https://doi.org/10.2352/issn.2168-3204.2025.22.1.5
This work is a U.S. Government work not subject to copyright in the United States (17 U.S.C. §105).
The work is also available for worldwide use and reuse under CC0 1.0 Universal.

Heritage Science – Spectral Sustainability and Innovative Dissemination

Fenella G. France, Preservation Research and Testing Division, Library of Congress, Washington DC, USA

Abstract

While spectral imaging has now been being utilized in cultural heritage for more than 20 years, there is still a lack of uptake by heritage practitioners. While some point to cost as an issue, it appears the real concern is that of communicating effectively with interested users – conservators, curators, scholars, heritage professionals. Many people are not aware of the range of types of information and data that can be captured and made available from collections, and the potential ease of interacting with the datasets. Since spectral imaging is essentially the next element of digitization and making heritage available in the digital realm, it seems necessary for more effort to be placed on shared knowledge of the spectral capture and processing methodology, so this becomes more accessible as a tool. Setting up a new spectral imaging system, communicating and creating networks for engagement, and addressing opportunities and challenges will be discussed.

Introduction

Talking with heritage colleagues, science and humanities, we have been concerned that even after decades of various forms of spectral imaging being successfully integrated into many heritage institution programs, that when engaging with conservators, scientists, and scholars, there was still a dearth of understanding of what spectral imaging could add to research projects, and the research questions that could be answered. Here spectral imaging is referring to multi/hyper spectral imaging modalities where illumination is used to capture data across an entire collection item, ranging from the ultraviolet, through the visible and into the infrared spectrums – visible and non-visible.

As part of a Fulbright Scholarship in Ireland, the author wanted to see how our profession could move past this communication challenge, and what might be some new and more innovative methods of dissemination. An additional motivation was realizing that the perception of spectral imaging was it being considered more of a "magic box" than an accessible and easily taught imaging process.

As many have experienced, when setting up any new instrument, and especially a new imaging system, more often than not, things do not always go as planned. Wires and connections might work one time, then not the next – lights don't turn on, some things are slightly damaged out of the box. The critical issue came down to software and equipment somehow not talking, USB hubs erroneously "remembering" or showing incompatibility. Having recently experienced all and more of these challenges in the installation of a new imaging system, what was made clear, was the absolute need for basic knowledge and understanding of elementary imaging principles when things go wrong. There is a strong reliance on Google search, along with the dependance on Microsoft "off-the-shelf" software. While this can be useful, it has unfortunately reduced our trouble shooting capacities – the challenges and joy of automation.

Moving Away from the Magic Box

The problem explored was how to ensure that we are communicating effectively the benefits and purpose of spectral imaging and how it works, in more accessible language that aligns with that specific audience or potential user. A more effective communication method is to expand from where a person is, regarding their knowledge, meet them "where they are" and use this to develop their skills and experience. This means that each situation will potentially be slightly different, but that is the joy of being a good teacher. Discussions with colleagues had us looking at aligning terminology with a person's background and using better methods for communicating and sharing this information.

The greater concern that was voiced by some of my humanities colleagues, was how to expand and correlate the technique of spectral imaging with specific questions, while also moving away from the often-pedantic reliance on "hidden text" as the only recognized data that spectral imaging can capture. To clarify, the term spectral imaging is being used in this context as a system that integrates data captured from collection items under illumination in the visible and non-visible spectrums – from the ultraviolet, through the visible and into the infrared (~350nm – 1000nm). Sometimes referred to as multi or hyper, here the term spectral will be used to be inclusive and agnostic of specific systems.

Part of the problem also related to the need for a more integrated and connected network of professionals across both heritage science and the humanities so that heritage professionals in the library, archive, museum, art gallery, academic and preservation arenas work together, sharing challenges and approaches while augmenting their expertise. The other obstacle that was part of the problem, was sustaining knowledge and connections in organizations when people move to other positions, and don't transfer those connections to other staff and colleagues. Another aspect of the problem is what methods of sharing the information can be used outside the traditional conferences and papers approach [1]. Further, how do we embed more hands-on access for training? Watching someone operate an instrument does not usually transfer knowledge usefully.

Approach to Change

Given the occasion of engaging in a previously unknown academic environment, the opportunity of starting on a clean canvas to begin to address the problem from the beginning, rather than dealing with existing relationships and communications, was unique and appealing. In this situation, the approach began by reaching out personally beyond existing connections in the humanities, to engage with the broader academic community at the University. Multiple examples; the science department had a forensics science division; the university was engaged with the local community to encourage school children to see themselves there; development offices were interested; and a new conservation lab had been established in the rare collection library.

