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Reunited

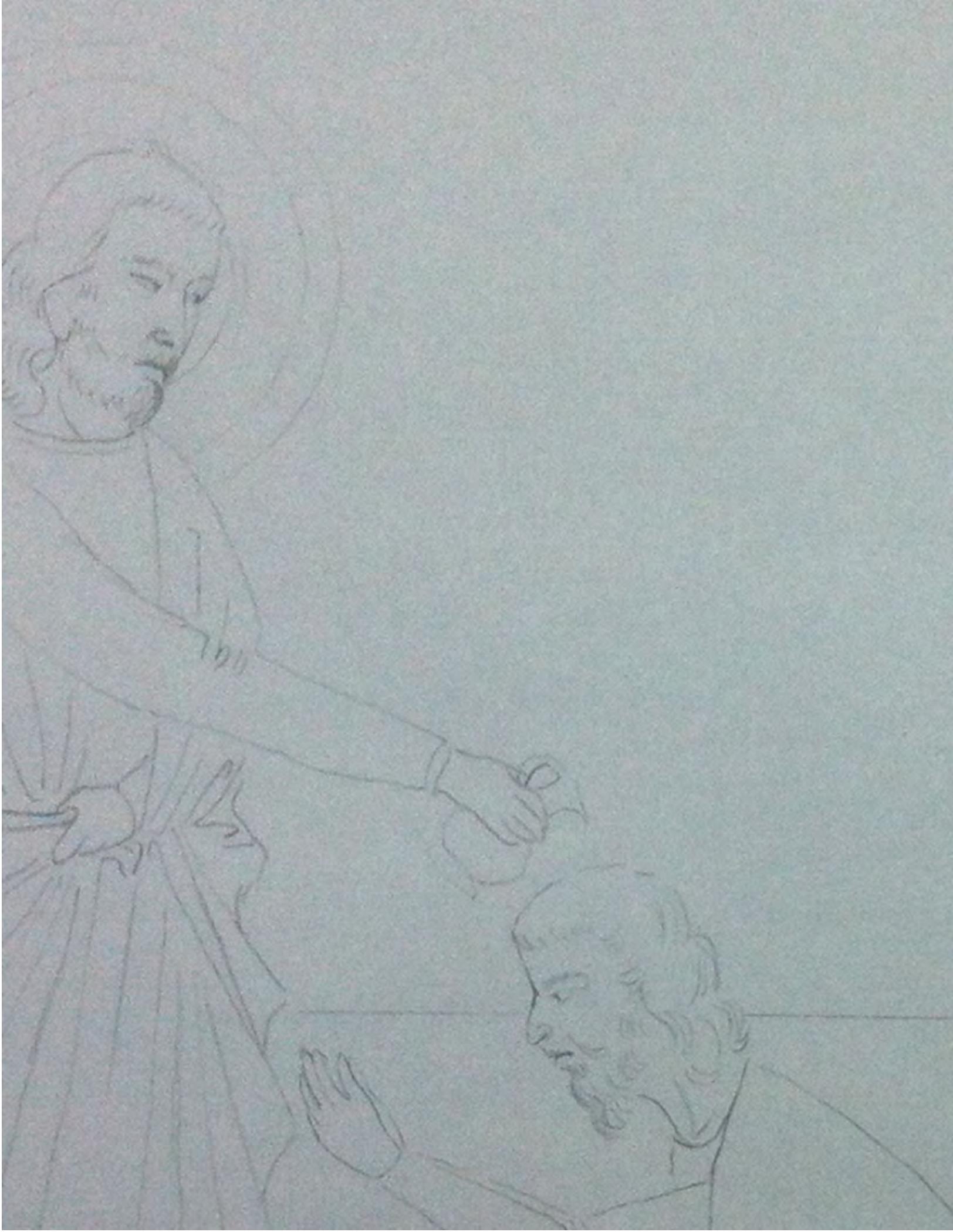
An art historical and
digital adventure

Ingrid Daubechies (editor)



in collaboration with 







REUNITED – AN ART HISTORICAL AND DIGITAL ADVENTURE

Editor: INGRID DAUBECHIES

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ART HISTORICAL AND DIGITAL ADVENTURES AROUND THE EXHIBITION

Reunited: Francescuccio Ghissi's St. John Altarpiece

BIOGRAPHIC INFORMATION ON THE CONTRIBUTORS

The biographies are given in alphabetical order of the contributors' last names.

