Updates in Paintings Conservation & Documentation: New Developments in Databases, Documentation and the Technical Imaging of Paintings

Proceedings of the ICOM-CC Documentation & Paintings Working Groups Joint Interim Meeting, 21st September 2013 at the RKD, The Hague
Introduction

by Ruven Pillay & Tiarna Doherty, ICOM-CC Coordinators for the Documentation & Paintings Working Groups

Dear members,

ICOM-CC is an international organization that gathers for Triennial Conferences. The 4-5 day Triennial Conferences are an opportunity to meet with colleagues and hear presentations by leading figures in our field. The papers presented are submitted long in advance of the conference so that pre-print volumes are available to attendees. In the interim periods the individual working group Coordinators and Assistant Coordinators work with the membership to produce newsletters and organize smaller meetings that will serve to share information and enrich our field.

In 2009, the ICOM-CC Paintings Working Group organized a one-day meeting on Conservation documentation: on-going projects and perspectives at the Wallace Collection in London. The meeting was designed to present current research in the field through presentations and panel discussions. Speakers were not asked to produce papers as the purpose of the meeting was to present work in progress. Following the success of this meeting, the Paintings Working Group and Documentation Working Group decided to collaborate on another interim meeting with a similar theme. Updates in Paintings Conservation Documentation was a one-day meeting held at the Rijksbureau voor Kunsthistorische Documentatie (RKD), in the Hague on Saturday, 21st September 2013. The RKD was an appropriate venue for such a meeting since it is the pre-eminent repository for documentation in the field of art history and now conservation in the Netherlands. The RKD staff were gracious hosts and we look forward to future collaborations with their organization.

The quality of the presentations at our meeting was very high and it was decided that in order to reach a wider audience we would ask the authors to contribute extended abstracts to this publication. We are extremely grateful to our colleagues and collaborators who have made this publication possible.

Organizing Committee: Tiarna Doherty, Ruven Pillay, Petria Noble, Andrea Sartorius, Wietske Donkersloot

Proceedings Edited by: Ruven Pillay & Andrea Sartorius
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Documentation at the RKD & On the Internet

by Wietske Donkersloot, Coordinator of Technical Documentation Department and Michiel Franken, Curator of Technical Documentation and Rembrandt & Rembrandt School, RKD

The RKD (Netherlands Institute for Art History) is one of the most important art-historical information centres in the world, administering a unique collection of documentary, library and archive material on Western art from the late Middle Ages to the present. Documentation about Dutch art forms is the nucleus of the collections. The RKD has an active collecting policy covering all types of documentation on painting, drawing and sculpture as well as monumental art, media art, and design.

The RKD has a lot to offer to conservators and to all people working or interested in the field of technical examination and conservation of works of art. On the one hand, conservators and researchers can have their information and documentation archived at the RKD and made accessible to the wider scholarly community. On the other hand, the RKD offers facilities to study information and documentation from colleagues working in the same field, now and in the past.

Archiving technical documentation at the RKD

The RKD started to build a collection of technical and conservation documentation in the beginning of the 1990s. The nucleus of the collection was formed by the large archives of Prof. J.R.J. van Asperen de Boer and Prof. Molly Faries, both pioneers in infrared reflectography (IRR). Following their example, several institutions, researchers and some multi-institutional projects have placed their material at the RKD to make it accessible to others. The RKD for instance holds the archives of various Dutch conservators and conservation studios, the archives of the Rembrandt Research Project and the Oranjezaal project and miscellaneous documentation from museums in Europe and the US.

At the moment, the RKD collaborates with Prof. Peter Klein to make the reports of his dendrochronology research accessible. Also, the RKD investigates the possibilities for making the “source material” (X-rays) and outcomes of the Thread Count Automation Project of Prof. Rick Johnson, Prof. Don Johnson and Dr. Rob Erdmann accessible on the long term. Furthermore, the RKD is coordinator of the Rembrandt Database project which aims at bringing together information and (technical) documentation on Rembrandt paintings from multiple institutions around the world at http://www.rembrandtdatabase.org.

The RKD carries out IRR research for museums and other institutions as well as private individuals and to support in-house projects. The RKD has IRR-equipment and - expertise and can examine paintings on request. The results are added to the collection of technical documentation.

