ANALYSIS AND IMAGING TECHNIQUES

IN THE CONSERVATION OF ART, CULTURAL AND NATURAL HERITAGE

A two-day educational symposium | Copenhagen - Denmark | October 31st - November 1st 2019

PROGRAM

Nationalmuseet
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MoK is a Nordic peer-reviewed journal for the conservation of art, cultural- and natural history objects. The intended readership includes the conservation professional in a broad sense: practising conservators of all types of objects, heritage and conservation scientists, collection or conservation managers, teachers and students of conservation, and academic researchers in the subject areas of arts, archaeology, natural history, built heritage, materials history, art technological research and material culture.

The symposium postprint is handled by MoK and is published in English.

Welcome to the 2019-NKF Symposium on analysis and imaging techniques

The organizing Committee

Maiken Ploug Riisom
Conservator at Medical Museion

Sigrid Ninel Kledal
Conservator at Kunstkonservaringen

Loa Ludvigsen
Conservator at SMK

Maj Ringgaard
Conservator Ph.D.

The symposium is arranged in collaboration with the National Museum of Denmark and the scientific journal of conservation, MoK (*Meddelelser om Konservering*).

The program is covering a wide range of methods and application of imaging- and material based techniques. The aim is to provide insight into the rapidly growing technology within the state-of-the-art of visual analysers, including several types of 3D imaging, MFT as well as the development within material-based analysis methods.

The main topics are:

3D imaging and photogrammetry

3D modelling and documentation

Digital Technologies in Heritage Conservation

Archaeological material analysis

Microfading techniques, X-ray and other analysis

We are honored to present our two keynote speakers:
Dr. Alex Ball, head of *Imaging and Analysis* at the Natural History Museum, UK
Prof. Karin Margarita Frei, research professor in Archaeometry at the The National Museum of Denmark

We hope that you find this program rich and engaging. The wide range of participants gives a unique opportunety to exchange and share new knowledge. And do take the opportunity to visit our beautiful and friendly city. Enjoy.

On behalf of NKF-dk

Maiken Ploug Riisom, Sigrid Ninel Kledal, Loa Ludvigsen and Maj Ringgaard

PROGRAM - THURSDAY THE 31ST OF OCTOBER, 2019

8.00 - 9.30	Registration (The National Museum)
9.30 - 9.45	Welcome
9.45 - 10.30	*Key note presentation:* Dr. Alexander D. Ball, Head of Imaging and Analysis at the Natural History Museum: *"Non-destructive Imaging and Analytical Techniques at The Natural History Museum, London"*
10.30 - 12.00	*Presentations: 3D imaging and photogrammetry* Valeria Carrillo: *"Establishing guidelines for 3D digitization of cultural heritage in conservation practice: An approach to digital photogrammetry and structured light scanning."* Susanne Kaun: *"Virtual exhibition of historic interiors: Full-spherical panorama versus photo-grammetry."* Kendra Roth, Jesse Ng & Deepa Paulus: *"To Build a Palace: The Digital Documentation of Louise Nevelson's Mrs. N's Palace."*
12.00 - 13.00	Lunch
13.00 - 14.00	*Presentations: 3D modelling and documentation* Erato Kartaki: *"3D capturing of ceramic and glass artefacts; creating digital 3D models suitable for printing."* Michelle Vergeer: *"Photogrammetry of paintings on a copper support: a tool for documentation, visualization and manufacturing a 3D support."*
14.00 - 14.15	Phaseone presentation
14.15 - 15.00	Coffee break & posters
15.00 - 16.00	*Presentations: 3D modelling and documentation* (continued) Alba Fuentes-Porto and Esteban Amador-García: *"Control methods and packaging optimization of archaeological metals by comparing and editing 3D models. A case study."* David Hauer: *"Assessment of structural response to seasonal climate variations of large, complex archaelogical wooden objects using 3D imaging. An investigation of global hygromechanical behaviour and comparison to wood components of the Oseberg ship."*
16.00 - 17.00	Discussions
19.00	Symposium dinner at *Restaurant Ofelia* at Skuespilhuset (Royal Danish Theatre) Address: Skt. Annæ plads 36 - DK 1250 København K

PROGRAM - FRIDAY THE 1ST OF NOVEMBER, 2019

9.00 - 9.30	Doors open, coffee
9.30 - 10.15	*Key note presentation:* Karin Frei, Research Professor in Archaeometry, The National Museum of Denmark: *"The relevance of merging fields - what archaeometry can't tell."*
10.15 - 11.45	Presentations: Digital Technologies in Heritage Conservation Birgit Vinther Hansen: *"Experience with MFT at the Royal Danish Library; testing of historical and modern materials and challenges."* Julia Owczarska: *"Cross-sections of wallpaper: a comparative look at iron beam sectioning vs Unicryl embedded thick sections."* Ulla Bøgvad Kejser and Birgit Vinther Hansen: *"Spectral imaging of archive and library materials."*
11.45 - 12.45	Lunch
12.45 - 14.15	*Presentations: Digital Technologies in Heritage Conservation* Christine Slottved Kimbriel: *"A miniature landscape: non-invasive technical study of a cabinet miniature by Isaac Oliver."* Josef Uher: *"RToo: The robotic scanner for material resolving X-ray imaging of art."* Jon Yngve Hardeberg: *"Cultural Heritage Analysis for New Generations - CHANGE - a new ITN project"*
14.15 - 14.30	Coffee break
14.30 - 15.30	*Presentations: Digital technologies and other techniques* Poul Erik Lindelof: *"A Neutron imaging studies of swords from the Viking and Roman Iron Ages"* Mona Hess: *"Digital Technologies in Heritage Conservation - integration of optical surveying and measurement methods and sensor technologies into classical heritage conservation and museum documentation."*
15.30 - 16.30	Discussions
16.30 - 16.45	Farewell (Please be aware that the museum closes at 17.00)

Alexander D. Ball

Alex Ball is the Head of the Imaging and Analysis Centre at The Natural History Museum. Alex's PhD at Royal Holloway (University of London) dealt with an early application of computer-aided 3D-reconstruction based on serial-sectioned materials, combined with light microscopy, SEM and TEM.