William P. Brown is Chief Conservator for the North Carolina Museum of Art (NCMA), Art Conservation Center where he is responsible for the long-term preservation of the collection. He is a specialist in the treatment of European Old Master Paintings, which the NCMA has strong holdings in. He established the Art + Science Initiative in 2012, which is an interdisciplinary collaboration with University Science and Math departments. He received his M.A. and Certificate of Advanced Studies in Conservation from State University College at Buffalo, in 1989 and joined the NCMA first as assistant conservator, then as associate conservator before his promotion to chief conservator in 2001. He is a Professional Associate, American Institute for Conservation of Historic and Artistic Works, and serves on the Paintings Committee of the International Council of Museums.

Charlotte Caspers is a visual artist; she carries out reconstructions on commission, and also teaches painting techniques, as a visiting instructor at the conservation program at the University of Amsterdam. She studied Art History at the Radboud Universiteit in Nijmegen (the Netherlands), and then trained as paintings conservator at the Stichting Restauratie Atelier Limburg (SRAL) in Maastricht.



Bruno Cornelis is an electrical engineer. He obtained a Ph.D. degree in Applied Sciences and Engineering from the Department of Electronics and Informatics at the Vrije Universiteit Brussel (the Free University in Brussels) in 2014. During his graduate studies he investigated the use of various image processing tools in support of art scholarship. He continued to pursue this topic as a postdoctoral researcher with Prof. Ingrid Daubechies at the Department of Mathematics at Duke University. As a part of his research work he co-developed a tool to remove cradling artifacts in X-ray images of paintings, implemented in a free-to-download software package and Photoshop plug-in called Platypus. He is currently a postdoctoral researcher at Vrije Universiteit Brussel (VUB) in Belgium, working on a project with the Belgian research institute IMEC that involves on-chip single cell sorting, for which he is presently developing high-speed image processing methods. His research interests include statistical data analysis and sparse representations in image processing.

Email: bcorneli@etrovub.be

Ingrid Daubechies is a mathematician. She is presently the James B. Duke Professor of Mathematics and Electrical and Computer Engineering at Duke University. She was trained in Theoretical Physics at the Vrije Universiteit Brussel, where she obtained both her B.Sc. and Ph.D. degrees, in 1975 and 1980. Her focus shifted towards applied mathematics as she started working on applications of mathematics outside physics as well. She is best known for her work on wavelets; some of the algorithms she developed with collaborators have been incorporated into the JPEG-2000 image compression standard. She has been interested in and working on developing image processing approaches and tools to assist art historians and art conservators since 2008.

Noelle Ocon received her undergraduate degree in Art History in 1990 from the University of North Carolina-Chapel Hill, concentrating on Northern European art of the 16th and 17th Centuries. Following an apprenticeship in Washington, D.C, Ms. Ocon entered the Art Conservation Program at State University College at Buffalo, NY in 1993. After interning at the Philadelphia Museum of Art and the Indianapolis Museum of Art, she graduated with a Masters of Art with a certificate of advanced studies in conservation in 1996. Ms. Ocon accepted a position in the conservation department at the NCMA in 1997.

Research and treatment of the permanent collection is her main focus, with contributions to the Systematic Catalogue of the Dutch and Flemish Collection and Egyptian Collection, and the upcoming Systematic Catalogues for the Classical and Northern Renaissance collections. Another focus is that of technology in the examination and documentation of paintings, including infrared reflectography and x-radiography. She was also one of a team to help develop confocal X-ray fluorescence at the Cornell High Energy Synchrotron Source and Project Platypus with Duke University.



David Steel is Curator of European Art at the North Carolina Museum of Art (NCMA). He received his undergraduate degree in Fine Arts and Latin from Dickinson College in 1975, and M.A. and Ph.D. degrees in the History of Art from Bryn Mawr, in 1979 and 1986. In the period 1980-1982 he was a Samuel H. Kress Fellow at the National Gallery of Art, Washington, D.C. He has curated many special exhibitions at NCMA, ranging from *Baroque Paintings from the Bob Jones University* to *Monet in Normandy* and *Alphonse Mucha: The Spirit of Art Nouveau*. Most recently, he curated the wonderful and very successful NCMA exhibition *The Worlds of M. C. Escher: Nature, Science, and Imagination*.

Rujie (Rachel) Yin is a mathematician. She is presently, and since 2012, a Ph.D. student in the applied mathematics program at Duke University, under the supervision of Prof. Ingrid Daubechies. She was trained in both mathematics and physics at Shanghai Jiao Tong University and received her Bachelor degree in 2012. During both her undergraduate and graduate studies, she has worked on projects related to image processing. She is particularly interested in developing and implementing machine-learning methods for challenging image processing problems.