The RKD welcomes deposits of documentation on conservation and technical examination of Dutch art from the late Middle Ages to the present, and related works of art from other schools. The documentation may cover any type of research technique and any type of document (written documents as well as images of any kind - digital or analogue).
The RKD also welcomes copies of digital material that is being kept elsewhere, or metadata on documents that are kept somewhere else, in order to make this documentation more known. Together with a depositor, the RKD looks for possibilities to carry out and finance the activities connected with the deposit.

Studying technical documentation at the RKD

The purpose of archiving technical documentation at the RKD is to better disclose the results of technical research for everyone professionally interested in the material aspects of paintings and the history of art production. For this purpose, the RKD has developed the database RKDtechnical. This database identifies the types of documentation, the researchers and conservators involved and the creation date, as well as the necessary administrative data (the archive a document is part of, the location where it is kept, etc.) and more contextual and descriptive metadata on the documents (whether they have been made in the framework of a specific research or conservation project, what part of a painting is presented in an image, a short description of the contents of a written document, etc.). At the moment, this database can only be consulted within the RKD - or selections of records can be sent via e-mail upon request.

In the next months, a selection of data from RKDtechnical will be made available online through the new user interface for all RKD databases, called RKD Explore. This interface, which can be accessed from www.rkd.nl, has recently been launched as a beta. It is our objective for the near future to provide more detailed metadata on the web and eventually, the possibility to study documents online. The functionalities offered would be comparable to those of the already existing Rembrandt Database website, which allows users to study high resolution images, read text files and - eventually - search for specific types of documents.

Until this is the case, the technical documentation can be consulted at the RKD by appointment, but under certain circumstances and for a fee it is also possible to order digital material for study at home or for publication. Inventories of certain parts of the collection are currently being made, which means that not all material is accessible yet.

For more information:
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Reexamination and documentation of existing paint cross-sections for The Rembrandt Database

by Annelies van Loon, Paintings Research Scientist, Royal Picture Gallery, The Hague

Dissemination of the paint samples

The Rembrandt Database is an online research resource for art-technical and conservation documentation related to Rembrandt’s paintings worldwide (www.rembrandtdatabase.org). It offers free access to high-resolution images, X-rays, historic treatment reports, as well as images of paint samples and related documentation. The Rembrandt Database is a joint initiative of the Netherlands Institute for Art History (RKD) and the Royal Picture Gallery Mauritshuis, generously supported by grants from the Andrew W. Mellon Foundation. It was developed as a pilot project that ran from 2008 to 2010, after which the RKD was awarded additional grants for further development. The database was officially launched in September 2012. At the present time, the majority of the documents relates to paintings in the Mauritshuis, but selected paintings from the National Gallery, London and The Metropolitan Museum in New York have also been incorporated. More content is in preparation, and over the coming years some twenty museums and research institutes in Europe and the US will present information and documentation of their paintings in The Rembrandt Database.

The Mauritshuis has nineteen paintings by and/or formerly attributed to Rembrandt in its collection and devotes considerable effort to their conservation and research. Over the past decades, hundreds of paint cross-sections have been taken by the Mauritshuis paintings conservators during the course of research, usually associated with conservation treatment. The cross-sections reveal information about the paint layer build-up, pigment composition, degradation phenomena, and thus give valuable insights into Rembrandt’s painting practice. They are stored in a systematic manner in the conservation studio of the Mauritshuis, together with documentation files of the paintings. The cross-sections have been examined with light microscopy to characterize the paint layer build-up and pigment composition, and in some cases, with more advanced analytical techniques, such as scanning electron microscopy coupled with a energy dispersive x-ray detector (SEM-EDX) to gain elemental information about the paint components.

When a paint sample is collected from a painting, a sample form is filled out by the conservator or scientist. This form contains basic information about the sample: sample number, painting, artist, name of researcher, date of sampling, reason of sampling, and description and coordinates of the sample location. Without this information the sample is useless. After embedding and polishing, the sample is examined using light microscopy, which forms the basis for further investigation with other analytical techniques. A tentative description of the paint layer build-up and pigment composition is given, based on the first observations with the light microscope, and usually a drawing is also made of the cross-section with color pencils; the latter helps to sharpen the observations. In the Conservation Documentation of the Mauritshuis, apart from the sample forms, analog slides and/or low-resolution digital images of the cross-sections, SEM-EDX and other scientific data pertaining to the sample also exits.