It was necessary to consider terminology for thinking about engagement and collaboration. This required moving past a multi-disciplinarity approach that drew on siloed knowledge from different disciplines and taking the connections and collaborations further than inter-disciplinarity; an approach that analyzes, and coordinates knowledge between disciplines into a coherent composite. After looking to the medical field, mentally considering collaboration as transdisciplinarity added value. While the first two approaches are additive and interactive, transdisciplinarity is holistic in nature creating one cohesive learning framework. The primary objective was to break down the walls between disciplines and focus on themes around using spectral imaging, and this methodology encouraged that happening.

Again, the approach starting by building personal connections and asking simple questions, and this brought out some of the misconceptions that existed. One startling quote that I received when asking about an interest in implementing spectral imaging, was the reply "we don't have anything with hidden information", a misunderstanding of what spectral imaging can do and a clear indication that we need to communicate to various audiences what the range is of information that can be gained, as well as how to know what you don't know yet.

Discussions led to a more focused approach for considering the definition of knowledge dissemination as a planned rather than ad-hoc process with the innovative aspect taking this beyond standard traditional publishing and meetings [2]. To facilitate uptake and better understanding this needed to include not just involvement but an education component. One of the key aspects in planning dissemination more effectively is the careful consideration of target audiences and how/what type of engagement is most valuable. Even with so many types of communication technologies available, defining the specific objectives and mapping potential target audiences are truly critical [3]. Part of this approach built upon how to use existing and new technologies from other fields for hands-on teaching.

Results

Addressing Communication Challenges

To solve the issues outlined above, the approach required being more thoughtful about the specific target audience and their knowledge base. As noted above, it became apparent that the engagement and indeed, success of the engagement, was dependent on understanding the specific colleague or heritage/preservation professional and their background, as well as their current research and work interests.

One area of the institution the author engaged with had just hired a photographer with a heritage background. Through an informal conversation and doing a hands-on demonstration, it was easier to explain in terminology more commonly used by photographers and refer to the process as capture under different lighting setups. We bonded when an error occurring in the new multispectral imaging (MSI) system camera was the same as a problem the photographer had been trying to solve in another existing camera in the photography suite.

***Figure 1**. Setting up a New Multispectral Imaging System (MSI)*

Encouraging communication between users with different backgrounds began to build a community that could share experiences, while also encouraging them to gain a broader concept of the type of information they themselves were looking for. This circles back to the notion of transdiciplinarity, where learning and integrating that learning from others is encouraged. This was especially important to see how the types of information they were seeking could cross over to additional disciplines – ranging from professors, scholars, conservators, administrators, outreach programs and donor relations managers.

Talking through a current imaging project with a conservator led to expressed interest in being able to detect historic treatments more easily. A trial imaging sequence quickly revealed a less than stellar historic repair, and strong enthusiasm to being able to use spectral imaging to assist treatment decisions. This developed into an ongoing conversation about the various modalities and what data could be extracted – reflected, raking (or side-lighting) transmitted illumination, and enhanced fluorescence.

An unexpected engagement with donor relations personnel led to a great discussion about how to describe the function, purpose, and unexpected potentials of collection imaging past digitization. There was also the realization and consideration that spectral imaging could be considered the next level of digitization. This would expand the often-untapped capacity for enhanced access to information buried in fragile collections that could be made available and disseminated outside the current more limited access within the institution.

Working with a humanities professor, we engaged with university students at various levels to gain a better understanding of their base knowledge about heritage collections and imaging. What became quickly apparent was the need to start with the basics and give them physical materials to handle, the materiality of collections, a concept potentially damaged from the lack of physical connection with collections due to the pandemic. While they understood the concept of paper, many had never considered that historic collections might also be on animal skins – parchment – and this led to them starting to consider and think about the materials from their region. One student from Mexico was intrigued when it was explained to them that codices from a similar time-period were made from a tree indigenous to South America, and rather gingerly touched the parchment as we pointed out the backbone and other unique features.

Examples of the Value of Spectral Data

Expanding interactions to informal conversations to gain a better understanding of the specific questions colleagues needed answered, was greatly enhanced when a hands-on capture could be demonstrated. This allowed experiential engagement, and when followed with visually sharing what data and measurements could be captured, even before processing, it began to expand the questions asked, and engender more curiosity.

