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Bognar, Madeleine

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**Gaps in the Standard: A Case Study of the Multi-Spectral Imaging Metadata Strategies at
KU Leuven Libraries**

By Madeleine Anne Bognar
Archivist, OCAD University
Formerly Visiting Scholar, KU Leuven
Email: mbognar@ocadu.ca
Linkedin: Madeleine Anne Bognar
ORCID: 0000-0001-7964-7760

Abstract

This paper focuses on strategies for attaching technical infrastructural environmental metadata to narrow band multi-spectral images of cultural heritage objects. It also provides a review and analysis of previous projects involving multi-spectral images and their approaches to attaching metadata elements at the image level. This is followed by a detailed description of the strategies applied at KU Leuven Libraries to successfully and consistently attach standardized metadata that covers all areas of importance of the image capture. This aims to give users full understanding of the dataset and to allow interoperability and reproducibility. In addition to this, the documents created to ensure the consistency of the metadata entered and outline the specific infrastructure present at KU Leuven, are discussed. This includes the considerations of their implementation and the digitization workflows to produce metadata records.

Keywords: multi-spectral imaging; digital cultural heritage; metadata standards

Introduction

Within the last two decades there have been an increasing number of projects conducted by cultural heritage institutions that feature multi-spectral imaging (MSI) technologies. These imaging technologies allow for a deeper understanding of the material composition of cultural heritage objects, which can shed light on conservation concerns. In certain cases, these images can also reveal new information about the object that was not previously visible. This is especially true for an object where information has been erased or covered, for example, a palimpsest. However, for the image captures that result from MSI to be understood correctly by the users, new strategies regarding technological and environmental metadata must be applied. It is essential to researchers, when utilizing MSI captures, that they have access to all the information surrounding the capture environment of this image as well as information about any processing applied to the image. Since MSI is regarded as a scientific imaging practice, it is imperative that the capture environment be described and documented, as any images that show scientific information must be able to be reproduced. Ensuring that this image capture data is provided at the image level has proved challenging. This paper will discuss the issues that arise in trying to identify the criteria of importance to include in image metadata as well as some of the strategies used to address them. I will also discuss other MSI projects that have approached some of these issues, including the metadata standard and strategies applied by KU Leuven for their MSI projects. Research for this article was conducted at KU Leuven Libraries, as well as in discussion with Mike Toth, Bill Christens-Barry and other professionals who conducted research and created metadata standards and additional documentation for *The Archimedes Palimpsest Project*.

Multi-spectral imaging captures image data within specific wavelength ranges across the electromagnetic spectrum, as opposed to the standard photographic practices that are captured using white light. This includes wavelengths that go beyond the visual range detectable to the human eye, such as ultraviolet and near-infrared. At KU Leuven Libraries the capture environment uses light panels positioned around the object being imaged and angled for specific captures. The light emitting diode (LED) light panels used to create the image captures at KU Leuven Libraries were created by Equipose Imaging LLC and allow for narrow band illumination (illumination using specific wavelengths of light) in at least 16 bands ranging from

365 nm to 940 nm.¹ These panels are portable and can be arranged around an image capture copy stand and angled as desired. Either the LED panels were applied for image capture or a transmitting panel was used. When the transmitting light panel was in use it rested over the object on the copy stand and would not be used in tandem with the LED light panels. In the instances where the transmitting panel is in use, the light being recorded by the camera is emitted by the light source and then is transmitted by the object as a result of a backlighting system.² In the Imaging Lab at KU Leuven Libraries, an achromatic Phase One XF IQ4 150MP camera is used in order to capture both reflective and fluorescent images that have been exposed to the specific wavelengths emitted by the light panels. These cameras have CMOS light sensors that are sensitive to wavelengths ranging from 350nm-1050 nm (though often the range is given as 400-1000)³ while the range of wavelengths visible to the human eye ranges around 380-700 nm.⁴ Therefore, the sensor is capturing wavelengths on both sides of the spectrum of light that are invisible to the human eye and rendering them visible through digital photographic technology. The different interactions of the light with the surface material and how it is captured by the camera sensor in the reflective and fluorescent image captures (whether or not with specific longpass or bandpass filters), has the ability to tell us different things about the material makeup of the object. It is possible in some cases that the switch between the various wavelengths can show underwritten texts or diagrams that are not visible in our own visual spectrum.

This technology is exciting to say the least, and there have been many projects that have made strides to image cultural heritage objects. In addition, some projects aim to share their information with researchers and the scholarly community. Good examples of projects that work with documentary heritage as well as archival and library materials include, but are not limited to, *The Archimedes Palimpsest Project*⁵, *Livingstone Online*⁶, and *Lazarus*.⁷ These projects utilize MSI data and many share their data openly. The British Museum's *CHARISMA* project should also be taken into consideration when discussing this topic. It is not a project using MSI but a proposal for creating a standard imaging protocol and processing MSI datasets with their NIP2 software.⁸

¹ R.B. Toth Associates, "Spectral Imaging & Partners," 2018, <http://rbtoth.com/spectral-imaging--partners.html>.

² Madeleine Anne Bognar, *et al.*, "3pi Project – KU Leuven NBMSI Metadata Standard 2.0," Zenodo, 2021, <https://doi.org/10.5281/zenodo.5255194>.

³ Edmund Optics, "Imaging Electronics 101: Understanding Camera Sensors for Machine Vision Applications," accessed January 23, 2020, <https://www.edmundoptics.com/knowledge-center/application-notes/imaging/understanding-camera-sensors-for-machine-vision-applications/>.

⁴ National Aeronautics and Space Administration, Science Mission Directorate, "Visible Light," NASA Science, 2010, https://science.nasa.gov/ems/09_visiblelight.

⁵ Paul Keyser, review of *The Archimedes Palimpsest*, ed. Reviel Netz, William Noel, Natalie Tchernetska, and Nigel Wilson, *Classical World* 106, no. 4 (2013): 708-709, <https://doi.org/10.1353/clw.2013.0081>.

⁶ Adrian S. Wisnicky *et al.*, "Spectrally Illuminating the Hidden Material History of David Livingstone's 1870 Field Diary," *Victorian Studies* 58, no. 2 (2016): 243, <https://doi.org/10.2979/victorianstudies.58.2.06>.