For the Rembrandt Database project, all existing documentation regarding each paint sample was evaluated and checked before being entered into the database, since the quality and level of completion of the information varied enormously. Moreover, since many of the digital images of the cross-sections were taken more than ten years ago, the quality and resolution of the images was deemed too poor. Therefore from 2009 to 2012, approximately 300 existing paint cross-sections of paintings in the Mauritshuis were re-examined under the light microscope and digitally re-photographed at high resolution in a standardised manner. The information contained in the original sample forms was transcribed, edited and completed. In the descriptions of the cross-sections, the color and function (for example, ground, undermodeling, or glaze) is given for each layer in the sample, together with its pigment composition and associated paint defect/s (if present). The results of SEM-EDX and other scientific analysis (where performed), as well as new insights into paint degradation processes were correlated to the existing information and incorporated in the descriptions. These transcribed sample forms, together with the new high-resolution digital photographs of the cross-sections, are presented in The Rembrandt Database. Eventually, the sample locations will be indicated on interactive, clickable images of the paintings, through which the samples and related documentation can be accessed (see figure - the sample locations are indicated as red dots on an interactive, clickable image of the painting, through which the samples and transcribed sample forms can be accessed). The application of new media solutions (high-resolution digital image viewer and comparison tool, searchable text files and metadata) will provide new possibilities for research.

Ongoing Rembrandt research in the Mauritshuis

The information about the paint samples will be subject to changes as new research is carried out and new discoveries are made. Rembrandt studies in the Mauritshuis are continuing as part of the Rembrandt in the Mauritshuis catalogue project, a revised edition of the 1978 publication with updated technical entries on each of the paintings (due 2019), and the ReVisRembrandt: Re-visualizing Late Rembrandt project (2012-17) funded by the NWO Science4Arts Program. As part of the ReVisRembrandt project, new imaging techniques such as macro XRF-scanning and hyperspectral visual and near-infrared imaging are being further developed and applied, and combined with advanced cross-section analyses, to study Rembrandt's late painting style. Research results will be shared via The Rembrandt Database.

Samples in other collections

At the moment, Rembrandt paint sample collections at the RCE (Groen) and the Doerner Institute (Kühn) are also being disseminated by means of The Rembrandt Database. Finally, during the pilot phase of the project, digital images and sample descriptions were collected of existing paint cross-sections from two Rembrandt paintings in the collection of the National Gallery, London during a one-week visit to their Scientific Department. Hopefully more museums and research institutes are willing to share their paint sample collections, since they present new unique research material for scholars.

Acknowledgements

The Rembrandt Database is managed, and will be maintained by the Netherlands Institute for Art History (RKD) in The Hague. It is funded by the Andrew W. Mellon Foundation in New York. As part of The Rembrandt Database project, the original sample forms were transcribed and translated into English by Rembrandt Database associate Thamar Weidema. Annelies van Loon re-examined and re-photographed some 300 existing paint cross-sections from Rembrandt paintings in the Mauritshuis, and edited and completed the transcribed sample forms in the period 2009-2012. I would like to thank my colleagues Petria Noble (Mauritshuis), Carol Pottasch (Mauritshuis), Wietske Donkersloot (RKD, project manager), Michiel Franken (RKD), Willem ter Velde (RKD), Thamar Weidema (RKD) and Sytske Weidema (RKD) for their help and support during the project. The visit to the National Gallery in Spring 2011 was made possible through the Charisma ArchLab Program. I am grateful to Ashok Roy (NGL, Scientific Department) and his colleagues for this opportunity and their warm hospitality during my one-week stay at their laboratory.
Introduction

The Bosch Research and Conservation Project (BRCP) is an ongoing effort to document and examine the entire oeuvre of Jheronimus Bosch. It is the first time in history that an entire oeuvre is being documented and examined in a standardized way, always using the same equipment and procedures. All panels are documented in very high resolution macro photographs in visible and infrared light by a professional art photographer (Rik Klein Gotink). The OSIRIS camera is used to collect infrared reflectograms, and, in selected areas, its macro lens is used to collect extremely high resolution close-ups. All images are simultaneously stitched and co-registered using a new algorithm that allows for precise registration across wavelengths, thereby enabling the use of our new browser-based curtain viewer to allow intuitive and quick access to the images across each of the imaging modalities. The BRCP conservator (Luuk Hoogstede) uses the same microscope to inspect each panel, and he makes detailed reports on painting technique and condition. He is also participating in a number of structural treatments of the panels through the Getty Panel Painting Initiative. The use of several new computer technologies enables the six members of the BRCP to work and collaborate effectively as they prepare their comprehensive conservation and art-historical investigation across Bosch’s oeuvre. The project leads up to a major exhibition in 2015/16 in Hertogenbosch.