Alex has over 25 years' expertise in scanning and transmission electron microscopy (SEM, TEM), variable pressure SEM, non-destructive imaging and analysis, micro- CT and light and confocal microscopy. In his time at the Natural History museum he has founded and developed three separate laboratories to provide centralised light microscopy, micro-CT and 3D surface scanning facilities.

Outside of the NHM, Alex is secretary to the Society of Electron Microscope Technology, a member of the Council of the Royal Microscopical Society and a member of the RMS' Electron Microscopy and Education and Outreach Committees.

Karin Margarita Frei

Research Professor of Archaeometry at the National Museum of Denmark sice 2016. Prof. Frei has a M.Sc. in geology/geochemistry from the University of Copenhagen. In her field-based M.Sc. project she analyzed some of the oldest rocks on Earth in Greenland with different isotope methods. She started to work within the field of archaeometry during her Ph.D. studies at the Center of Textile Research (CTR) at University of Copenhagen, in which she further developed isotope techniques to investigate the provenance of raw materials of ancient textiles. In 2011 she was awarded with the international "Best PhD thesis Award in Archaeometry", by the Groupe des Méthodes Pluridisciplinaires Contribuant à l'Archéologie (GMPCA). Shortly after she received the "For Women in Science Fellowship Award 2011", awarded by L'Oréal Denmark, UNESCO and The Royal Danish Academy of Sciences and Letters. Her list of awards continues with several national and international prices, the latest being the 2017 *"Shanghai Archaeological Forum Research Award"*. Prof. Frei is also a lifemember of The Danish Royal Academy of Sciences and Letters.

Her research in the last 10 years has focused on developing and applying isotope techniques to trace human and animal mobility in several parts of the world and covering different prehistoric and historic periods. She has worked with archaeological remains and materials from e.g. Mesolithic in Sweden, from Bronze Age in Denmark, Hungary and Italy, from Viking Age and Middle Ages in Denmark, Island and Greenland, and from pre-Columbian in Peru. Currently she leads two research projects, *"Tales of Bronze Age Women"* and *"Tales of Bronze Age People"* and participates in two others. She has published more than 70 peer reviewed articles in a diversity of journals including *Antiquity*, *World Archaeology*, *The European Journal of Archaeology*, *Journal of Archaeological Science*, *Scientific Reports (Nature Group)*, PNAS and *PlosOne*.

Non-destructive Imaging and Analytical Techniques at The Natural History Museum, London

Alexander D. Ball

Head of Imaging and Analysis
The Natural History Museum
London, United Kingdom

London's Natural History Museum represents the culmination of almost 300 years of collecting, curation, research, exhibition and publication from generations of collectors, curators, researchers and archivists. The collections (around 80 million objects) include specimens from across the natural world, encompassing rocks, minerals, fossils, animals and plants as well as manuscripts, note books, maps, drawings and paintings. These include items of great scientific or historical significance.

Many of the specimens are unique and delicate and the NHM's research laboratories offer a very flexible range of advanced imaging and analytical techniques to address this multiplicity of specimen types. We work closely with our Research and Conservation teams and in investigating samples, interactions between the specimen and the instrumentation may compromise effective future study, so considerable time and energy are invested in trying to understand the nature and consequences of these interactions. For example, the effect of micro-CT examination on the recovery of DNA from modern and historical bones and tissue samples has been tested, methods for the measurement of the contamination rates of samples under examination by SEM-EDX were developed for extra-terrestrial samples. Minimally destructive techniques are sometimes employed for sub-sampling. However, increasingly sensitive analytical techniques mean that we may only need a few micro-grams of sample and can employ micro-drills, or make use of laser-ablation inductively-coupled-mass spectrometry (LA-ICP-MS) for sample analysis. We increasingly use micro-CT to precisely locate the region of interest thus ensuring our sample is representative and targeted, minimising loss of information.

As we develop new ways to acquire 3D data (photogrammetry, laser scanning, focus variation microscopy, micro-CT, confocal microscopy and SEM photogrammetry) the management and delivery of 3D datasets to a variety of different audiences becomes a new challenge to address and the expectations of our different audiences need to be met.

This presentation will consider a range of examples drawn from the Museum's collections and from some of our collaborators to illustrate the different approaches adopted and the role of new developments in instrumentation.

Establishing guidelines for 3D digitization of cultural heritage in conservation practice:
an approach to digital photogrammetry and structured light scanning

Valeria Carrillo

Conservator
Mexico

Keywords:
3D, digitization, digitalization, guidelines, good practice, standards, handbook, digital photogrammetry, structured light scanning, white light scanning, virtual museum

The use of 3D-digitization techniques for the study of cultural heritage in Mexico is an expanding field of study. In recent years, the significant results of its application in conservation projects have effectively proven the advantages of new imaging and analysis technologies for the discipline.

