Institution: University of Oxford

Unit of Assessment: 31

Title of case study: Achieving Economic and Cultural Impact through Digital Humanities: The Effect of Multi-spectral Imaging

1. Summary of the impact (indicative maximum 100 words)

Research in Multi-spectral Imaging (MSI) of manuscripts by researchers in the University of Oxford's Faculty of Classics has led to advances in imaging technology. A series of initiatives by Dr Dirk Obbink that captured images through MSI technology have led to the decipherment of new texts that have made a substantial mark in the public sector. Equity spinout of this technology has resulted in the entry in the market of the first portable multispectral scanning unit in flat-bed desktop format. The scanner, which uses innovative patented LED technology at different levels of the light spectrum, was developed under funding from ISIS, Oxford University's technology transfer division.

2. Underpinning research (indicative maximum 500 words)

The development of the multispectral scanner is the result of a major Digital Humanities project in the Faculty of Classics at Oxford, with Obbink as Principal Investigator. Research into ancient manuscripts has developed the ability to detect traces of faded or hidden inks and paints in historical manuscripts, to analyse documents and art works for physical components or authenticity, and to explore forensic evidence such as fingerprints and stains. The technology, known as Multi-spectral imaging, scans objects at 16 different levels both within and beyond the visible spectrum of light. By this means details can be captured not normally visible by the human eye. The technology led to the discovery of new poems by the 7th century BC Greek poets Archilochus and Sappho and philosophical treatises by the Epicurean philosopher Philodemus from Herculaneum.

In addition the identification and decipherment of hundreds of manuscripts through improved readings and image enhancement has been made possible through public participation in the Ancient Lives crowd-sourcing project and the Friends of Herculaneum Society, a registered charity (no. 1107134) and Classics Faculty research project. These include hundreds of previously unknown works of literature from Graeco-Roman Egypt and from the Villa of the Papyri on the Bay of Naples in Italy. Data produced by imaging of the manuscripts and crowd-sourced transcriptions was used to perfect a new type of scanner in a manuscript imaging laboratory. Over 500,000 individual images were created and analysed by editorial and algorithmic methods to optimise results. By layering the images on top of each other, the software enabled a more detailed analysis of the writing, in particular through the interrogation of particular features such as the surface structure, fibres, and ink; on modern documents, features include stains, watermarks, fingerprints, and alterations.

The imaging system was then miniaturized by application of a patented LED technology and housed in an ordinary desktop scanner unit. The system is able to detect which surfaces or pigments, e.g. carbon or iron-gall ink or paint, provide the best contrast – even with a dark background – by its behaviour in either the infra-red or ultra-violet range of the light spectrum, or where the clearest picture emerges by combining images from several frequencies. Programming was written to enable an easy-to-use interface with simplified enhancement routines for use by office or lab workers or in the home. As the unit is portable, it can be used in the field: in a foreign library or museum, on an archaeological site, or on a crime scene.

A technology transfer grant from the University's spinout division ISIS Innovation facilitated the patenting of the technology and the formation of a company structure. The technology attracted the University's first Chinese investor, a property and imaging company based in Beijing, who partnered with the University and the researchers to form the limited company, Oxford Multi Spectral Ltd., which markets the device and engages in further development of the product and related systems for the scanner market.

The key researcher is Dr Dirk Obbink, Official Student (Tutorial Fellow) in Greek, Christ Church,

Oxford and University Lecturer in Papyrology and Greek Literature (1995-present), Director of the Ancient Lives Project, Trustee of the Herculaneum Society, and Founding Director of Oxford Multi Spectral Ltd. (2011).
Other Oxford researchers who have made important contributions to the project are Dr Alexander Kovalchuk, Research Associate in Optical Physics and co-founder of Oxford Multi Spectral Ltd.; Mr Paul Ellis, Data Management Specialist; Mr Spiro Vranjes, IT and Imaging Specialist; Dr Chris Lintott, Zooniverse Project; Professor Roger Davies, Department of Astrophysics.

3. References to the research (indicative maximum of six references)
The key outputs are:
Multispectral Desktop Document Scanner, produced by Oxford Multi Spectral Ltd (http://www.oxfordmultispectral.com)
'Advanced Multispectral Imaging at Oxford' at: http://163.1.169.223/MSI/welcome.html.
Ancient Lives project website: http://www.ancientlives.org
D. Obbink, 'Imaging the Carbonized Papyri from Herculaneum', *Literary and Linguistic Computing* 12(3) (1997), 159-162. Peer reviewed journal, doi: 10.1093/llc/12.3.159
D. Obbink, 'Lucretius and the Herculaneum Library', in S. Gillespie and P. Hardie (eds.), *The Cambridge Companion to Lucretius* (Cambridge 2007) 33-40. Doi: 10.1017/CCOL9780521848015
D. Obbink, 'A New Archilochus Poem', *Zeitschrift für Papyrologie und Epigraphik* 156 (2006) 1-9 with plate 1. Peer reviewed journal, available on request.
[text removed for publication]