Photography

In order to facilitate direct comparison between different painted surfaces, all Bosch paintings are photographed using a consistent set of cameras and lenses across the entire oeuvre. We utilize a custom-built collapsible aluminum frame (Figure 1) along with laser range-finding to enable the camera to translate parallel to the plane of the painted surface, so that parallax errors and perspective distortion are minimized. The imaging is carried out using two cameras: a Hasselblad H4D-60-IR 60MP camera is used for visible-light photography and infrared photography, and an OSIRIS 16 MP camera with InGaAs array is used for infrared reflectography in the 900nm - 1700nm range.

When capturing visible images, an IR-blocking filter is employed (BG-39), whereas the infrared photographs are captured while employing an IR pass filter (Schott 093) that allows us to image at wavelengths up to 1100nm. The camera resolutions and working distances correspond to effective resolutions of 1250 pixel/in for the Hasselblad camera and 260 pixel/in for the OSIRIS camera. The individual photographs cover the entirety of the painted surface, with approximately 20% areal overlap between images in order to ensure high-quality automated stitching. The Metamorfoze Preservation Imaging Guidelines are used to ensure color accuracy, white balance and tonal capture, and consistent illumination. Full specifications of the imaging setup are available online1.

Examination

A standardized approach and a standardized set of equipment are also used for on-location examination

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of all paintings. The examination procedure covers all aspects of the painting technique and condition, including picture support, ground, preparatory layers, paint layers, surface finish, frame and framing, and the conditions of the support, ground and paint layers, and surface finish. Visible and UV examination is performed, and an Olympus stereo microscope with fiber-optic illumination and digital color image capture are used to capture high-resolution photomicrographs of specific areas of interest (Figure 2). A detailed examination report is subsequently written from the detailed on-location notes, photographs, and photomicrographs, and every report is entered into a custom BRCP wiki using a standardized document template so that comparisons can be easily made between different pictures.

**Digital Image Processing**

After the individual visible-light, infrared photograph, and infrared reflectogram images are captured, they are processed to stitch and co-register them. We utilize an algorithm in which stitching and registration are performed simultaneously at the level of the individual photographs, so that a global optimum placement of each constituent image relative to its intra- and inter-wavelength pairs is achieved. A schematic of the overall data processing pipeline is shown in Figure 3. The basic steps in the image-processing pipeline are as follows. The SURF algorithm is used to identify approximately 10,000 characteristic feature points in each constituent image, following which the features from each image are compared to find similar features in other overlapping images. Feature points on the frame and other out-of-plane locations could cause misregistration due to parallax shift between overlapping photos, so those features are removed. Global optimization is then performed to solve for the exact rotation, translation, scale, and perspective correction (cumulatively, a homography), that would bring corresponding features from different images (both intra- and inter-wavelength) into the closest proximity by minimizing the sum of squared distances between all matching feature points. The RANSAC algorithm is used to remove feature-point pairs corresponding to geometrically implausible matches. The process of optimization and filtration is repeated iteratively until the r.m.s. error among all feature points is less than 1.2 pixel. Finally, the images are resampled using high-order Lanczos interpolation and assembled into a seamless whole using a multiscale blending algorithm detailed elsewhere at which point they are ready for online visualization. In order to facilitate direct comparison between the visible-light photography, infrared photography, and infrared reflectography, we have developed a novel visualization technique which we call the *curtain view*. In this approach, the user is provided with a single smoothly-zooming view into the painted surface in a web browser. Clicking and dragging are used to pan the images, while double-clicking or mouse-wheel scrolling are used to zoom in and out. The window is continuously divided into three or four panes at the location of the mouse cursor, so that above the cursor the visible-light image is shown, while below and to the left and below and to the right the infrared photograph and infrared reflectogram are shown. Moving the mouse cursor thus causes the division between these different views to move dynamically, giving the impression of lifting the curtain or pulling back the curtain from one wavelength to the other, thereby facilitating the direct comparison of the underdrawing or underpainting to the normal

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view of the picture without forcing the user to perform context switching. A screenshot of the curtain view is shown at the bottom right of figure 3, and a live demonstration can be viewed online.$^1$

Figure 3: Schematic of image processing pipeline from source images to final visualizations

$^1$http://boschproject.org
ConservationSpace is a project to develop a web-based, open-source software application for managing conservation documents, increasing access, expanding research opportunities, supporting workflow procedures, and reducing the loss of documents. Thirty years ago, virtually all conservation records were either paper or film-based artifacts that could be easily organized in filing cabinets. Record management tasks in the digital age, however, have become extraordinarily complex and many institutions, conservators, and scientists lack the skills and infrastructure to handle them. While a few software applications are available for conservation document management, the field would benefit from a more robust solution.