This contribution reports how the digitization of the Museo virtual de Arqueología Subacuática's (Virtual Museum of Maritime Archaeology) collection supported the definition and establishment of new guidelines for a systematic survey of cultural objects using 3D-digitization techniques. Certainly, in the midst of a national context where applications had been creative but not methodical, proposing a document that conducts structured-light scanning and photogrammetric approaches was imperative.

A historiographical review of the origins of digitization technologies and their use in this area of knowledge was followed by a technical analysis that covered, among other aspects, their performance, required equipment and software, basic workflow, and obtainable products. This assisted the identification of clear statements regarding how their use can benefit Conservation. Later, the artifacts digitization and further analysis of resulting 3D-models allowed pondering important factors concerning 3D-data acquisition and its processing procedures.

Nevertheless, the study not only investigates and discloses the shortcomings or drawbacks of current practice, it suggests a way to improve it. Research findings were incorporated into a handbook titled: *The 3D-digitalization of cultural heritage: a guide for good practice*. The aforementioned model raises guidelines for a systematic registration of cultural heritage using 3D-digitization techniques; it helps users choose the most suitable approach for a specific study case and assists the reader while planning an appropriate workflow and carrying out the survey correctly.

Thus, *"3D digitization of cultural heritage: a guide to good practice"* has profound implications for the consolidation of 3D-digitization as a preservation method. More importantly, it can be considered a call-to-action towards conservation professionals in Mexico to explore the potential of these technologies and expand the depth to which cultural objects are documented, conserved and researched in the country.

Although this study deals with a specific case directed towards the dissemination of a particular body of artifacts, the most valuable concepts were carefully abstracted taking into account that they would later be presented in a straightforward manner for its generalization into wider scenarios with diverse objectives. Given its methodological value and practical applications, this accomplishment is not only beneficial for Conservation, but also other related disciplines; such initiative could serve cultural institutions around the world with similar unsolved dilemmas.

Undoubtedly, these results present a method for the establishment of guidelines for 3D-digitization of cultural heritage in Mexico. Furthermore, findings constitute advancement in adjusting Conservation practice (and the study of cultural heritage in general) to the new demands of the digital world that contains it.

Virtual exhibition of historic interiors: Full-spherical panorama versus photogrammetry

Susanne Kaun

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The Norwegian Institute for Cultural Heritage Research
Oslo, Norway

Keywords:
3D-scanning, image-based-modelling, presentation, museum, exposition, digital

Not all historic interiors are accessible to anyone. It may be private homes, vulnerable interiors or simply because the building is on the other side of the globe. Some interiors are also difficult to experience alone without several tourist groups or without disturbing furniture. There are many reasons why a virtual presentation of an historical interior is desirable. New digital photo techniques provide the experience of the third dimension, which is especially interesting for interiors, where traditional photography is limited to convey a room feeling.

Two types of digital photo techniques stand out to transport a three-dimensional experience of an interior: a full-spherical panorama and a 3D model made with photogrammetry (image-based modeling). The photos for the case studies were taken by a full format digital camera. The 3D-modell was generated with the software *Agisoft*, and for panorama stitching the software *PTgui* was used.

The lecture will compare the above-mentioned photo techniques for the purpose of conveying virtual a historical interior. Both methods vil be presented from both a technical and practical perspective, as well as challenges related to diverse materials and recording situations will be shown. Comparative criteria will be the quality of the result, presentation options, challenges during recording and modelling, time spent on generating the final model and costs for equipment and software. Finally, recommendations are given on how to increase the quality of the final model in both methods.

To Build a Palace: The Digital documentation of Louise Nevelson's *Mrs. N's Palace*

Scott Geffert[1], Kendra Roth[2], Jesse Ng[3], Deepa Paulus[3] & Wilson Santiago[4]

[1]Metropolitan Museum of Art's Advanced Imaging team, [2]Sculpture Conservator of Modern and Contemporary Art, [3]Production Assistant with the Imaging Department, [4] Imaging Production Manager
The Metropolitan Museum of Art, New York, USA

Keywords:
Louise Nevelson, Mrs. N's Palace, 3D scanning, Artec Eva, photogrammetry, Faro Focus Lidar, digital documentation

Mrs. N's Palace is arguably the most ambitious single work ever built by Louise Nevelson. It is a free-standing structure that she built over the course of 13 years (1964-1977). It is comprised of more than 200 different components, most of which are wood painted a matte black. The Met received the work as a gift from the artist in 1985, when it was briefly on view and then relegated to storage where it languished for the next 20 years. A request for loan as part of an artist's retrospective in 2006 brought it out of storage. Having had limited public exposure, there was very little known about how the work was to be assembled – documentation consisted of a few photographs and a sketched plan provided by the gallery. An ambitious undertaking was made at that time to determine how it was to be assembled and ultimately restored.

Following the exhibition, the sculpture, now housed in 33 crates, was again shipped offsite until a request late last year for it to go on permanent view in the Met's collection. This prompted a new review of the existing documentation and feasibility for display.

New tools and technology offered possibilities for a more thorough documentation of the entire work in order to produce a comprehensive guide for assembly. By partnering with the museum's Imaging Department, a plan was devised for organizing the components and creating digital documentation through the use of the latest technology in 3D scanning. The flat wooden surfaces, the wide variety of attached contoured shapes and elements, and the uniform matte black paint presented very specific challenges for 3D scanning technologies. The Imaging Department researched and tested various scanners and photogrammetry techniques to find those best suited for such a complex undertaking. The Advanced Imaging team eventually arrived at the Artec Eva scanner. This structured light scanner proved appropriate for the size of the components to be scanned, and had the capability of capturing both the geometry and texture of the sculptural elements. It also had the capture speed required for scanning in the galleries as the work was being assembled and to meet the tight exhibition deadline. The imaging team was comprised of three photographers that scanned the artwork and two production assistants that operated the 3D software on the computer connected to the scanner -all working on rotation so scanning could be completed within the three-week installation window. In addition to structured light scanning, a Faro Focus Lidar scanner was used to capture the dimensions and form of the preliminary structure and its surroundings before installation. Photogrammetry was used to make an overall model of Mrs. N's Palace.