⁷ Kathleen McGarvey, "The Future of the Past," *Rochester Review* 79, no. 4 (March-April 2017), https://www.rochester.edu/pr/Review/V79N4/0501_heyworth.html.

⁸ Joanne Dyer, Giovanni Verri, and John Cupitt, "Multispectral Imaging in Reflectance and Photo-induced Luminescence Modes: A User Manual," Version 1.0, European CHARISMA Project, October 2013, https://www.researchgate.net/publication/267266175_Multispectral_Imaging_in_Reflectance_and_Photo-induced_Luminescence_modes_A_User_Manual [original published at the URL <http://www.britishmuseum.org/pdf/charisma-multispectral-imaging-manual-2013.pdf>].

With the *3pi project*⁹ KU Leuven has recently received the infrastructure to execute Narrow Band Multi-Spectral Imaging or NBMSI on their own collections and other materials brought for consultation by researchers and partnering institutions. Within the context of this project the focus is laid on the imaging of papyrus, parchment and paper materials, hence the name “3pi.”¹⁰ While other projects have included some image processing and capture environment information, it was of special concern to the KU Leuven Libraries to develop a strategy in order to include the technological infrastructural environment information about the image capture in a manner that was consistent with widely recognised and published standards for image metadata. These standards outline parameters of what metadata elements should be captured and how those values should be recorded. This allows for a level of consistency and quality across institutions and increases interoperability and understanding across institutions. This needed to be an approach that could be consistently implemented into their workflows.

The image capture process at KU Leuven used different sets of predetermined wavelength values for standard image capture, though this could of course be changed. Furthermore, filters were applied to some of the captures, particularly those capturing fluorescent light emittance. KU Leuven Libraries utilized software developed by the researchers and staff working on the *The Archimedes Palimpsest Project*. This software, Spectral XV, works in tandem with the Capture One and Phase One infrastructure for NBMSI. This means the software controls the applied light sources, either a light panel or a transmitting panel, as well as the camera system and the filter wheel. However, there still remained no way that any of the software could know some of the physical aspects of the capture environment were. For example, what angle the light panels were placed at, how high the camera sensor was from the floor, whether the light panels were positioned in a symmetrical manner, or what type of filters may have been placed between the light source and the object or the lens and the object. All of these are examples of the technological environmental information that is necessary for someone looking at the final image to fully understand what circumstances the object has been put in to achieve this image capture, and therefore what the image is actually showing. It is this information that we were intent on finding ways to attach at the image level.

Relevant Documentary Heritage MSI Projects and their Metadata Strategies

Past cultural heritage projects have used multi-spectral imaging to image specific cultural heritage items or collections, such as *Livingstone Online* and *The Archimedes Palimpsest Project*. Furthermore, projects like the British Museum’s *CHARISMA* focused on setting a standard for best practices in terms of multi-spectral imaging. These projects are very useful because they have been made openly accessible and detail the set up and practices for each project through their online presence. However, many of these projects overlook some of the environmental technological information that could be embedded or attached to the images through metadata, giving the images greatly enriched research information and general context about how the images were made.

⁹ Hendrik Hameeuw *et al.*, “3Pi Project - KU Leuven NBMSI Hardware Document,” Zenodo, 2020, <https://doi.org/10.5281/zenodo.3607302>.

¹⁰ Illuminare – Centre for Medieval and Renaissance Art, “The 3Pi Project,” KU Leuven, 2021, <http://www.illuminare.be/accordion-item/the-3pi-project/>.

Livingstone Online

This project focused on providing digital access to the material culture surrounding the Victorian explorer David Livingstone (1813-73).¹¹ The collection, available online, is extensive and contains over 15,000 images and 780 transcriptions. This project's spectral imaging component utilized the professional skills of expert scholars, scientists and librarians from both the United Kingdom and America. Through multi-spectral imaging, the professionals working on this project were able to reveal hidden text that has not been visible for over 140 years.

In terms of accessing and utilizing the images created with multi-spectral infrastructure, one can use their digital catalog to search for these specific images. *The Livingstone Spectral Imaging Project* began using multi-spectral technology beginning in 2010, while the overall project began in 2004.¹² Their web page provides an online viewing environment with features that detail the item's contextual metadata, and some of the information about the web host. One is able to download the image or use the viewer to compare different images, which can be selected from a drop-down menu. The drop-down menu gives the user a number of options about different types of imaging that has been conducted on the object. Details of each of these imaging processes are found through the link that redirects the user to the "Notes on Processed Spectral Images." This page details all the processing categories. For instance, one type of processing refers to a "color" image. In the processing description the following information is included: the type of light, file type, spectral bands applied, colour checker and white swatch brands, and whether the image is flattened.¹³ Additionally, if one decides to download the image, a zip file is downloaded that has all images in the sequence of spectral imaging (all the images available on the drop-down menu) as well as text, MD5 and XMP files. The text files contain the metadata that goes along with each image of the same name designation. The metadata standard used in these files is the *Archimedes Palimpsest Metadata Standard, Version 1.0*. This standard was created in 2006 for a different MSI project on the Archimedes Palimpsest.

The Archimedes Palimpsest Project

This project centers around a manuscript called the Archimedes Palimpsest. The object is a prayer book, and like any other palimpsest, contains writing that has been recorded over previously effaced writing. The palimpsest undertext dates from the 10th century CE and contains works by Archimedes of Syracuse (3rd century BCE) and several other authors. This was overwritten by a Christian text in the 13th century. The undertext includes scientific treatises that cannot be found anywhere else.¹⁴ From the years 1999-2008, the palimpsest underwent a significant amount of imaging and conservation. This took place at the Walters Art Museum, in Baltimore, Maryland and the project was managed, in terms of imaging and data, by Michael B. Toth of R.B Toth Associates. R.B. Toth Associates work in applying innovative technological approaches to the study of cultural heritage.¹⁵ The conservation of the Archimedes Palimpsest was taken on by Abigail Quandt, Senior Conservator of Rare Books and Manuscripts at Walters

¹¹ Adrian S. Wisnicki *et al.*, "Notes on Processed Spectral Images," Livingstone Online, 2017, <http://livingstoneonline.org/uuid/node/58a3243f-182c-4d5a-b174-293eaf2129b>.