In 2006, the Andrew W. Mellon Foundation organized meetings in New York and London to discuss approaches to conservation documentation with museum directors, conservators, curators, and scientists. And in 2009, the Office of Digital Assets and Infrastructure (ODAI) at Yale University led a project to identify functional requirements for a software application to support and manage conservation documents, business processes, and related scientific data. Professionals from the United States, Europe, and Australia, representing forty-nine institutions and organizations attended community-design workshops and identified nineteen workflows commonly used by conservators and conservation scientists; these workflows have served as guides for moving forward.

The Mellon foundation has for years provided grants to support the development of computer-based applications and systems for museums and art conservation; liberal arts and humanistic scholarship in higher education; scholarly communications; the performing arts; and conservation of the natural environment. Two of these Mellon projects, CollectionSpace and ResearchSpace, share significant common interest with ConservationSpace.
The National Gallery of Art, Washington, now leads the initiative to actually build Conservation-Space, in partnership with the Courtauld Institute of Art, Denver Art Museum, Indianapolis Museum of Art, Metropolitan Museum of Art, Statens Museum for Kunst, and Yale University. The goal is to develop open-source software, available at minimal expense, that serves a diverse conservation community working in institutions and private practice. It is imperative that it improve and simplify business processes for conservators, scientists, and others users in institutions or private practice.

The first release of ConservationSpace will be a cloud-based, hosted version, which should minimize cost of installation and simplify software maintenance and technical support. With a “software-as-a-service” implementation, each institution would have separate access to their own information at a common location in the cloud.

While this hosted approach may bring about operational savings over the long term, some institutions may prefer an application that is hosted on their own servers, an approach that would probably increase security for sensitive data. However, it will be challenging to build the interfaces required to integrate ConservationSpace with existing systems within institutions. The software must work seamlessly within an organization’s network in order to improve productivity, reduce data entry requirements, ensure data consistency across applications, and enhance search capabilities.

Because analog and digital photography and scientific imaging are essential components of conservation documentation, ConservationSpace will provide basic tools for adequate annotation and manipulation of high-resolution images. For sophisticated imaging processes, additional software will be required.

The partners selected four of the nineteen workflows identified in the ODAI project for inclusion in Release 1.0 of ConservationSpace:

1. examination of a single object
2. examination of multiple objects
3. treatment
4. managing and preserving documents

For each workflow, functional requirements, use case models, and a list of minimum system object fields and templates were defined. In addition, a high-level design for the software architecture, domain models, and a development plan were created.

Sirma ITT, a Bulgarian company that is a subsidiary of the Sirma Group, has been contracted to build the application, and Release 1.0 should be available in spring, 2014.

The first release will provide only core capabilities needed by conservators. Therefore, the system design must be extensible in order to allow for adding workflows or functionality. The intent is to continue developing ConservationSpace with additional support from the Mellon Foundation. Eventually, ConservationSpace must become self-supporting. No sustainability model has been developed at this time but it may be advantageous to find a solution that would address the needs of other Mellon Foundation “Space” initiatives.
The Ethical Representation of Cultural Objects: A ResearchSpace Perspective

by Dominic Oldman, Principal Investigator, ResearchSpace, British Museum

The Wunderkammer - a 16th and 17th century cabinet of curiosity

The Wunderkammer project is based at the British Museum, London and is funded by the Andrew W. Mellon Foundation. Its aim is to create a shared infrastructure and service that supports collaborative research. This includes the development of communication and research tools, access to digital methods, and the harmonisation of data to create a knowledge environment akin to a modern day digital Wunderkammer, transforming individual institutional knowledge into a network of connections and meanings that extend the questions that we can ask and the research directions that are available. Much of this data would also be available for general reuse as Linked Open Data.