This data will become a rough 3D blueprint that will aid in the final virtual reconstruction. Post production is currently underway and preliminary designs are being developed for the ultimate assembly guide.

This presentation aims to put this sculpture in context and describe the processes and techniques used to document it.

3D capturing of ceramic and glass artefacts; creating digital 3D models suitable for printing

Erato Kartaki

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Kings College, London

Keywords:
3D capturing, 3D modelling, ceramic, glass, artefacts, restoration, photogrammetry

Nowadays, applications of 3D capturing archaeological artefacts have been used in conservation for the creation of condition reports, as examination tools, for restoration scenarios and for creating replicas of the objects with the use of additive manufacturing (3D printing). Photogrammetry and 3D laser scanning are considered the most accurate methods for creating 3D models of the upper surface of artefacts. For further investigation of the internal part of an artefact in 3D format, computed tomography is recommended.

This paper presents the process of 3D capturing ceramic and glass artefacts from the British Museum, as part of research regarding the additive manufacturing (3D printing) technology and its use for the restoration of ceramic and glass artefacts. The digital 3D models created are digitally restored, according to conservation ethics and the guidance of the Museum's curators, in order to be used for the physical restoration of the artefacts, with the application of additive manufacturing technology.

To accomplish this aim of the study the photogrammetry method has been applied on ceramic and glass artefacts from the Greek-Roman, Chinese and Islamic collection of the British Museum. These objects were considered suitable for this study due to their different shape, manufacturing technology, materials and variety in shape of missing parts.

Photogrammetry of paintings on a copper support: a tool for documentation, visualization and manufacturing a 3D support

Michelle Vergeer & Anne Haack Christensen

Conservator
Statens Museum for Kunst (SMK)
Copenhagen

Keywords:
3D, photography, photogrammetry, copper painting, documentation, visualization, 3D support, Brueghel, framing, preventive conservation, CNC technology

This research focuses on the use of photogrammetry to solve the challenges of the framing of copper paintings that have bent and warped. Two seventeenth-century paintings from the collection of the Statens Museum for Kunst attributed to the workshop of Brueghel served as case studies. During conservation treatment it became apparent that the curvature of the copper plates would make framing problematic. The use of a traditional framing system where pressure is applied to align the copper support with the frame rebate, could cause further warping, eventually leading to additional damage in the vulnerable 400- year-old paint layers.

To safely frame the paintings a perfect fitting 3D support needed to be manufactured, which required the curvature of the paintings to be 3D scanned. The 3D support should follow the exact curves of the copper plate and divide the framing pressure evenly across the surface. The support also had to meet conservation requirements and be manufactured from a stable, flexible and inert material.

Photogrammetry was selected to create a visualization of the curvature of the paintings. To produce a dataset for a high quality 3D reconstruction hundreds of photographs are required from each visible feature from at least three different camera angles. Afterwards, photogrammetry software detects the identical features visible on several photographs. This results in a point cloud; a cluster of sometimes millions of points representing the geometry of the scanned object. The point cloud is converted into a polygonal mesh, which can be manipulated to create the 3D visualization. The data was also converted to a set of coordinates used to program the machine producing the foam support. With the help of CNC technology a piece of foam will be cut as a tray that follows the exact curvature of the bent copper plate. The manufactured 3D support will serve as a tray inserted in the frame, but it can also be used to safely transport and store the painting in the conservation studios.

The dataset applied to create the geometry of the 3D model can also be used to generate surface texture maps with a photorealistic appearance. A 360-degree view of the object is available online for zooming in on details and exploring the backside of the painting. This visualization adds a whole new dimension to the experience of the art work.

Preliminary results of this ongoing study show the potential of photogrammetry as an imaging technique in conservation and preservation of cultural heritage. While research has already established this technique to be successful in documenting and monitoring the condition of museum objects, this study shows an additional potential within preventive conservation and the developing of safer framing systems.

Control methods and packaging optimization of archaeological metals by comparing and editing 3D models. A case study

Alba Fuentes-Porto[1,2] and Esteban Amador-García[1,3]

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Keywords:
Archaeological metals, Preventive conservation, 3D recording,Packing, Point cloud analysis

The use of geomatic techniques in the documentation of Cultural Heritage has been translates into the appearance of multiple resources focused on its preservation, dissemination and valorization. Within this context of technological innovation, we propose a line of research focused on testing the use of 3D records in the optimization of control and transportation systems of metal archaeological pieces.

The temporary transfer of an iron sixteenth century helmet, an archaeological piece associated with the conquest of the Canary Islands period and safeguarded in the Museo Histórico Militar de Canarias (Military Historical Museum of the Canary Islands), has served as an excuse for the application of 3D documentation techniques conceived as inspection tools. The goal, enabling to detect possible structural changes during its loan. In addition, the combination of these models with the use of new digital manufacturing technologies has made possible the elaboration of a personalized plinth. This design ensures the support and integral damping of the piece by adapting perfectly to its obverse side, affected by accused processes of corrosion and mineralization.