Exposing redacted text, is probably the most commonly known application of spectral imaging and is indeed a good place to start conversations. A heavily stained and degraded parchment manuscript as illustrated below in figure 2, quickly illustrates the ability of spectral imaging to reveal information that cannot be easily seen by the un-aided eye. Utilizing this to encourage scholars, conservators and humanists to share their questions then allows for a richer interaction, and can stimulate requests for other types of data, especially when different modalities are being utilized and integrated together.

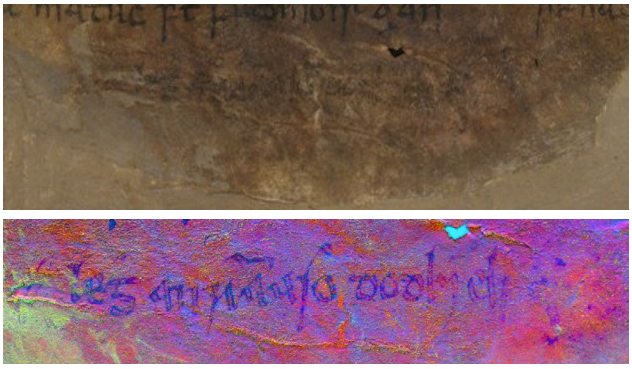

***Figure 2**. Upper: Visible, Lower: enhanced false color image*

Revealing previous conservation treatments under different imaging modalities reveals different types of data. The below images in ultraviolet and raking infrared show different aspects of a tissue repair that provides data about methodology. When specific glues have been used, that fluorescence adds additional information.

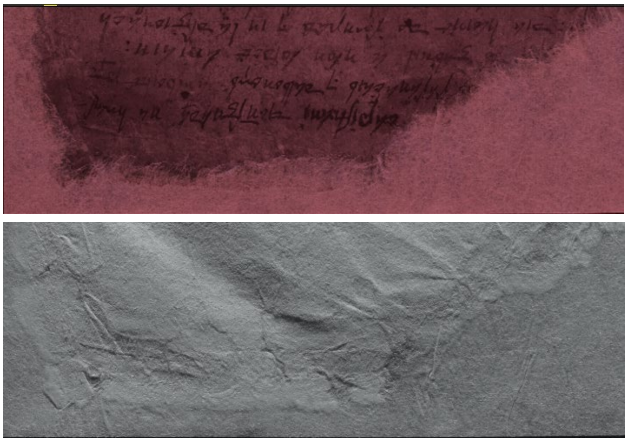

***Figure 3**. Upper: Visible, Lower: enhanced false color image*

Conservation treatments can show "hidden data" and in this context the application is seen as separate to redacted text given the purpose is very different. Mapping the spectral response of components on the collection item enables treatment decisions to be made and supports moving forward or revising a treatment. The "spectral false color map" in figure 4 quickly shows the ability to map the pixel spectral response from different components, with the image below showing a treatment to remove staining being effective in reverting the spectral response back to that of the un-stained paper.

Other examples of how tracking data can be utilized are through using spectral imaging before and after items go on exhibit, to track in real-time, the impact of duration and light exposure, as well as other environmental factors.

***Figure 4**. Change Detection in Lower Left Corner after Successful Test*

Construction and creation techniques are another aspect that has been utilized heavily in looking at parchment makers in medieval Ireland, starting to compare how they are using the moon-blade and other tools, as well as revealing their expertise, or lack, through the presence of veining and scraping marks. This has potential for tracking parchmenters and knowledge sharing in monasteries and counties.

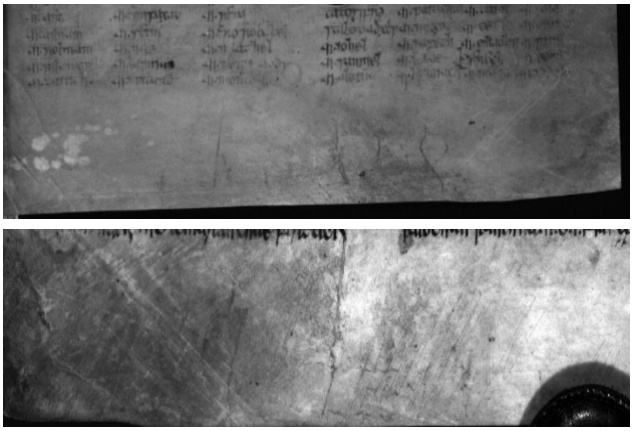

***Figure 5.** Upper: Veining on Parchment, Lower: Scraping Marks*

An area of great interest to medieval and other scholars is examining the scribal process. Spectral imaging can illustrate trends and distinctive features of specific scribes, as well as when changes have been made, and/or parchment intended for other documents and purposes, utilized in various gatherings. For example, rulings of two columns on a page where text is in one column, can only be easily detected through spectral modalities, and indicated a prior intent for that piece of parchment. Different spectral captures aid humanities scholars with aspects as seemingly trivial as prick marks and rulings across a page or folio, that enable comparisons and differences to be distinguished.