Key research grants:
AHRB Research Grants Scheme award for: 'Imaging Papyri at Oxford', 1999: £294,272.
MacArthur Foundation Fellows Program Award, 2001: USD 500,000.
John Fell OUP Research Fund Grant for: 'Advanced Multi-Spectral Imaging of Oxford Papyrus Collections and of the Carbonised Papyrus from Derveni', 2006: £92,262.
Leverhulme Trust Research Grant for: 'The Reception of Greek Literature: Traditions of the Fragment 300 BC-800 AD', 2006: £118,212.
John Fell OUP Research Fund Grant for 'Advanced 3D and MSI Imaging', 2008: £68,068.
UCSF / IUIF grant from ISIS Innovation, University of Oxford Technology Transfer, for 'A Portable Multispectral Scanner' and associated spinout company, 2010: £47,900.
AHRC 'Digital Equipment and Database Enhancement for Impact' (DEDEFI) scheme award for 'A Collaboration between Classics and Astrophysics: An Advanced Multispectral Imaging Laboratory Optimised through Crowd-Sourced Statistical Analysis, 2010: £113,487.

4. Details of the impact (indicative maximum 750 words)
The creation of Oxford Multi Spectral Ltd. has had an important cultural and economic impact within the Classics discipline, and the subsequent use of the technology in other industries has contributed to substantial discoveries and innovations in those fields. Media interest in these developments has brought about greater public understanding of the use of scientific techniques within the Humanities.

Obbink's digital research has led to the creation of an Advanced Multi-spectral Imaging Laboratory in the Papyrology Rooms of the Sackler Library. This has led to an important economic impact through the creation of Oxford Multi Spectral Ltd, the company that produces the scanners. In addition to the grant funding required to develop the scanner for research, and a grant from the University Challenge Seed Fund for prototyping work, the company attracted an initial investment of £400,000 from a Chinese investor Changsha Yaodong Investment Consulting Co and its UK based partner RTC Innovations, enabling it to commercialise, manufacture, and market the scanners globally. Oxford Multi Spectral was the first ever spin-out company from the University of Oxford's Faculty of Classics and indeed from the University's Humanities Division. Obbink serves as managing director of Oxford Multi Spectral Ltd.; he is also a member of the Association of Questioned Document Examiners. The scanner units are manufactured by Worldlight Ltd., Hong Kong, while the company, which has a current book value of £2.5m, employs three UK staff, including a CEO, and projects sales of 100 units per year by 2016.

Increasing cultural capital

The scanner has had important cultural impact through its application to a range of material. As described more fully in a separate case-study submitted by this Unit, multispectral images produced by the scanner were included in the online interface of the AHRC Ancient Lives Project (www.ancientlives.org), where hundreds of thousands of volunteer transcribers helped to determine by statistical analysis exactly where and to what degree multispectral images offered an improved record of legibility over conventional images. Although the scanner was developed for imaging ancient papyri, the technology has been used to successfully scan, restore and archive over a half-million historically significant archival documents. The scanner is able to detect an artist or writer's signature under multiple layers of paint or a pencil sketch under a watercolour.

Examples of its use include:

- Enabling the reading of a poem by Archilochus that is now used in the teaching of Greek literature in Universities and discussed by online groups.[i]
  [text removed for publication]
- Recovering one of the oldest Hebrew commentaries on the Old Testament (now in the Bodleian Library), which dates from the 10th century AD, and was rendered illegible in the late 19th century during chemical attempts to make it more readable. Combining data from different frequencies has highlighted the old ink and allowed the document to be read, thus restoring it to public view and use.[ii]
- Making legible for the first time the text of an Egyptian Hieroglyphic papyrus manual of how to build and decorate a temple ('The Book of the Temple'), for which Professor Joachim Quack (University of Heidelberg) was awarded a prestigious Leibniz prize.
- Revealing that a crossed-out signature on a manuscript of poems in the New Library of Christ Church, Oxford was that of William Shakespeare , and facilitating its illustration in a public exhibition of manuscripts.
- Proving a previously accepted signature of Paul Cezanne to have been misread and to have deceived art historians and the public in painting valuation and sale in the UK[2].
- Authenticating the artist's signature in an early portrait painting of Karl Marx offered for public sale in the Netherlands.[3]