The applied methodology consisted in the 3D digitalization before and after the removal through a structured-light scanner. This model has been complemented by a close-range photogrammetric study in order to obtain a greater precision in the documentation of chromatic qualities.

Also, these 3D models allowed us to protect the physical structure of the archaeological piece by designing a support on which it could rest completely. To do this, its back-side mesh was extruded with a modeling software and then sectioned in parallel layers. Finally, this design was transferred to an acid-free polyethylene foam with good vibration and shock dispersion properties.

Finally, geometric differences between the meshes captured before and after the temporal loan were analyzed with an open source computer tool for the management and comparison of three-dimensional point clouds and polygonal meshes. Based on the Chamfer matching algorithm, this software quantifies the distance between the points of two meshes and projects them on a map that shows all the changes undergone by using a chromatic gradation.

Assessment of structural response to seasonal climate variations of large, complex archaeological wooden objects using 3D imaging

An investigation of global hygromechanical behaviour and comparison to wood components of the Oseberg ship.

David Hauer[1], Paolo Dionisi-Vici[2], Susan Braovac[1], Geir I. Vestøl[3], Kristofer Gamstedt[4]

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Keywords:
wooden structures, climate responce, 3D imaging, photogrammetry, deformation monitoring

Extensive research has been undertaken on the effects of fluctuating climate on historical and archaeological wood. Nevertheless, most of this work covers prepared wood samples, wood powder, single wooden components, or structurally relatively simple objects like frames and panels. Research on hygromechanical behaviour on large, complex wooden objects at a global, or overarching level, is very limited. The Viking Ship Museum, part of the Museum of Cultural History, University of Oslo, houses one of the most comprehensive collections of wooden Viking age objects to date. Most of the objects are in display cases with a controlled climate. However, two virtually complete Viking ships, the Oseberg and Gokstad ships, are exhibited on open display and exposed to the climate variations within the building envelope. The climate is uncontrolled in the summer season and limited to moderate use of radiators in the winter season.

The objective of this paper is to investigate the correlations between global structural change of the Oseberg ship and climate fluctuations in the room. The data on global structural change is retrieved by repeated 3D measurements every fourth week with fixed point photogrammetry. These data will be correlated to climate monitoring, and strain on component level utilizing displacement sensors on samples of recent and archaeological oak, and directly on two strakes in the ship.

The hygroscopic and orthotropic nature of wood causes changes in material geometry when it is exposed to moisture sorption. The response ratio deviates in the three primary and mutually perpendicular directions - the longitudinal, radial and tangential directions. The primary elements of moisture induced deformation are found at the cellular and subcellular levels in wood. However, moving up from the subcellular level of wood to the global level of a wooden structure, the response to climate fluctuations can be more complicated to predict. At the global level added factors of complexity comes into play such as joined wood components of different grain directions, heterogeneous deterioration states of the material, fractures, varying capacities of mechanical joints and the use of recent wood as restoration material – all factors commonly found on large archaeological wooden objects, which add to their complex hygromechanical behaviour. Furthermore, large load-carrying structures are vulnerable to mechanosorptive creep, and global structural movements can cause tension build-up in local strain fields leading to material fracture.

Linking global periodic sub-millimetre monitoring of the ship structure to environmental factors (relative humidity and temperature), is a new general approach to understand the structural behaviour of large, complex archaeological wooden objects. This will increase understanding of material characteristics, structural behaviour related to climate fluctuations and deformation trends. In turn, the acquisition of global monitoring data can help optimize climate set points, evaluate allowable mechanical loads and improve the geometric design of support systems. This will contribute to more accurate risk assessment and informed long-term preservation strategies.

The relevance of merging fields - what archaeometry can't tell

Karin Margarita Frei

Research Professor in Archaeometry
National Museum of Denmark
Copenhagen, Denmark

Archaeology and natural sciences have a long history of working together. Yet, within the last decades a cascade of new and improved scientific methodologies has somewhat transformed current archaeological practice. The accelerated rate at which the field of archaeological science/archaeometry has developed during the last years, has led to many new cross-disciplinary studies.

Also in archaeological conferences there is a noticeable increase in the number of sessions that either focus on - or include, some form of archaeological science/archaeometry topics. The exponential growth of data stemming from the analyses conducted on a large pallet of archaeological and environmental materials is, however, not always easy to understand. Therefore, several scholars have pointed out that there is a need for establishing more integrated forms of collaborations between archaeologists and the natural scientists.

I personally agree with this point of view, though, how to move from a multi- or cross disciplinary type of practice to a more transdisciplinary approach seems to be a very challenging undertake. An undertake which is made continuously more difficult as more and more methodologies are being used. In this presentation I will reflect upon and discuss this issue, and offer some thoughts based mostly on own experience. What is lacking? What is needed? What can we as archaeometrists/archaeological scientists do to address the issues and concerns raised by archaeologists? Is it enough to find a common language, or are the research questions we pose the key to reach a higher level of mutual integration between the natural sciences and archaeology?

Experience with MFT at the Royal Danish Library
testing of historical and modern materials - and challenges

Birgit Vinther Hansen

Conservator
The Royal Danish Library
Copenhagen, Denmark

Keywords:
Light sensitivity, microfading (MFT), exposure policy, iron gall ink

The Royal Danish Library holds extensive collections of manuscripts from the Early Middle Ages until the latest time in the form of illuminated manuscripts, letters, diaries, sketches as well as maps, photographs and printed books. These items are made of a myriad of different inks and colours, which, for a large part, is still in a pristine condition.