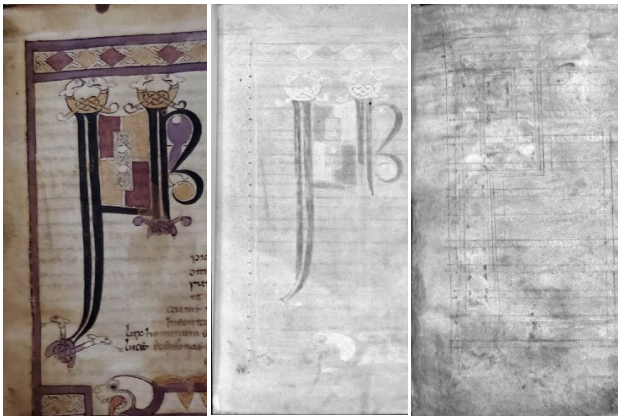

Figure 6. *Left-Right: Visual, Prick Marks, Rulings*

Redefining Dissemination

Following on from the abovementioned materiality, another approach around innovative dissemination was remixing traditional inputs and being "live", specifically to engage new audiences. An afternoon session at a museum with lots of hands-on materials to touch, and images to share, was a huge hit with adults who rarely get the opportunity to touch and feel like we do for children. The visuality of a false color image that mapped different material aspects of a collection item, or a zoomed in microscope-like image engendered fascination and highlighted some of the advantages of spectral imaging. Seeing the original collection item, and then the data captured outside what people can see, as well as letting them flip from visible to ultraviolet or infrared, made the information transfer more effective. Being able to present different types of data in a range of colors and visual forms shards new perspectives.

Figure 7*. Hands-on Engagement*

An example of how the shift to transdisciplinary collaboration was effective, was illustrated through a successful international collaboration with colleagues from Ireland. The initial engagement focused around what techniques could capture and reveal, developed into sharing with people how our initial conversations around humanities questions had evolved, and how this linked to spectral imaging and other heritage science techniques for medieval Gaelic manuscripts [4] [5]. We also emphasized the transdisciplinary aspect where while we could reveal and expose text that had been badly stained or faded, we needed scholars and those who could read the language to be part of the team to complete the circle and share the knowledge.

Another benefit was that expanding access to the spectral data to other interested humanities scholars, led to a discussion of what sources and software they had to interact with images, and how we could ensure there were ways that made access to the images and data visualized, easy to engage with. Including the spectral data that led back to the methods used to create the animal skins, exposed creation techniques, and made them ready for writing on, was of fascination to parents and children alike [6].

Engaging with science scholars and researchers who had a scientific background still led to wonder through this hands-on approach, as they were encouraged to look beyond seeing spectral imaging as an instrument or tool. The use of storytelling dissemination is often overlooked, and weaving the tales that allowed scientists to converse more with their humanities colleagues led to a real sharing of knowledge and expertise. Having fun with the system and an image created using the different lights to show people in color, was a surprising hit in helping people think about how we were interacting with the collection item and revealing different types of information (image 8).

Figure 8*. Heritage Scientist and Humanities Scholar in Many Colors.*

Multiple approaches were utilized to share and explain the imaging setup, capture and processing components. The hands-on engagement remained the best method for sharing complex information, along with anecdotes about previous errors, and letting people make their own mistakes to learn from them. Finding the correct tools and drafting simple one-page explanations to take away worked well, including encouraging people to re-write notes in their own words, with plenty of screen captures for software actions to prompt memory.

Another aspect that is often not shared, and can greatly assist with better understanding, is to involve others in troubleshooting as problems occur. While the human response is often to want to fix the problem then move on, this had led to a loss of the capacity for inter-generational problem solving. Stepping back, and being patient, is under-utilized. An evolution from this realization was that recording and creating a short YouTube video better connects with how some generations seek information, and possibly an area we are not applying effectively.