Wider business applications

The scanner has also had important impact on business and government agencies. While Oxford Multi Spectral Limited focuses on the applications in restoring manuscripts and art, it has also entered the market for detecting forged security and border control documents, bank notes, forensic evidence, and bio-medical applications. The scanner has been variously used, from recovering the inked out names of parents on orphan's birth records to comparing bank notes and passports with reference documents of known reflective properties. The business impact of the scanner was underscored by Paul Westwood, Managing Director of Forensic Document Services, the largest forensic document company in the Asia Pacific, who has stated that 'the portable nature of the scanner means that it is a great resource when document examiners are required to undertake examinations out of the laboratory environment, such as at Court Registries or the offices of opposing lawyers.'[iii]

Models of the Oxford Multi Spectral scanner are now in use or under development in locations as far afield as the University of California Berkeley's Center for the Study of the Tebtunis Papyri, Baylor University's collection of historic Robert Browning manuscripts (to read Browning's notes on Greek texts), the Thomas Jefferson papers in the Special Collections Room of the Library of the University of Virginia (to enable the decipherment of badly faded hand-written documents from the papers of Thomas Jefferson),[1] The Library of Congress (for conservation purposes), the US Postal Service (fraud detection), the National Archives, Washington DC (to read invisible watermarks), and the Thames Valley Police Force's fingerprint detection and analysis departments (for detection of fingerprints on bank-notes)[4], as well as widely across several provinces in China, where it is employed mainly in document verification, immigration, and forensics[5].

Public understanding

The technology developed in Oxford has also received much media attention and other forms of coverage, including articles in the *Economist*[iv], the *Wall Street Journal*[v], and business technology

websites[vi]. The MSI project, with backing from the investors, completed the permanent installation of the Papyri and Multi Spectral Imaging exhibit in the 'Reading, Writing, and Counting' gallery (Room 6) of the Ashmolean Museum, which opened in November 2009 and receives more than 1 million visitors per year. This exhibit contains a large panel on the MSI process, as well as the original papyrus of the poem by Archilochus newly recovered through application of the technology, together with a translation of it by Dr Obbink.[vii] Public colloquia during the Meeting of the Friends of Herculaneum Society at the British Museum, in conjunction with the exhibition *Life and Death in Pompeii and Herculaneum* in June 2013, showcased the results of applying MSI imaging technology to the books of the Herculaneum Library over the past five years; the exhibition (which had c. 300,000 visitors in 4 months to the end of July 2013) included MSI images on the unrolling and preservation of the Herculaneum papyri. Work on Herculaneum papyri using MSI technology supports the goals of the Friends of Herculaneum Society, of which Obbink is a trustee, and which undertakes outreach activities including an annual writing competition for schoolchildren and a biennial outreach magazine, *Herculaneum Archaeology*.[viii] The success of MSI imaging also led the Italian Archeological Service to undertake and complete an initial feasibility study (2008) for the excavation of the Villa dei Papiri for the remainder of the library and papyri, assessing the ecology and impact on the local community.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Testimony

[1] Corroboration of use of scanner on Thomas Jefferson materials available from the Head of Digitization Services, University of Virginia Library

[2] Corroboration of Cezanne painting signature verification available from the Director, Information in Images, Ltd.

[3] Corroboration of Karl Marx portrait painter's signature available from Antiquarian bookdealer, Konstantinopel Rare Books, Enschede, Netherlands.

[4] Corroboration of use of scanner by Thames Valley Police available from the CEO, Oxford Multi Spectral.

[5] Corroboration of the forensic use of the scanner in China available from Director, RTC Innovation, Ltd.

Other evidence sources

[i] Archilochus papyrus: e.g. https://www.gc.cuny.edu/CUNY_GC/media/CUNY-Graduate-Center/PDF/Classics/Greek-reading-list-for-translation---MA---PhD.pdf; http://www.linkedin.com/groups/HIDDEN-TREASURES-OXYRYNCHUS-Read-poem-3795477.S.148390509

[ii] Oldest Hebrew commentary on Old Testament made public: 'Advanced Multispectral Imaging at Oxford' at: http://163.1.169.223/MSI/welcome.html

[iii] Westwood quotation: 'Oxford Scanner Reveals Secrets of Documents, Ancient and Modern': http://www.ox.ac.uk/media/news_releases_for_journalists/110913.html

[iv] Charles Babbage, 'Document Analysis: A Classic Invention', *The Economist online* 27th September 2011 (http://www.economist.com/blogs/babbage/2011/09/document-analysis)

[v] 'The Next Age of Discovery', 8 May 2009, *Wall Street Journal* http://online.wsj.com/news/articles/SB124173896716198603#mod=todays_us_weekend_journal

[vi] Coverage in business technology journal: 'Scanner to detect fake documents', http://www.ciol.com/ciol/news/52067/scanner-detect-fake-documents

[vii] http://www.ashmolean.org/documents/AR2008-10-high.pdf , pp. 10-11.

[viii] Herculaneum Society project website: http://www.herculaneum.ox.ac.uk, especially under 'Papyri'.