Since the Black Diamond, with its huge inlet of daylight, was built in 1999, the conservators have had special focus on light sensitivity and exposure as exhibitions also were installed outside the controlled exhibition areas. The light challenge emphasised the need for decisions made on analysis rather than an interpretation of published data for groups of materials translated into real objects of high importance. Equal looking colours may have different chemical composition and alike objects may have a different history of exposure making the sensitivity very different.

The library invested in the analytical technique Micro-fading Tester (MFT), a Whitmore type with a Xenon lamp, in 2015, and since then it has routinely been in use. Prior to accepting objects for exhibition, all colours on each object are analysed by MFT whenever the sensitivity to light is unclear. Knowing the light sensitivity, we can pay special attention to very light-sensitive inks and colours. The vast majority of objects, in turn, can be exposed at a higher light level because they prove to be quite stable. With MFT, in combination with our defined light exposure policy accepting 1 Just Noticeable Fade (JNF) over 25 years, we can preserve the colours for a longer time and save resources.

Through MFT, we have discovered that some items are extremely sensitive to light and much more sensitive than the Blue wool (BW) category 1. Therefore, we have defined light sensitivity categories even below BW1. Especially modern inks have proven to be extremely light sensitive and may irreversibly fade away. Since the collections hold a massive number of manuscripts written in modern inks, this is a recurrent challenge. Iron gall inks are another challenge since we are uncertain how to predict their fading in light as the inks regain most of the colour loss when exposure ends. A new research project to start in 2020 will look closer into this issue.

With the recent exhibition of our finest treasures, as an example with many surprising results, MFT and its applicability for the analysis of sensitivity and identification of pigments at the Royal Danish Library will be presented. Also, challenges using MFT, being a technique developed within the cultural heritage, which does not have an established support, and the interpretation of MFT results into a light policy, will be addressed.

Cross-sections of wallpaper: a comparative look at ion beam sectioning vs Unicryl embedded thick sections.

Julia Owczarska

Conservator in training (postmaster)
Conservation and Restoration of Cultural Heritage
University of Amsterdam, the Netherlands

Keywords:
paper cross-section, ion-milling, focused ion beam, cross-section topography, Unicryl, sample embedding, scanning electron microscopy, light microscopy.

Cross-sectioning of samples is an investigative technique for the study of layer structures found in historical artefacts. This technique has a long history of use with a variety of materials and in many cases cross-sectioning of samples is an established step in object examination. However, this practice has not taken as firm of a hold in the field of paper conservation. Cross-sections of paper sparsely appear in publications and there are no paper-specific published guidelines to aid the sampling and preparation process.

This research introduces a new cross-sectioning technique of ion-milling to the field of paper conservation, a method that is frequently used by the paper industry but which has not been previously explored in the context of historical papers. The resulting sections are compared to samples prepared using a conventional resin embedding method, but using a new resin Unicryl, which is well suited for electron microscopy imaging. Light Microscopy and Scanning Electron Microscopy photomicrograph analyses form the basis for the comparative analysis.

Ion-milling of samples into cross-sections is a system where a focused ion beam is used to ablate materials. The beam causes the sputtering of surface material in a level and uniform way, thereby permitting the cross-sectioning of materials which are vulnerable to mechanical abrasions necessary in traditional cross-sectioning methods. As a porous and soft material, it was suspected that paper would be very vulnerable to forces exerted during conventional mechanical cross-section preparation methods, therefore making the ion-milling process appear very advantageous. It was hypothesized that the resulting cross-sections would have a perfectly preserved layer structure, which would allow an accurate side view at the 'true' undisturbed paper structure, something that a embedded sample would never be able to show due to resin infiltration. The research evaluated the effectiveness of the ion-milling method and assessed its potential for the analytical study of historical papers.

This article aims to show the advantages and drawbacks of ion-milling but also to establish paper as a three-dimensional material benefitting of cross-section analysis. The discussion focuses on the preparation methods and quality of the cross-sections rather than on object analysis. Samples of wallpaper were selected in order to present an example of what a multi-layered cross-section of a paper artefact might look.

This research was carried out as a part of a master's thesis at the University of Amsterdam and in collaboration with the Dutch Cultural Heritage Agency.

Spectral imaging of archive and library materials

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Keywords:
spectral imaging, non-destructive, cultural heritage, preservation, digitization, large datasets, workflow management

Researchers and other users of archive and library materials may come across works where the text or images they want to study are difficult to read or even completely obscured. The reason for this may be that the physical material constituting the work has degraded. For example, over time inks may fade or they may deteriorate the paper so that it darkens and, in both cases, this decreases the contrast between the ink and the paper making reading, at best, slow and, at worst, impossible.

Works may also contain hidden information because the author, authorities, or others have deliberately wanted to edit the content. For example, an author may have made over scores or added overlays in a text, or completely removed information. In order to support reading of such hidden information, the Royal Danish Library established a new studio for spectral imaging in 2018. Besides the studies related to recovery of hidden information, the library is currently looking into the use of spectral imaging for studying watermarks in paper and for the identification of pigments used in manuscripts and other works of art.

In short, spectral imaging is a non-destructive, photographic recording technique that combines digitization with spectroscopy. In addition to ordinary digitization, which uses visible light to capture the work, a spectral imaging system can record image data at several different frequencies across the electromagnetic spectrum – from ultraviolet (UV) across the visual spectrum, and into the infrared (IR) radiation. This method exploits the fact that different properties of the imaged materials reflect the radiation differently. By processing and combining the image data from different spectra using special image processing techniques, it is possible to increase the visibility of the digitized information. This method also has the potential to identify historic pigments by analyzing the different reflectance properties.