The Wunderkammer (a 16th and 17th century cabinet of curiosity) contained a representative selection of objects that at first glance conveyed the chaos of nature, but on further reflection exposed meaningful connections and resemblances that operated across the natural world. These relationships extended to the artificial objects which were derived from - and therefore also reflected - nature's unity. Under the prevailing knowledge system each individual cabinet represented part of a network of meanings that existed harmoniously and were mutually extensive. The unified and simple view of the Wunderkammer was replaced in the 18th Century by a more scientific (and also commercially motivated) approach, accompanied by the development of aesthetics. Comprehensive rather than represen-
tative collections (still incorporating both natural and artificial objects) evoked broad and sophisticated questions about the world and the nature of art. The sheer volume of these collections, and the development of subject specialisms, led to their division into separate museums and libraries where different classification systems and perspectives continued to develop, but the element of unity, once found in the Wunderkammer, was lost.

In the modern world visions of uniting knowledge through inter-museum networks accompanied the early development of humanities computing. Since 1968, when the first large conference on museums and computing was held in New York at the Metropolitan Museum of Art, experts have instinctively worked to establish interdisciplinary knowledge networks. But they have been unsuccessful, in part due to an inability to resolve differences between cultural organisations without resorting to the homogenisation and the flattening of data. The World Wide Web has given the illusion of heterogeneity and connectivity but in reality hosts expensive handcrafted silos, and at the expense of divorcing internal knowledge infrastructures from external digital representations.

Now the vision of the inter-museum network has returned but although the representation of cultural heritage data is seen as important and has attracted significant amounts of funding, particularly for projects such as Europeana, the value of difference and perspective is still ignored in favour of scale and commoditisation. The quality and superficial nature of digital outputs in many projects would not be tolerated in traditional forms of communication and this creates a problem for the promotion of ‘digital’ (computing) as a valid and ethical means of academic research. In many cases local and regional perspectives are lost to so-called, ‘data cleaning’ and centralised common schemas that squeeze out the meaning and therefore the history of data. These big data projects provide a “bird’s-eye” view without considering what has been sacrificed and obscured to achieve it.

Historical analysis and interpretation benefits from distance, but only if it is built on a foundation of data that facilitates meaningful connections and relationships. It is the aggregation of these relationships that provides layered insight and the potential to reveal the bigger picture. Data must be represented so that, when aggregated, it retains enough of its original meaning to support different arrangements or ‘models’ that have the potential to uncover new knowledge. The modelling and exploration of data demands its ethical representation.

The ResearchSpace project seeks to harmonise data in a way that retains local meanings and perspectives within a ‘big data’ environment, and support analysis and interpretation at different levels of distance and proximity. Its methodology means that digital tools are aligned with scholarly methods and standards rather than conflicting with them. It will provide unity, or harmony, with a knowledge representation system, the CIDOC Conceptual Reference Model - a real world ontology based on scientific principles and a detailed understanding of the cultural heritage domain, and which supports the use of computing to understand connections that go far beyond that imagined by the original Wunderkammer.
Museums long been involved in the use of spectral imaging technologies in order to document and analyze works of art. This has ranged from filter-based multispectral systems, such as the VASARI and CRISAT systems over a decade ago to modern diffraction-grating based hyperspectral systems. These earlier multispectral cameras acquired 7 and 13 spectral bands respectively. Hyperspectral imaging, however, can acquire hundreds of spectral bands giving far greater spectral accuracy and allowing us to perform more sophisticated signal processing than was previously possible. This precision in the spectral domain combined with a high spatial resolution makes it possible to detect subtle differences within the painting, perform materials identification and, of course, make an accurate and quantitative recording of the painting at a point in time.

A customized pushbroom hyperspectral system has been put together at the C2RMF in order to perform hyperspectral analysis of paintings, marquetry, drawings and other objects. The system is based on a high resolution VNIR (visible - near infra-red) hyperspectral camera mounted on an automated XY motorized frame (figure 1). The camera, manufactured by Norsk Elektro Optikk, is capable of acquiring data at a spatial resolution of 60µm with up to 160 spectral bands between a wavelength of approximately 400nm and 1000nm at each point on the painting. A electronically stabilized halogen light source is fixed to and moves with the XY frame, allowing a constant illumination to be used that only need illuminate a small part of the painting at any one time. The camera is moved by the XY frame and acquires data column by column. Calibration is performed to correct for variations in the lighting and sensor sensitivities and both spectrally using spectral reference targets and spatially for geometric distortions and to take into account non-linearities in the sensor model. The calibrated data is then registered, fused and stitched into a mosaic to produce a final data cube.