¹² Adrian S. Wisnicki and Megan Ward, "The Livingstone Spectral Imaging Project: An Introduction," Livingstone Online, 2018, <http://livingstoneonline.org/uuid/node/8082ba50-e1cb-47bb-b5b8-18c9d2aeb395>.

¹³ Wisnicki *et al.*, 2017.

¹⁴ The Archimedes Palimpsest Project, "The Archimedes Palimpsest Project," The Archimedes Palimpsest, accessed January 23, 2020, <http://archimedespalimpsest.org/>.

¹⁵ R.B. Toth Associates, "R.B. Toth Associates," 2018, <https://rbtoth.com/index.html>.

Art Museum. “Work on disbinding the manuscript started in February 2000, and finished in February 2004.”¹⁶

The palimpsest was imaged in three different spectral bands before 2006 but in 2007 they created new image captures of the entire palimpsest using bands in the range of 365, 445, 470, 505, 530, 570, 617, and 625 nanometers as well as infrared imaging taken at 700, 735, and 870 nanometers. Finally, they also imaged the entire palimpsest with raking light setups at both 910 and 470 nanometer peak wavelengths.¹⁷ Prior to 2008 images were post-processed using a software, initially used in medical imaging, called ImageJ. Subsequently, images were processed by Keith Knox using Archie 1.0 software tools.¹⁸ These post-processing software tools search for the areas of most difference and produce pseudocolour images, which can reveal even more of the underlying text.¹⁹ There is additional and more elaborate scholarship on other aspects of *The Archimedes Palimpsest Project*, however I wish to bring your attention to the metadata information that the project provided.

In 2008, all the data that was produced through the imaging and conservation of this manuscript were published online. On the main webpage, www.archimedespalimpsest.org, under the section for “Digital” there is a section entitled “Core Archimedes Data,” (see figure 1). Linked to this there are readme files, file lists, lists of corrections and additions to the data, data folders, document folders, research contribution folders, supplemental folders, and support folders; the metadata information is present within the “Documents” folder under “Internal,” (see figures 2 and 3).

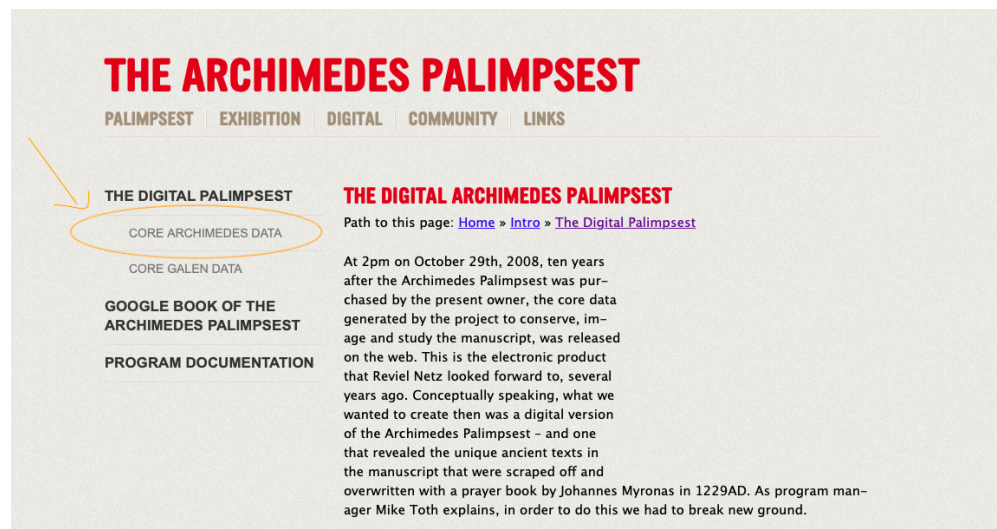


Figure 1 www.archimedespalimpsest.org/digital "Core Archimedes Data" Link Location

¹⁶ The Archimedes Palimpsest Project, “The Conservation of the Archimedes Palimpsest,” The Archimedes Palimpsest, accessed October 7, 2022, <http://archimedespalimpsest.org/about/conservation.php>.

¹⁷ Fenella G. France, Doug Emery, and Michael B Toth, “The Convergence of Information Technology, Data, and Management in a Library Imaging Program,” *The Library Quarterly: Information, Community, Policy* 80, no. 1 (2010): 37, <https://doi.org/10.1086/648462>

¹⁸ Keith T. Knox, “Archie Software Architecture,” The Archimedes Palimpsest, May 25, 2002, <http://archimedespalimpsest.org/pdf/archie-software-architecture.pdf>.

¹⁹ Keith T. Knox, "Enhancement of Overwritten Text in the Archimedes Palimpsest," *Proceedings of the SPIE*, Vol. 6810 (2008): 681004, <https://doi.org/10.1117/12.766679>.











	Name	Last modified	Size
	0_ReadMe.html	2008-10-29 04:21	24K
	0_ReadMe.txt	2008-10-29 02:24	13K
	1_FileList.html	2018-09-14 17:08	1.0M
	1_FileList.txt	2018-09-14 17:14	916K
	2_CorrectionsAndAdditions_2011.html	2011-11-01 20:19	9.9K
	2_CorrectionsAndAdditions_2011.txt	2011-11-01 20:15	4.9K
	Data/	2011-11-01 16:40	-
	Documents/	2011-11-01 10:52	-
	ResearchContrib/	2022-08-05 16:37	-
	Supplemental/	2011-11-01 10:52	-
	Support/	2011-11-01 10:52	-
	manifest-md5.txt	2019-10-07 16:59	395K
	robots.txt	2020-06-12 11:55	124

Figure 2 “Documents” folder *www.archimedespalimpsest.net*

	Name	Last modified	Size
	Parent Directory		-
	External/	2008-10-29 01:22	-
	Internal/	2011-11-01 16:40	-

Figure 3 “Internal” folder within the “Documents” folder
www.archimedespalimpsest.net/Documents

Firstly, the files created for this project follow a file naming convention, which is laid out in their “File Naming Convention” document. The images are given file names that show the following information: the prayer book folio, the undertext folio, the image group, the image processing details, the illumination (which includes type of illumination as well as the peak wavelength), the set index, processing tag, and the file extension.²⁰ There is a significant amount of metadata within the filename alone. Additionally, within this “Internal” folder there are two metadata documents to consider, the “Image_Metadata_Standard” and the “Metadata_Data_Dictionary,” (see figure 4). I will begin by discussing the former.

