ONE CUBE TO RULE THEM ALL:

Source-fused HSI-XRF data cube production for enhanced pigment identification

Molly B. Fort[1], John R. Gilchrist[2], Adam Gibson[3]

[1]Institute of Sustainable Heritage, UCL, London, WC1H 0NN
[2]ClydeHSI, 1 Aurora Avenue Queens Quay, Clydebank, G81 1BF
3Department of Medical Physics, UCL, London, WC1E 6BT

UCL

ONE CUBE OR TWO

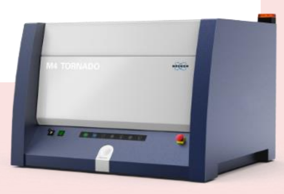
Heritage science often relies on imaging data to visualise a history of materiality and degradation within an object. Seldom is a single method used to prove a whole picture of an object.
Hyperspectral Imaging (HSI) and X-ray Fluorescence Imaing (XRF) are examples of complementary spectro-spatial techniques now common in research and visualisation.

Complementary approaches may be used together but processedindependently. This separates true multi-modality from quality dataanalysis. **Why not have both?**

Hypercube nature of XRF and HSI make this pipeline a possibility andopens the door to a plethora of visualisation and analysis methods thathave yet to be used for fused multi-source imaging of this nature.

TWO TECHNIQUES

XRF
Elemental Data
Heavy Elements
Characterise composition


Bruker M4 Tornado

HSI
Molecular Data
Layered splicing
Characterise spectral fingerprint


ClydeHSI VNIR

Our Work on Netflix

Q: Does Fusion Improve Endmember Separation of Signals & Features?

THE PROCESS : A JOURNEY

Pre-Processing Data
- Assign to hypercube
- Cropping spectral regions

Image Registration
- Projective image registration
- Cube Registration
- Region Cropping

Data-Fusion
- Weighting of Data points
- Spectral Alignment
  - Per Pixel Concatenation

Image Processing
- PCA
  - Abundance Mapping
    - Spectral Assessment
  - Endmember Extraction
- Spectral Matching

RESULTS

Fused HSI-XRF Abundance Maps

Figure 1: Fusion Image Cube Abundance Maps of a Kepler volume manuscript bound cover held by UCL Special Collections; STRONG ROOM C 1606 K2/2. HSI-XRF Co-Registered, source-level fused. Endmember estimation through NWHFC. Endmember extraction using NFINDR identified 16 endmembers. LMM abundance maps produced with FCLS and plotted in sequence.

Endmember features Present

Feature	HSI (5)	XRF (9)	Fused (16)
Black ink (front)	2,3,4	5,6,7	1,8,10,11,12,13,16
Black ink (back)	4	5,6,7	10,12,13,16
Red ink	1	1	3,6,14,15,16
"T"	3	2,4,7,9	1,2,5,7,8,9,11
T Decoration	-	2,3,4,9	-
T Border	2	2,4	1,2,5,7,9,11
Cartoon	3,4	-	7,12
Paper	2,3,5	6,8,9	2,4,5,7,16

Figure 2: Features categorised by strong presence in endmember abundance maps for HSI, XRF and Fused image cubes. Numbers represent the number of the endmember map. Red numbers representing feature visualisation through absence.

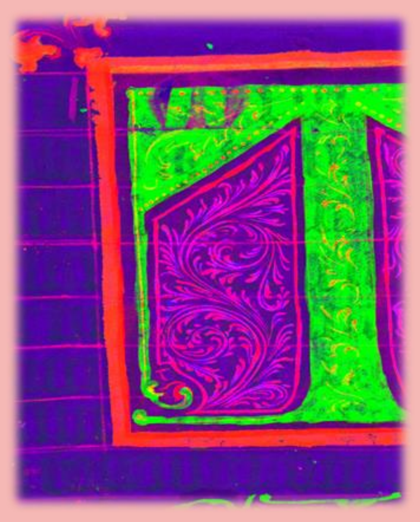


Figure 3: "T" detail revealed in XRF Images

Figure 4: Cartoon revealed in HSI images

VISUALISING THE FUTURE

- Validation through standardized datasets
- Exploring Non-linear/bi-linear unmixing models for complex interactions
- Wider Heritage object samples
- Formation of material libraries for identification
- Use of deep learning models

A SINGLE SOURCE OF TRUTH?

- Outperformance of single modalities providing broad feature extraction
- Revelation of hidden features to high resolution
- One feature not presented in fused data from XRF
- Higher potential for separation of front ink from back ink

CLYDE HSI

UKRI Engineering and Physical Sciences Research Council

For information email: Molly.fort.21@ucl.ac.uk