This paper will discuss selection of file and metadata formats, system calibration, and quality control, as well as the development of a new workflow, which must also take into account the extremely poor physical condition of some of the materials. Spectral imaging produces relatively large datasets, including technical metadata that cannot be handled by the library's ordinary imaging workflows. Thus, processing, preserving, and providing access to the datasets represent new challenges that the Royal Danish Library has to solve. Also, the challenges and opportunities encountered in establishing effective communication channels between potential users of spectral data, the collections' owners, and the spectral imaging staff is discussed.

A miniature landscape: non-invasive technical study of a cabinet miniature by Isaac Oliver

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Keywords:
non-invasive analyses; FT-IR spectroscopy; Isaac Oliver, cabinet miniatures; copper sulphates

This paper will describe the results of an extensive non-invasive analytical campaign carried out on *A party in the open air*. Allegory on conjugal Love, a small but incredibly detailed cabinet miniature painted by Isaac Oliver (c.1565-1617) at the end of the 16th century. Currently in the collection of the Statens Museum for Kunst (SMK, the National Gallery of Denmark), the miniature was analysed in 2018 through a collaboration between the Fitzwilliam Museum and Hamilton Kerr Institute in Cambridge (UK), and the Centre for Art Technological Studies and Conservation (CATS) in Copenhagen. Such research is part of a project focusing on technical analysis of Isaac Oliver's oeuvre. A highly accomplished draughtsman and miniaturist, Oliver is an enigmatic and versatile artist who did not leave any written documentation about his life or artistic practice. Often introduced as Nicholas Hilliard's most famous pupil, Oliver was already highly skilled in his own right, and arguably more talented than his teacher. The rigorous, non-invasive technical protocol employed during the project will be briefly presented and explained, highlighting its significant potential as well as its reliance on a broad set of specialist skills, which can only be found in cross-disciplinary research teams. The paper will then focus on the results obtained on the SMK miniature by means of a range of imaging and spectroscopic methods, including UV, IR and X-ray imaging, optical microscopy, X-ray Fluorescence (XRF) spectroscopy, Fourier transform infrared (FT-IR) spectroscopy, Raman spectroscopy and reflectance spectroscopy in the UV-vis-NIR range (FORS). The broad range of technical means used to execute a very diverse and elaborate subject matter, including underdrawing in different media as well as skilful modelling of fabrics with multiple layers of metallic paint and organic glazes, will also be described. Finally, a specific mention will be made of the pigments used to paint the natural and architectural landscape passages, which suggest close links between this work of a French-born, English-based artist with contemporary artistic practice in Flanders and neighbouring regions.

The paper will conclude by highlighting the potential of FT-IR spectroscopy carried out in external reflection, for the identification of binding media, which is still the most challenging aspect of non-invasive analysis of delicate artworks such as miniatures.

Cultural Heritage Analysis for New Generations *CHANGE* - a new ITN project

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Keywords:
multispectral imaging, hyperspectral imaging, 3d imaging, conservation science

Cultural heritage (CH) objects have been constantly undergoing changes/degradations over time. In order to pass the legacy of these objects to future generations, it is important to monitor, estimate and understand these changes as accurately as possible. Such investigations will support the conservators to plan necessary treatments in advance or to slow down the specific deterioration processes. The dynamic characteristics of materials vary from one object to another and are influenced by several factors. To detect and predict their changes, accurate documentation and analysis tools and methodologies are necessary.

Over the years, CH digitization using scientific imaging techniques has become more widespread and has created a massive amount of datasets of different forms in 2D and 3D. Several past projects focused on different aspects of technological developments for better digitization methods. There has been less focus on the processing and analysis of these datasets to make the greatest use of them and to their further exploration for monitoring changes in CH artefacts for conservation purposes. The lack of adequate digital tools for monitoring these changes is related to material behavior and stability, which still need to be addressed.

In this context, we have received funding through the Marie Sklodowska-Curie Actions in Horizon 2020 new Innovative Training Network (ITN) project entitled "Cultural Heritage Analysis for New Generations – CHANGE." The project is co-ordinated at the Norwegian Colour and Visual Computing Laboratory (Colourlab) at NTNU – Norwegian University of Science and Technology, involves a total of 19 partner institutions throughout Europe, and will employ 15 Early Stage Researchers (ESR) / PhD students who will work on individual research projects supervised by experts from multiple disciplines and sectors, and also benefit from an extensive network-wide training programme. See http://www.change-itn.eu for more information.

The CHANGE project will take cultural heritage digitization to a new level by exploring digital datasets for deeper analysis and interpretation. The main idea is to develop methodologies for the assessment of changes in CH objects by comparing and combining digital datasets captured at different time periods. The validity of the methods has to be evaluated through case studies conducted in collaboration with CH experts and stakeholders. The project uses an interdisciplinary approach combining expertise on imaging techniques, computing, CH, and conservation science.

In this presentation I will give an overview of the project at its current early state, share some experiences and advice about ITN funding, and also provide some context including related CH imaging research at the NTNU Colourlab.

Biography: Jon Y. Hardeberg received his sivilingeniør (MSc) degree in signal processing from the Norwegian Institute of Technology in Trondheim, Norway in 1995, and his PhD from Ecole Nationale Supérieure des Télécommunications in Paris, France in 1999. He is now Professor of Colour Imaging at NTNU, Department of Computer Science, The Norwegian Colour and Visual Computing Laboratory, Gjøvik, Norway. His current research interests include spectral imaging, image quality, colour management, material appearance, cultural heritage imaging, and medical imaging, and he has co-authored more than 300 publications within the field. He has led several research projects funded by the Research Council of Norway, been NTNU's representative in two Erasmus Mundus Joint Master Degrees (CIMET and COSI), and the coordinator of three Marie Curie ITN projects (CP7.0, ApPEARS, CHANGE).