***Figure 9**. Image Capture Troubleshooting*

Further research into engagement and dissemination, led to an area the author had worked with nearly a decade ago, the utilization of haptics, technology that stimulates the senses of touch and motion, especially to reproduce in remote operation or computer simulation real and physical sensations that would be felt directly by a user who was interacting directly with physical objects. This teaching and learning technique developed in the medical field, was created to provide hands-on interaction with precise surgical methods. This aligns well with the handling and imaging of fragile historic heritage collections. Work is ongoing in this area especially as it applies to differently abled audiences and their interaction with heritage materials [7].

Further work with instruments that can share spectral data in tactile layers led to experiments with tactile representations of redacted text and recovered information using swell form machines, to share those renderings for users to physically feel the materiality of the history of a collection item [8]. Discussions with colleagues at the National Library Services for the Blind and Print Disabled (NLS) has evolved into new methods for disseminating and engaging with spectral data.

Conclusions

The discussions above have illustrated how a focused approach and a careful understanding of audiences can lead to better integration and engagement to both assimilate spectral imaging in more locations and encourage transdisciplinarity amongst heritage colleagues. Enabling people to engage and start from "where they are", as well as encouraging spectral imagers to explain information in a manner that relates more closely to the persons background, begins to break down the "magic box" concept. Making data more easily accessible to all through connecting this with their research or questions, enables greater comfort with the range of types of information that can be captured and made available from collections. Since spectral imaging allows heritage collection data to be available in the digital realm, putting time into sharing and empowering more users will potentially expand usage.

Building strong transdisciplinary collaborations as well as looking outside traditional methods of dissemination (and audiences) can broaden the access to, and acceptance of newer imaging technologies and modalities. Ensuring spectral imaging is described in a user-friendly manner, and with more hands-on and direct links to user needs will hopefully encourage more participatory engagement and accessibility to potentially attract new users and audiences.

References

[1] Alperin, J.P., Muñoz Nieves, C., Schimanski, L.A., Fischman, G.E., Niles, M.T., McKiernan, E.C., "Meta-Research: How significant are the public dimensions of faculty work in review, promotion and tenure documents?" eLife, Feb 12 (2019) https://doi.org/10.7554/eLife.42254

[2] Wilson, P.M., Petticrew, M., Calnan, M.W. and Nazareth, I., "Disseminating research findings: what should researchers do? A systematic scoping review of conceptual frameworks", Implementation Science, Vol. 5, Article number: 91 (2010).

[3] Ross-Hellauer, T, Tennant, J.P., Banelytė, V., Gorogh, E., Luzi, D., Kraker , P., Pisacane , L., Ruggieri, R., Sifacaki , E., and Vignoli, M., "Ten simple rules for innovative dissemination of research", PLOS Computational Biology, https://doi.org/10.1371/journal.pcbi.1007704 April 16, (2020).

[4] France, F.G., "Linking Heritage Science to the Materiality of Collections – Inks&Skins " two-Day Symposium, Library of Congress, Sep (2023).

[5] Biolcati, V., Wilson, M., Fiddyment, S., Unitt, R., Connelly Ryan, C., Hoffmann, A., Gillis, J., France, F., Ó Macháin, P, and Iacopino, D., "The Book of Uí Mhaine: An Interdisciplinary Analysis of the Materiality of the Gaelic Manuscript Tradition", Heritage (2023) 6, 5393–5409, https://doi.org/10.3390/heritage6070284.

[6] France, F.G., "Heritage Science – Perspective, Provenance, Preservation", Archiving IS&T, Washington D.C., April 2024.

[7] Bergamasco, M, Frisoli A., Barbagli, F., "Haptics technologies and cultural heritage applications", IEEE Xplore, Proceedings of Computer Animation conference, February (2002) DOI:10.1109/CA.2002.1017503

[8] Khalaila, A., Harrison, L., Kim, N.K., and Cashman, D., "They Aren't Built For Me": A Replication Study of Visual Graphical Perception with Tactile Representations of Data for Visually Impaired Users", Article submitted to ACM; arXiv:2410.08438v1 [cs.HC] 11 Oct 2024

Author Biography

Dr. France, Chief of the Preservation Research and Testing Division at the Library of Congress, researches non-invasive techniques and integration and access between scientific and scholarly data. An international specialist on environmental deterioration to cultural objects, her focus is connecting mechanical, chemical and optical properties from the impact of environment and treatments. She maintains collaborations with colleagues from academic, cultural, forensic and federal institutions through her service on a number of international bodies. In September 2024 Dr. France was awarded a 3-month US Fulbright Scholarship in Ireland.