Image Processing

The resulting data cubes can be used in a number of ways. One of the most useful of these has been the application of image processing techniques to reveal “hidden” features. The spectral signal is a rich source of data that can contain information impossible to obtain from the standard imaging techniques typically used in conservation studios, such as color, infra-red or ultra-violet fluorescence images. Techniques such as principal component analysis (PCA) can be applied to the spectral signal to help extract and segment this information into related clusters.

An example of the use of this technique is from the painting The Holy Woman from the musée Jacquemart-André in Paris (Anonymus, Oil on Canvas, 80.0 x 45.0 cm). The use of PCA (see figure 2) clearly reveals decoration around the edge of the robe, which is not visible in standard color, infra-red or UV images.

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Handling High Resolution Spectral Data

High resolution hyperspectral imaging can generate vast quantities of data - up to 150GB for a single 1m x 1m painting. The type and quantity of data produced makes it difficult to manipulate and visualize full resolution hyperspectral data. As a result, such images often remain underexploited and poorly accessible. Hyperspectral data is, therefore, rarely shared or made available either within institutions or to the general public. To address this issue, powerful open source software has been developed to process, visualize and analyze these volumes of data.

In particular, for visualization and the networked distribution of multispectral, hyperspectral and other scientific imagery, the IIPImage visualization framework, has been developed to enable access to high resolution imagery.

IIPImage is an open source image server for extremely high resolution scientific images that can handle up to terrapixel scale data as well as an extended range of bit depths including 8, 16 and 32 bits per channel. It can be used directly from archive-grade image formats, such as TIFF or JPEG2000 and is able to perform dynamic gamma, colour mapping and contrast adjustments. It is also able to dynamically export selected views, compare different image modalities and enable the visualization of spectral curves at any point. Multispectral and hyperspectral data can, therefore, be viewed, compared, and analyzed interactively and in real time within a standard web browser over a network.

The use of such an image server has allowed high resolution multispectral and hyperspectral data to be directly included within the C2RMF research database, thereby making such full resolution scientific data accessible to conservators and restorers. Users can access multispectral imagery remotely using a standard web browser and interact, compare and analyze the high resolution imaging.
Photothermal Tomography - Revealing Hidden Colors Using Mid-Infrared Imaging

by Tim Zaman, PhD candidate at the Delft University of Technology

In the artwork conservation field many different non-destructive imaging methods have been developed that can reveal sub-surface features. Such features can often be found in paintings and are often not directly visible to the naked eye. Imaging techniques that can see such features often make use of a different part of the electromagnetic spectrum than our human eyes are visible to. Consequently, the features that are revealed by these techniques are not necessarily correlated with what our eyes would see below the surface. Existing imaging techniques can reveal the type of material below the surface, which can indicate the pigment or color that resides below the surface.

A new imaging method is proposed that partly works in the visible range of the electromagnetic spectrum, and can reveal the color below the surface. It works through illuminating the object with red, green and blue light consecutively. A (mid-wave) infrared camera then captures the thermal response of the surface.

Instead of seeing colors by looking at their appearance in the visual range (like our eyes do or common cameras), colors can also be seen by capturing their absorption and conversion into heat in the material. This is what the three illuminants and the thermal camera is used for.

Taking in account that most materials have at least a (small) degree of transparency to our incoming light, we can assume this light also dissipates into heat below the surface where sub-surface features might reside. This heat then radiates and diffuses to the surface. This thermal diffusion is slow and will be visible at the surface with a small time delay compared to the time the object was illuminated. This time difference is a function of material constants and the depth of the feature.

A stroboscopic light is used and flashes with a frequency the camera can tune into. The resulting images are then used to analyze the thermal profile with a very high accuracy. By using different flashing frequencies, the thermal depth profile can be computed. A three dimensional colored image can then be made with the time delay (related to depth) as the third dimension.
The development of this method of photothermal tomography is still in an early stage. Exciting results have already been produced and the boundary conditions in which this method works are being investigated.
Computers as Tools for Conservators

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The rapid developments in computer hardware and software are changing the way that conservators perform their work. The presentation provides an outlook on how computers will and should affect conservation practice in the years to come.