The “Image_Metadata_Standard” redirects to a standard of metadata elements that record information about images created by *The Archimedes Palimpsest Project*. The *Archimedes Palimpsest Metadata Standard 1.0* is the document shown when one selects “Image_Metadata_Standard,” (figure 4) and this document defines the objective and scope of the standard as well as citing other vocabularies and standards used to create it. Primarily, though, this standard functions to define the elements that are necessary to fill out in order to accurately record information about the image and determines whether they are “Core,” or required elements. These are outlined in the standard’s “Metadata Production Rules.” These rules give guidelines on how to construct the metadata information and if there can be multiple entries for one element.²¹ These are governed by the “Type,” and “Domain,” rules of the convention. An example of this would be the “Date” element (identified in figure 5). One can see that the element has been defined, identified as a core element, designated as a single element entry (meaning there can only be one entry), and outlined as a text entry to show how to enter the information.

²⁰ Doug Emery, “File Naming Conventions,” *The Archimedes Palimpsest*, May 23, 2008, <http://archimedespalimpsest.net/Documents/Internal/FileNamingConventions.txt>.

²¹ William Christens-Barry and Michael B. Toth, “Archimedes Palimpsest Metadata Standard 1.0,” June 7, 2006, https://www.archimedespalimpsest.net/Documents/Internal/Image_Metadata_Standard.pdf.















	<u>Name</u>	<u>Last modified</u>	<u>Size</u>
	Parent Directory		-
	Archie_1.0.pdf	2008-05-29 14:54	444K
	FileNamingConventions.html	2008-05-29 14:54	23K
	FileNamingConventions.txt	2008-10-29 02:29	14K
	FolioIndex.html	2011-11-01 10:52	87K
	FolioIndex.txt	2011-11-01 10:52	138K
	Image_Metadata_Standard.pdf	2008-05-29 14:54	133K
	Image_Metadata_Standard_XRF_Extensions.pdf	2008-05-29 14:54	90K
	MD5_ReadMe.txt	2008-05-29 14:54	3.9K
	Metadata_Data_Dictionary.txt	2008-10-29 04:17	17K
	TEI_Encoding.html	2011-11-01 10:52	23K
	TEI_Encoding.txt	2011-11-01 10:52	11K
	Transcription Integration Plan_2.0.pdf	2008-10-29 03:03	113K
	Transcription_Metadata_Mapping.txt	2008-05-29 14:54	2.6K

Figure 4 "Image_Metadata_Standard" and "Metadata_Data_Dictionary" within the "Internal" folder www.archimedespalimpsest.net/Documents/Internal/

1.2. Date: Date of creation of resource.
CORE: YES TYPE: SINGLE
DOMAIN: TEXT

Figure 5 "Date" element entry information from the Archimedes Palimpsest Metadata Standard 1.0, 7 June 2006, Revision 5

The subtypes defined in the standard are "1. Identification Information, 2. Spatial Data Reference Information or Coverage, 3. Imaging and Spectral Data Reference Information, 4. Data Type Information, 5. Content Description Information, 6. Metadata Reference Information."²² These subtypes group the metadata into categories that cover different aspects of the image. "Identification Information," has elements that cover "basic information about the

²² *Ibid.*, 2.

data set.”²³ “Spatial Data Reference Information or Coverage,” includes elements that outline “the spatial extent or scope of the data set.”²⁴ “Imaging and Spectral Data Reference Information,” has elements with “information describing the conditions used to acquire image or scanned data objects.”²⁵ “Data Type Information,” covers elements that show information about the file itself including version, type and processing.²⁶ “Content Description Information,” has elements that cover “a general assessment of the content of the data set.”²⁷ Finally, “Metadata Reference Information,” covers elements that hold “information on the validity and state of the metadata information and the responsible party.”²⁸

These areas cover a large amount of metadata information, but the *Metadata Data Dictionary* elaborates on the included elements even more so. This document expands on the elements as they are defined in the standard. For example, the “Illumination” element as defined in the standard gives a short definition of the element, and defines the entry and outlines the production rules (see figure 6).²⁹ Within the *Metadata Data Dictionary* however, a number of additional elements are defined that are extensions of the “Illumination” metadata element (see figure 7). These include things like “wavelength” and “angle of incidence.”³⁰ One can see from this example that the *Metadata Data Dictionary* provides further clarification on how to construct metadata records using the *Archimedes Palimpsest Metadata Standard 1.0*. This document does not include “Metadata Production Rules,” that are present in the metadata standard.

²³ *Ibid.*, 2.

²⁴ *Ibid.*, 3.

²⁵ *Ibid.*, 4.

²⁶ *Ibid.*, 5.

²⁷ *Ibid.*, 6.

²⁸ *Ibid.*, 7.

²⁹ *Ibid.*, 4-5.

³⁰ Doug Emery, “Metadata Data Dictionary,” The Archimedes Palimpsest, October 29, 2008, http://archimedespalimpsest.net/Documents/Internal/Metadata_Data_Dictionary.txt.

3.2 Illumination: Type of lighting or energy used to produce image or scanned data.

CORE: YES TYPE: SINGLE

DOMAIN: "Tungsten"

"Quartz"

"LWUV"

"X-Ray"

Figure 6 "Illumination" element entry information from the Archimedes Palimpsest Metadata Standard 1.0, 7 June 2006, Revision 5

- * IMG_Illumination_Wavelength_Meas_Unit
 - 3.2 Illumination: Illumination Wavelength Meas Unit
- * IMG_Illumination_Source_Wattage
 - 3.2 Illumination: Illumination Source Wattage
- * IMG_Illumination_Type
 - 3.2 Illumination: Illumination Type
- * IMG_Illumination_Wavelength
 - 3.2 Illumination: Illumination Wavelength
- * IMG_Illumination_Spectral_Range
 - 3.2 Illumination: Spectral Range of Illumination at half maximum intensity
- * IMG_Illumination_Spectral_Range_Unit_of_Measure
- * IMG_White_Balance
 - 3.2 Illumination: White Balance
- * IMG_Illumination_Source_No
 - 3.2 Illumination: Illumination Source Number
- * IMG_Comment
- * IMG_Illumination_Comment
- * IMG_Illumination_Incidence_Angle_Az_0
 - 3.2 Illumination: Angle of incidence of light from normal at azimuthal angle 0, with Archie text up oriented at 0/North.
- * IMG_Illumination_Incidence_Angle_Az_90
 - 3.2 Illumination: Angle of incidence of light from normal at azimuthal angle 90, with Archie text up oriented at 0/North.
- * IMG_Illumination_Incidence_Angle_Az_180
 - 3.2 Illumination: Angle of incidence of light from normal at azimuthal angle 180, with Archie text up oriented at 0/North.

