG: Research to Production

- Kiosk in National Gallery Sainsbury Wing shop opened June 2003
- Choice from full National Gallery collection.
- \(~4\Delta E\) (max 10) end-to-end
- Initially - productivity semi-gloss paper, UV inks, 42” HP DesignJet 5500ps
  - Replace by a HP DesignJet Z3200, currently **HP DesignJet Z6200**.
  - Project originally supported by Hewlett-Packard
- Content generated automatically: only 3 paintings proofed.
- Posters were meant to be colour facsimiles (under the right viewing conditions)
- The service was popular, **but some issues did arise**, particularly with darker paintings.
Checking painting reproductions within the National Gallery under D50 light.
Kiosk in National Gallery Sainsbury Wing shop opened June 2003

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Moved to Hasselblad cameras in 2006

Currently using a H5D-200

NG Micro-positioning computer controlled easel: 2013

© The National Gallery, London
© The National Gallery, London
NG3863: Vincent van Gogh, *Sunflowers*, 1888
© The National Gallery, London
NG258: Master of Liesborn, *The Adoration of the Kings*, probably 1470-80
© The National Gallery, London

NG6565: Claude Monet, *La Pointe de la Hève, Sainte-Adresse*, 1864
© The National Gallery, London

NG6517: Caspar David Friedrich, *Winter Landscape*, probably 1811
© The National Gallery, London

NG1169: Ary Scheffer, *Mrs Robert Holland*, 1851
© The National Gallery, London
Colour Printing 7.0: Next Generation Multi-Channel Printing

• CP0.7 - Marie Curie Initial Training Network (ITN)
  – 2011 – 2015 (http://cp70.org/)
  – FP7-PEOPLE, Grant agreement ID: 290154

• Collaborative PhD, with the University of West of England- Centre for Fine Print Research (Professor Carinna Parraman)
  – https://www.uwe.ac.uk/sca/research/cfpr/

• ‘The Development of Multi-Channel Printing Methodologies for Fine Art Applications.’ – Dr. Melisa Olen
  – https://uwe-repository.worktribe.com/output/885830

• Secondment to the National Gallery – Exploring how alternative printing methods could improve the reproduction of colours in darker regions of paintings.
NG172: Michelangelo Merisi da Caravaggio, *The Supper at Emmaus*, 1601

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*Lower middle section*

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*Simple brightening to highlight details*

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Reflectance Spectra were used to evaluate the performance of various direct channel/multi-pass (DC/MP) printing methods.

Work highlighted the loss of colour variation in print reproductions of dark areas – using standard ICC Colour Managed workflows.

DC/MP printing methods showed cleared improved colour reproduction for 18/19 spots when measured spectrally and 16/19 spots when comparing ΔE2000 calculations.

The approach was limited to printing patches of colour.
AHRC funded: Collaborative Doctoral Awards Scheme

- 2014 -2018
- Collaborative PhD, with the University of West of England - Centre for Fine Print Research (Professor Carinna Parramanan)
  - https://www.uwe.ac.uk/sca/research/cfpr/
- ‘2.5D and 3D image capture and print in the cultural heritage field - evaluation of current and developing technologies, potential applications and practical workflows,’ – Dr. Xavier Aure Calvet
  - https://uwe-repository.worktribe.com/output/1491140
Generating 3D models of paintings through the combination of 2D, 3D and RTI data

- Aiming to produce quality models that could be viewed via web based tools.
- Laser scanner system would produce (50 x 80cm painting), a model of over 10 million triangles.
- This method of combining multiple data sources produced a realistic usable model.
- Possible to combine models of different resolutions.

The project explored the potential of CNC milling based on RTI and laser scan data.

Showing promising results.

Data capture and processing pipeline was quite complex.

Work also examined how this data could be used to create foam supports for art works undergoing conservation.

Figure 6.15 Render of the whole support for Spinello Aretino *Saint Michael and Other Angels* NG1216.1.

Image from: Aure Calvet, X. The application of 2.5D and 3D technologies for the conservation and presentation of surface texture in paintings. (Thesis). University of the West of England.
In 2016 the National Gallery began setting up a new hyperspectral imaging system, with the support of the Foyle Foundation and Hewlett Packard, and in collaboration with the National Gallery of Art, Washington.

- Spectral range: 400-2500 nm (visible, near and short-wave infrared)
- Spectral resolution: 3 nm, equivalent of up to 700 bands
- Spatial resolution: up to 50 µm (around 500 PPI)
- Relatively low light exposure (a few thousand lux)
- Acquisition time: 1m² in a couple of hours (i.e. relatively fast)
NG - HSI

System modelled on the equipment developed by John Delaney at the National Gallery of Art, Washington DC.

Two separate cameras

SWIR 1000-2500nm
VNIR 400-1000nm

Complex data capture procedure, connected to the existing computer controlled micro-positioning easel.

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Hyper-Spectral Imaging at The National Gallery

InSb sensor
Spectral range: 1000-2500 nm
Spectral resolution: 3 nm

Hyper-Spectral Imaging at The National Gallery

ACQUISITION
- Front lens - painting distance: ca 30 cm
- FOW: ca 20 cm
- Camera parameters: integration time 100 msec, collection rate: 8Hz
- Pixel size at painting surface: ca 0.191 mm
- Easel scan rate: 1.528 mm/s
- Acquisition time: ca 20 mins for each strip (75 cm length)
- Light levels: under 1200 lux

PROCESSING SOFTWARE
- HSI Data viewer
- HSI Register
- ENVI Classic (64 bits)

InSb sensor
Spectral range: 1000-2500 nm
Spectral resolution: 3 nm


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The National Gallery’s future imaging and printing research

**ARTICT - Art Through the ICT Lens**

3 year project - Imaging and signal processing – exploring the potential of combining HIS and XRF data with technical imaging

**National Gallery**

Continued development of our HSI system, particularly the VNIR camera.

Further development of our use of 3D imaging for documentation and public engagement.

Continued development of our 2D imaging capabilities.

**CFPR - UWE**

CFPR – granted an ‘Expanding Excellence in England’ (E3) Fund

The National Gallery will be collaborating to continue to explore the development of 2D and 3D printing in relation to the study and care of old master paintings.
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Thank you

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