RToo: the robotic scanner for material resolving X-ray imaging of art

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Keywords:
x-ray analysis, new imaging technology, 3D scanning of art, robotic scanner for art inspection, material resolving x-ray imaging of art, colour x-ray images

X-ray imaging is a well-established tool within the portfolio of art non-destructive inspection methods. A new generation of hyperspectral photon counting X-ray imaging detectors combined with robotics pushes the image quality way beyond the current technologies.

The new X-ray imaging detectors have array of "clever" pixels. Each pixel contains electronics capable of processing every detected photon measuring its wavelength. Therefore, it acquires "color" X-ray images where colors are associated with different materials identified in the image. All at spatial resolution of less than 55 μm.

The modern cutting-edge X-ray imaging detectors therefore enable new methods such as X-ray spectral imaging (XRSI), material resolved X-ray imaging and X-ray "color" imaging (XRCI). The technology extends the portfolio of physics methods used in art inspection.

A comparison of scans taken with the new imaging technology and common X-ray imaging devices such as imaging plates and flat panels will be shown.

Compact size of the new detectors furthermore allows attaching a detector and X-ray tube on a pair of robotic arms. This opens a wide range of new possibilities in addition to the regular X-ray imaging. The robots allow easy scanning of other art pieces such as sculptures, furniture etc.
An overview of further ongoing research and development of the system will be given as well. The long-term goal is to create a tool that integrates several imaging modalities together. The imaging modules currently under development are macro-photography and X-ray diffraction. Later will follow also XRF and even air-coupled ultrasound which is an interesting new technique for art analysis.

An overview of the technology possibilities will be given together with examples of measured samples.

Neutron imaging studies of swords from the Viking and Roman Iron Ages

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Keywords:
Archaeometallurgy, 3D Neutron-imaging, neutron-scattering, non-invasive technique, Roman swords, Viking swords, structure analysis

The technological development of iron artefacts has played an important role from the beginning of the Iron Age. The most advanced progress has been in the weapons industry and nowhere more so than in the fabrication of swords. For swords fabricated in the Roman Iron Age and later, the socalled pattern-welded technique has been crucial. By this technique several parallel pieces of iron alloyed with different concentration of phosphor or carbon were welded together to form strong swords. The pattern-welded structure has the extra benefit of giving a decorative surface of the sword blades. 3-dimensional neutron imaging and microstructural characterization today allow studies of the inside composition of swords non-invasively. This opens up studies of even the most valuable swords exhibited at museums. Three Viking Age swords from the National Museum of Denmark found in Danish waters have been studied by neutron scattering at the neutron source FRM II (Antares) at MLZ, München. We have been able to image the precise layer structure of the swords as well as their crystalline structure and materials composition. In upcoming experiments we are going to study swords from the Roman Iron Age found in Illerup Ådal (Denmark). We will in particular do neutron scattering on a type of swords with the iron strips welded perpendicular to their length direction. This type of swords has not earlier been studied in any detail.

Digital Technologies in Heritage Conservation
-integration of optical surveying and measurement methods and sensor technologies into classical heritage conservation and museum documentation

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Keywords:
digital technologies in heritage conservation, digital documentation, 3D imaging, 3D laser scanning, photogrammetry, knowledge transfer, museum

Today, innovative digitisation techniques are adopted in the fields of heritage conservation and monument preservation, museum studies and the protection of cultural assets. The digital recording of buildings and objects is now as much a part of the preservation of historical monuments as the permanent monitoring of the condition of a building or artefact with intelligent sensor systems.

In this ongoing development, the new field of "Digital Heritage" or Digital Technologies in Heritage Conservation the underlying principles of 2D and 3D optical measurement methodologies and technologies need to be understood by heritage and museum stakeholders, as well as the state-of-the art developments in the field of heritage, its management and in cultural institutions. Methodologies for imaging include active methods - for example 3D terrestrial laser scanning for buildings, and 3D lasers scanning or structured light scanning for objects, i.e. close range scanning - as well as passive methods - photogrammetry and structure from motion, RTI as 2.5D, and 2D by multispectral - or multiple methods in combination depending on the task and object. The aim is the digital synthesis of all data relevant to the object. All data should be carefully recorded, including metadata, to form the basis for metric and scientific evidence that can be retrievable and reproducible.

The digital data could be used for the following scenarios: answer a conservation by visual analysis, question like alternatives for reconstruction virtually, dimensional monitoring of an object, contribution to condition assessment and documentation, comparison of similar types of objects, use for public engagement and interactive exhibitions. This presentation will give a short overview about the current state-of-the art digitisation technologies and examples for use for heritage conservation and museum documentation. It is important to understand to what extent guidelines and physical basics from surveying and measurement methods from engineering must be used, in order to produce high-quality outcomes and fit-for-purpose data in order to enable later use for comparison (monitoring) and proper digital preservation, i.e. long-term storage of data. Furthermore, it is important for heritage specialists to be able to define specifications for the intended outcome, and be in a dialogue with the recording engineer. Even better would be, ir the museum or heritage specialists would acquire these skills through Continued Professional Development or a degree and form an in-house capacity in these methodologies. It is still an ongoing question how these methodologies could be integrated into classical activities in a heritage or museum environment.

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