Figure 7 Illumination metadata elements as seen in the Metadata Data Dictionary, October 29, 2008

One thing that is important to note is that the “Spatial Data Reference Information or Coverage,” elements in the *Archimedes Palimpsest Metadata Standard 1.0* refer to spatial elements of the image itself, and not of the spatial considerations within the image capture environment. The “Imaging and Spectral Data Reference Information,” set of elements does cover aspects of the capture environment including filters and illumination. However, the information regarding all the technical and physical conditions of the image capture environment are notably missing from the *Archimedes Palimpsest Metadata Standard 1.0*. Examples of these missing elements include but are not limited to: the angle of the light panels, height of the table,

distance of the object being imaged from the camera lens and the positioning of the light panels around the copy stand table itself. This will be discussed further in a later portion of this paper. There was one project worth reviewing because it appeared to consider these factors in its goal to develop best practices for scientific imaging and other conservational concerns.³¹ This was *The CHARISMA Project*.

The Charisma Project

This project was presented by the British Museum, working together with 22 other European institutions to “develop and promote best scientific practice for the interdisciplinary study of cultural heritage and to disseminate knowledge.”³² In the ‘Technical Imaging’ part of their web page they discussed multispectral imaging techniques saying that previous “imaging techniques - and particularly luminescence imaging techniques - have tended to be highly set-up dependent, making cross-comparison between different institutions and researchers very difficult.”³³ It should be noted that, unfortunately, the *CHARISMA Project* is no longer available on the British Museum website. Parts of The British Museum website’s pages on the *CHARISMA Project* and www.charismaproject.eu are available through The Internet Archive Wayback Machine.³⁴ The *CHARISMA Project* “User Manual” however, is still available through ResearchGate. For the purposes of this paper I will only be discussing the “User Manual” provided by *The CHARISMA Project* because of its direct reference to the metadata that should be attached to image captures. I maintain that the *CHARISMA Project* remains relevant for review on this topic. This is because it provides an example of another MSI project’s approach to recording image metadata. This was also a valuable resource for comparison during the development of the *KU Leuven NBMSI Metadata Standard*.

The *CHARISMA* “User Manual”³⁵ takes the time to outline the different techniques used in MSI and general digitization, including flat-fielding, to create a uniform image. Additionally, the manual outlines the difference between reflected images and photo-induced luminescence images. Following this, they have a section on “Experimental Set-Up” wherein they detail what one will need to create a capture environment. Among the equipment needed, including radiation sources, filters, and a recording device, they state that one needs “a set of standards to enable the post processing methods.”³⁶ There is then a diagram showing how the equipment can be set up with some unclear angle references for the positioning of the radiance sources. There are recommendations for the equipment, followed by a section on standards. The standards include the colour checker recommendation, flat-fielding information, reflectance standards and the white point spectralon diffuse standard equipment. In terms of the equipment set-up, the manual

³¹ Dyer, Verri, and Cupitt, “Multispectral Imaging in Reflectance and Photo-induced Luminescence Modes.”

³² *Ibid.*, 3.

³³ The British Museum, “Technical Imaging,” May 18, 2018,

http://www.britishmuseum.org/research/research_projects/all_current_projects/charisma/technical_imaging.aspx [Can be accessed at:

https://web.archive.org/web/20180518101111/http://www.britishmuseum.org/research/research_projects/all_current_projects/charisma/technical_imaging.aspx]

³⁴ A capture of The British Museum’s webpage on the *CHARISMA Project* can be found at:

https://web.archive.org/web/20171117150839/http://www.britishmuseum.org:80/research/research_projects/all_current_projects/charisma.aspx; A capture of www.charismaproject.eu can be found at:

<https://web.archive.org/web/20160315212158/http://www.charismaproject.eu/>

³⁵ *Ibid.*

³⁶ *Ibid.*, 41.

recommends looking at the *AIC Guide to Digital Photography and Conservation Documentation*³⁷ as well as *Lighting Objects for Photographing Museum Objects*.³⁸ The first resource was published by the American Institute for Conservation and reviews topics like workflows, equipment, camera settings, image processing, and techniques to implement in photography for conservation. The second resource was published by the Canadian Conservation Institute and outlines how lighting affects the outcome of imaging an object.

Following this suggestion, the *CHARISMA Project* “User Manual” comes to the crucial metadata that would allow for someone to reproduce the photograph if necessary, as well as knowing the capture conditions. The metadata that is suggested covers camera settings such as ISO, shutter speed, as well as some positional information like the “Angle between the normal to the object and the direction of the incident radiation.”³⁹ It also includes some filter information and the height and distance of the radiation sources from the object. However, the metadata they have included is not specific enough to fully recreate the image. There is little information about the object support, as well as the object’s measurements in relation to the camera. There is also little information about the angle at which the radiation source is positioned within the set-up. Finally, though this is a good start in terms of addressing the problems of attaching metadata to image captures, there is one crucial element missing. This missing element is a standard that can be accepted throughout institutions which has been created with interoperability in mind. The metadata fields they have suggested are available to be filled in using their software at the end of post-processing.⁴⁰ There is little reference to the standards from which this element set was created. There was ease in using the element set because of the incorporation of it into the software, but there was nothing that outlined what should be entered in the fields. This was nothing like the metadata guidance that *The Archimedes Palimpsest Project* provided, which took the time to fully define what text should be entered into each metadata element field with the *Metadata Data Dictionary* and the *Archimedes Palimpsest Metadata Standard 1.0*.