At the outset it should be made explicit that computers cannot and will not take over the conservator's work. The task faced by conservators is far too complex to be realized by computers. Making any predictions about some remote future where computers may be able to take over any domain of expertise is pure speculation and certainly not relevant for present-day challenges. Instead, our starting point is the observation that computers offer potentially powerful tools for supporting conservators in the analysis and visualization of the increasing data volumes generated by modern imaging and analysis systems. For instance, multispectral imaging of art works may generate hundreds or thousands of spectral images. Relevant information may be distributed over a large subset of these images and may be very hard to find manually. Computer algorithms offer useful tools for doing so. Linear and nonlinear methods such as principal component analysis and independent component analysis are powerful computational tools, but only when properly used by a conservator who can interpret the results.

During the Fifth International Workshop on Image Processing for Art Investigations (IP4AI5[1]) held at the North Carolina Museum of Art, a number of novel computational tools were presented to support the analysis of art works. The tools presented varied from virtual restoration software for detecting and removing the cracks in paintings to software to create visual reconstructions of hidden paintings from X-ray fluorescence imaging data. The adoption of such tools by conservators requires the software to be developed into user-friendly programs (which typically requires quite some effort) and some training of conservators.

During the last eight years, our group was involved in the development of so-called thread-counting algorithms for automatically determining the “thread density” of canvas. Given a digital X-ray image of a painting, the horizontal and vertical threads of the canvas can be extracted and counted.

![Figure 1: Illustration of the automatic canvas detection task](http://ip4ai.org/fifth-ip4ai/)
automatically. From a computer-science perspective, the extraction and counting algorithm is not innovative. It is based on a two-dimensional Fourier transform, which is one of the most elementary transforms in digital image processing. However, applying the algorithm to X-ray images of canvasses is very innovative. By measuring small deviations in the thread densities of paintings, matching pairs of paintings can be found that are likely to originate from adjacent locations on the roll of canvas. These “weave matches” support inferences about the relative dating of paintings. Professor Rick Johnson of Cornell University is to be credited for turning thread-counting software into a useful tool for art historians and conservators. The interested reader is referred to a recent paper in The Burlington Magazine about using weave matching applied to the dating of Van Gogh’s paintings.

The application of computers for visual analysis is still hampered by the sheer complexity of visual perception. As a case in point, we have been working on the automatic identification of (primed) canvas in a frontal image of a painting, the so-called automatic canvas detection task. Figure 1 is an illustration showing paint superimposed on primed canvas. For human observers (even naive ones), it is quite easy to distinguish between the painted and unpainted areas. Present-day computers fail to perform the task at a satisfactory level of accuracy. Apparently, human observers combine a wide variety of visual cues to infer that a certain region contains no paint. As a consequence, current computers require human support to solve the canvas-detection task. Still, with the rapid progress in image processing it is to be expected that tasks such as the canvas detection become solvable within 5 to 10 years.

The REVIGO (REassessing Vincent van Gogh) project is one of the NWO funded Science4Arts projects in which we collaborate with the Techni
cal University Delft, the Van Gogh Museum and Cultural Heritage Agency. The project aims at developing computational tools that support conservators to integrate knowledge sources that are of relevance for the conservation of drawings or paintings by Van Gogh or other artists. The emphasis is on the aging of pigments and their (virtual) rejuvenation. Knowledge sources vary from knowledge about the aging of the constituent pigments to historical knowledge.

Figure 2 shows an example of the relevance of historical knowledge. The left part of the figure shows The Bedroom by Van Gogh with what appears to be a green shadow under the chair. Considering the painting in isolation, the question arises if the “shadow” under the chair is the result of pigment degradation or if it was intended by Van Gogh. A photographic reproduction of the painting taken in 1904, shown on the right of the figure, reveals that the shadow was not intended by Van Gogh and resulted from the aging of pigments.

The REVIGO project aims at creating a blueprint for computer software that integrates various knowledge sources and is able to generate virtual reproductions of artworks in their (estimated) past and future appearances. In this way conservators can assess the visual consequences of their intended actions. The result of REVIGO will represent a helpful (but not infallible) tool that extends the expertise of conservators.

![Figure 2](image.png)

**Figure 2:** Left: the current version of Van Gogh’s Bedroom with a green “shadow” under the chair. Right: photographic reproduction of the same painting created in 1904 where no shadow is visible under the chair.

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