Therefore, upon review of this particular project, it was apparent that not only did we want a standard that both recorded the entire detail of the image capture environment and something that defines the metadata fields and entries, but that could be utilized by institutions outside of KU Leuven conducting multi-spectral imaging projects.

MSI at KU Leuven

After conducting a review of the projects that work with multi-spectral imaging and assessing their metadata strategies, it was imperative to assess the situation at KU Leuven in regard to their approach to MSI and the metadata that would be attached to those images. KU Leuven Libraries worked with Mike Toth from R.B. Toth Associates as well as Bill Christens-Barry of Equipose Imaging (both of whom worked with the Archimedes Palimpsest and created the program Spectral XV). This software program is used in tandem with Capture One⁴¹ software to capture and organize images taken with spectral imaging equipment. KU Leuven works with a

³⁷ Franziska Frey et al., *The AIC Guide to Digital Photography and Conservation Documentation*, ed. Jeffrey Warda, 3rd ed. (Washington, DC: American Institute of Conservation, 2017).

³⁸ Carl Bigras, Mylène Choquette, and Jeremy Powell, *Lighting Methods for Photographing Museum Objects* (Ottawa: Canadian Conservation Institute, 2010).

³⁹ Dyer, Verri, and Cupitt, “Multispectral Imaging in Reflectance and Photo-induced Luminescence Modes,” 64.

⁴⁰ *Ibid.*

⁴¹ Capture One, “Capture One,” accessed January 27, 2020, <https://www.captureone.com/en/>.

Phase One camera, Equipose Imaging light panels, and the software programs Spectral XV and Capture One. After image processing, the Archie 1.0 software program (which produced pseudocolour images for *The Archimedes Palimpsest Project* above) can be used⁴². The program has algorithms to find the largest instance of difference between the images in a set, and this can reveal material information about the object that was imaged. For the purposes of this paper, and indeed the research I conducted at KU Leuven, the images created using the software, and the metadata that may be attached to them, will not be included in this discussion as they go beyond the scope of the project.

I was lucky enough to have Mike Toth visiting at KU Leuven, and available for discussion in regard to the creation of the metadata for *The Archimedes Palimpsest Project*. In place of reinventing the wheel in terms of creating a metadata standard, the team working on MSI at KU Leuven adopted the strategy of referencing the metadata standard that was created for *The Archimedes Palimpsest Project*. Therefore, the first step was to review the standard that was created in 2006 (the most recent version is from 2008). The review was undertaken in conversation with Mike Toth, in the interest of updating their own metadata standard, as well as with Hendrik Hameeuw and Bruno Vandermeulen, to complete the goal of creating a reference tool that could be published by KU Leuven and be specific to their needs.

When reviewing *The Archimedes Palimpsest Project* metadata standard, the focus for editing and expanding the standard was to alter the scope and objectives to include research that was not conducted on the palimpsest. It was important to review the element set and review the clarity of the value fields that are set out in the standard. There was also a discussion of the necessity of certain elements as they may have been redundant. The element fields that outlined the capture environment details, including filters (both in front of the lens and in front of the camera), measurements of distance of the object from the floor, from the camera and from the light source, angular measurements of the camera and light panels, and the angular positioning of the panels, were discussed at length. Finally, there was a discrepancy between *The Archimedes Palimpsest Metadata Standard 1.0* and the *Metadata Data Dictionary* files on the project's website. Some terms were added to the metadata but were not given a definition. Many of the terms added had no specification for the value field entry. Finally, none of the terms outlined in the *Metadata Data Dictionary* had the conventions that outlined the "Metadata Production Rules," reviewed earlier in this paper. The revision and expansion of the element content and the values entered into their fields allowed for more appropriate coverage of the images being used for research. However, the clarity of the definitions and the specifications of these fields and the conventions applied to each field allows for a consistency that allows researchers to navigate the information of many different images with the same directions.

The reference tools created for KU Leuven Libraries ended up being split into two separate tools that covered different objectives, but both worked towards providing a fuller understanding of the metadata the institution was using for their projects (such as the *3pi Project*) and the specific equipment being used. The *KU Leuven NBMSI Metadata Standard* (now updated to version 2.0) focused on providing something similar to what had been discussed with Mike Toth in terms of an updated *Archimedes Palimpsest Metadata Standard*. However, there were some slight changes made in order to allow this document the ability to provide a standard that could cover standard image capture situations, non-standard image capture situations and to provide the metadata information that *was not* provided by metadata standards

⁴² Knox, 2002.

attached to image processing software such as Exif or IPTC. Exif stand for “Exchangeable image file format,”⁴³ and functions as a standard for metadata that many media recording devices fill out automatically and attach to the media file. IPTC (International Press Telecommunications Council) is a similar standard that provides descriptions, rights and administrative information.⁴⁴ An additional standard could therefore be filled out and then pasted into the IPTC or Exif “Description” field used by many image processing software programs. In this way one can add additional metadata and have it within the fields attached to the image itself. Additionally, this document had a specific section that focused on “Environmental and Infrastructural Information,” and this section also consisted of diagrams that allowed for further clarity in the description of what details of the capture environment each element field was referring to and specifically how to measure the values and record them. The “Environmental and Infrastructural Information,” subsection of metadata elements is defined by “the infrastructure and set up that was used in the capture of multi-spectral images.”⁴⁵ The physical set up of the capture environment that is used at KU Leuven is illustrated through diagrams (see figures 8, 9 and 10). These diagrams include a general set-up with the copy stand, camera and LED light panels. The following diagram shows different possible set-up options for the camera sensor with angles included, and the final diagram shows a top view of the general set up of the capture environment with different options for positioning the light sources around the imaging object.

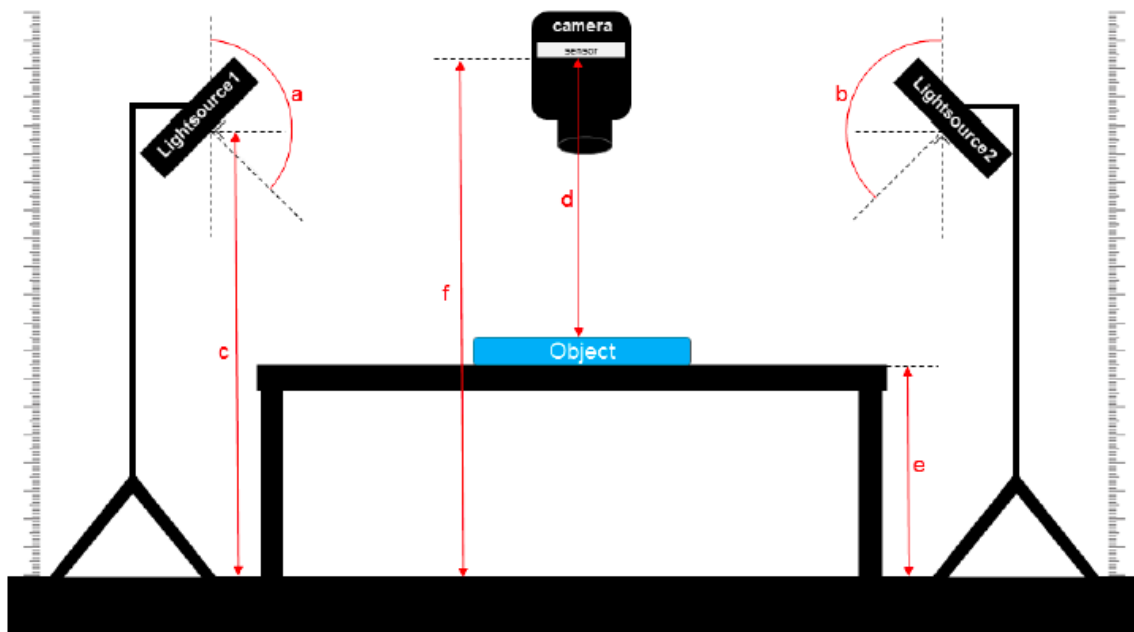


Diagram 1
Front view on general set-up, heights and angles of various hardware

Figure 8 Diagram showing general technical infrastructure set up in the KU Leuven Libraries. Taken from the KU Leuven NBMSI Metadata Standard Version 2.0

⁴³ Phil Harvey, “EXIF Tags,” ExifTool, last modified October 1, 2022, <https://exiftool.org/TagNames/EXIF.html>.

⁴⁴ International Press Telecommunications Standards, “IPTC Standards,” 2022, <https://iptc.org/standards/>.

⁴⁵ Bognar *et al.*, “3pi Project – KU Leuven NBMSI Metadata Standard 2.0,” 6.

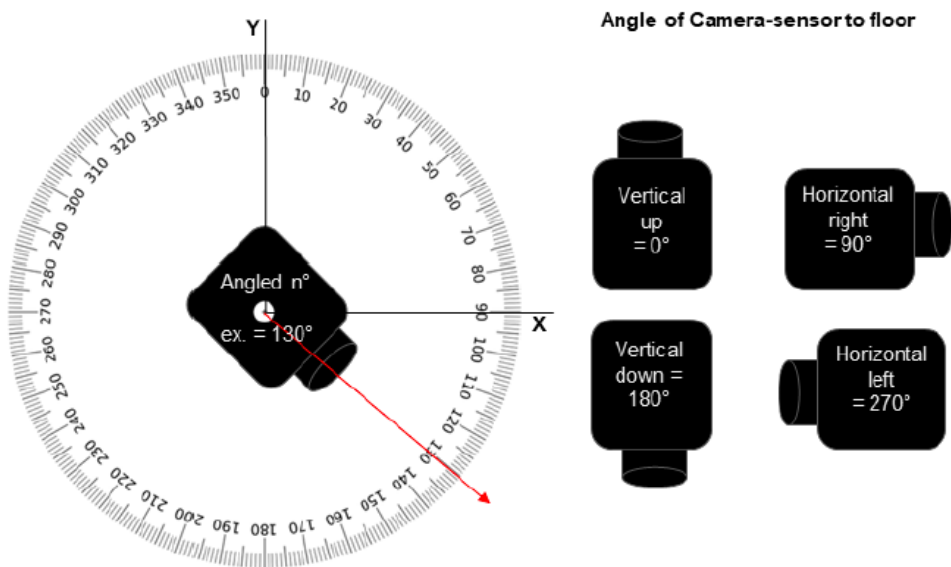


Diagram 2
Front view on set-up camera-sensor

Figure 9 Diagram showing camera angles in the capture environment of the KU Leuven Libraries. Taken from the KU Leuven NBMSI Metadata Standard Version 2.0

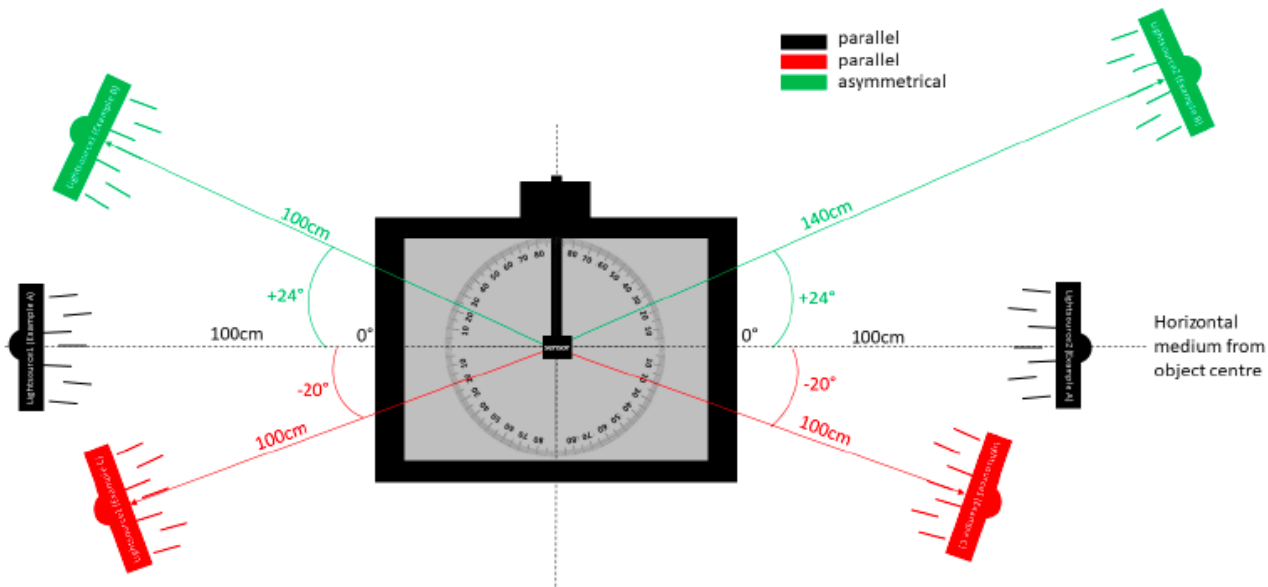


Diagram 3:
Top view on general setup, multiple examples of positions light sources

Figure 10 Diagram showing light panel angles in relation to the copy stand in the capture environment of the KU Leuven Libraries. Taken from the KU Leuven NBMSI Metadata Standard Version 2.0

The *KU Leuven NBMSI Metadata Standard* was organized in a similar manner to the *Archimedes Palimpsest Metadata Standard 1.0*. By this I mean that there were subsections of metadata elements that were defined and categorized. There are also conventions similar to the “Metadata Production Rules,” in the *Archimedes Palimpsest Metadata Standard 1.0*. The crucial difference in the *KU Leuven NBMSI Metadata Standard* is the addition of the “Environmental and Infrastructural Information,” category that fills in an important gap in being able to record information about these images. Additionally, the standard outlines the steps that KU Leuven specifically took to attach this important additional metadata to the images. This was through the Exif “Description” field. As mentioned above, Exif is metadata that is attached to an image file. One of the fields is a free text option called “Description.” We used this field to copy and paste the fields of the metadata that were filled out according to the standard and therefore attach our additional metadata to the image. Finally, the second version of the *KU Leuven NBMSI Metadata Standard*, includes two implementation examples.⁴⁶ These are very useful in outlining how a metadata record is produced.

The second document created for KU Leuven Libraries was a more specific document called *The KU Leuven MSI Hardware Document*.⁴⁷ This document was first created by Hendrik Hammeuw (with later additions from myself) and it contains the specific material information about the specific technological infrastructure used by KU Leuven Libraries in their digitization lab. The first section includes a complete overview of the standard capture sequence and dark capture sequence and the wavelengths used in this sequence as executed by Spectral XV. This is followed by the Eureka Light Panel information including the manufacturers and part numbers of each light bulb and the filter information from the panel. The final section outlines all the filters used in the capture including manufacturer information and transmission data of each filter. This tool is intended for a platform such as GitHub where institutions can update the information in a document like this with ease, allowing open sharing of the changing infrastructure within the institution.

Considerations

Some considerations had to be taken into account in terms of the application of this metadata standard. First and foremost was how to attach this information at the image level and not have that metadata stripped upon any conversion. When the images are initially captured, they are raw image files and they are later converted to .tiff files by Spectral XV. Therefore, we spoke to Bill Christens-Barry about adding a description field to the Spectral XV data entry window, and discussed issues with the metadata getting stripped upon this conversion. Another approach that we took to attach this information to the images was to use a digital asset management application such as Adobe Bridge⁴⁸ where after some experimentation it was seen that one can copy and paste the filled-out metadata fields into the Exif “Description” field, details of which were already described.

Another consideration is the implementation of this metadata enrichment within the digitization workflow. It is equally important to establish workflows for entering metadata as

⁴⁶ *Ibid.*, 20-25.

⁴⁷ Hammeuw *et al.*, “3Pi Project - KU Leuven NBMSI Hardware Document.”

⁴⁸ “Centralize Your Creative Assets,” Adobe Bridge, Adobe, accessed January 27, 2020, https://www.adobe.com/be_en/products/bridge.html#.

well as having the standards for the metadata. As the metadata is produced and *then* attached into a description field, the standard is filled out for each individual capture. Workflows establish procedure in how to create these records to ensure quality and consistency. KU Leuven Libraries have some workflows created that have phases of creating meaningful metadata records. These include “Metadating/ Collection Items,” as well as “Standard Digitization,” and “Enrichment,”⁴⁹ which can be somewhat confusing. However, the first phase focuses mostly on the descriptive metadata of the object that is being imaged and not the images as objects in their own right. Additionally, multi-spectral imaging does not necessarily fall into the “Standard Digitization” description as it is an advanced imaging technique. These would fall short in similar ways to previous metadata standards as they do not cover the specifics of the image capture environment. The “Enrichment” stage of the workflows is the natural place for the implementation of the standard. This implementation was not put in place during the time I conducted my research. However, follow up consultations will allow for the standard to be carried out effectively within the institution. One can already see in version 2.0 of the standard that clarity in how to enter the metadata information is provided in the “Implementation Example[s].”⁵⁰

Conclusions

The metadata attached to multi-spectral images is vital to understanding the resulting digital objects, as well as ensuring the reproducibility of any image capture. It is clear that these images require that supplemental information to allow for properly informed research to be conducted. Projects in the past have included some, but not all of the capture environment details and some have not defined and specified the parameters of the metadata effectively enough to ensure that images can be recreated in the same image capture environment. This project aimed to both provide researchers with the information they need to fully understand the image captures they are working with, as well as clearly defining the manner in which this information should be measured, read and recorded. In the hopes of creating more awareness of the issues with technical and infrastructural metadata, KU Leuven Libraries has made this project available and open for public use as well as pursuing this topic in working group discussions and further scholarship. This will hopefully lead to more focus on advanced imaging metadata strategies and solutions in institutions, technology, software, and scholarship.

⁴⁹ Bruno Vandermeulen and Hendrik Hameeuw, “Advanced Imaging Services at KU Leuven Libraries” (PowerPoint Presentation, IMPACT & OPF Webinar, October 18, 2018), <https://www.slideshare.net/impactproject/advanced-imaging-services-at-ku-leuven-libraries-webinar-slides>.

⁵⁰ Bognar *et al.*, “3pi Project – KU Leuven NBMSI Metadata Standard 2.0,” 6.

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