Bill Brown and **David Steel** are the co-curators of the NCMA exhibition *Reunited: Francescuccio Ghisis St. John Altarpiece*, September 10, 2016 – March 5, 2017.

The project of virtually aging and rejuvenating the Ghissi panels would not have been possible without the hard work of the following five Duke undergraduate students:

Geena Gomez
Raphael Kim
Mitchell Parekh
Samuel Slack
Mason Taylor.

Finally, we would like to acknowledge the contribution of **Carolyn Calderbank** to the process of adding realistic cracks to finish the “virtual aging” of the panel painted by Charlotte Caspers.



ACKNOWLEDGMENTS

The authors and editor gratefully acknowledge support from the Samuel H. Kress Foundation for the virtual cradle removal effort that became the Platypus project; this project would not have been possible without their generous grant. The visit by Charlotte Caspers to NCMA and Duke University in Fall 2012 was made possible by support from the North Carolina Museum of Art, the Visiting Artist Program at Duke University and the Samuel H. Kress Foundation. The *Reunited* exhibition itself was supported by a grant from the Samuel H. Kress Foundation; image material was developed by several projects at the Information Initiative at Duke, with help from Wired! at Duke.

We are also grateful to our many colleagues and friends who supported us throughout this project. In particular, we want to thank Scott Lindroth, Vice Provost for the Arts at Duke University and Robert Calderbank, Director of the Information Initiative at Duke, who, at the beginning of this project, sponsored the ART + initiative, showcasing many interactions between mathematics and art, and Warren Warren, Director of the Center for Molecular and Biomolecular Imaging at Duke, who started the Art + Science Initiative at Duke that brought some of us together.



ART HISTORICAL AND DIGITAL ADVENTURES AROUND THE EXHIBITION

Reunited: Francescuccio Ghissi's St. John Altarpiece

INTRODUCTION

The essays in this collection all touch upon interesting intellectual and technical adventures rooted in the project of organizing an exhibition at the North Carolina Museum of Art (NCMA). This exhibition would reunite, for the first time in more than 100 years, the eight known panels of the 14th-century Italian altarpiece by Francescuccio Ghissi, depicting Jesus's crucifixion and scenes in the life of St. John the Evangelist. The main protagonists (from such diverse walks in life as the study of art history, art conservation, mathematics and engineering) highlight in their stories some of the multiple facets of this venture.

HOW IT ALL STARTED

As he describes in his essay, head NCMA conservator Bill Brown had long wished to reunite the different panels of the 14th century altarpiece by Francescuccio Ghissi. Like many others, this altarpiece had been removed from its church in the 19th or early 20th century, and dismantled. (More background about this process is given in the piece by David Steel, curator of NCMA for European Art.) The individual scenes (one central scene depicting the crucifixion, and 8 smaller pictures illustrating the life of St. John the Evangelist) were sawn apart, and the resulting panels ended up in different collections. Samuel Kress owned four of the small panels; in accordance with his will, they (as well as many other works from his collection) were distributed over regional museums in cities where the Kress department stores had been established. Three of the Kress Ghissi panels are now at NCMA; the fourth one is in the Portland Art Museum. Three other small panels are with the Metropolitan Museum in New York; the larger central panel is in the Art Institute in Chicago. But $3 + 1 + 3 + 1$ adds up to only 8, not 9 – the ninth panel (the last of the 8 smaller scenes) is lost. Even if the different museums would lend their Ghissi panels, a Reunion would still not be able to show



the full altarpiece ...

RECONSTRUCTING THE LOST PANEL?

Bill told me about the Ghissi altarpiece one afternoon in early 2012, meandering onto the topic in the middle of a discussion about a digital image analysis project of the Giotto altarpiece¹, one of the crown jewels of the NCMA collection. We had by then been collaborating for several months. I had worked on several art-related projects before moving to North Carolina in 2011, and in particular on the conception and construction of image processing tools to help study art. Soon after I moved to Duke University, I had the good fortune to be introduced, at a lecture series, to Bill Brown and his colleague NCMA art conservator Noelle Ocon (who has her own piece in this collection, as explained below). I was delighted to find them very interested in such collaborative projects. When Bill mentioned the missing 9th panel of the Ghissi altarpiece, I wondered whether the Dutch artist and art reconstruction expert Charlotte Caspers could help. As she describes in her own essay in this collection, Charlotte specializes in reconstructing old paintings using the original techniques and types of materials. Reconstructing a lost panel would be a new adventure for her, but after thinking it over, she decided to accept this commission from the NCMA.

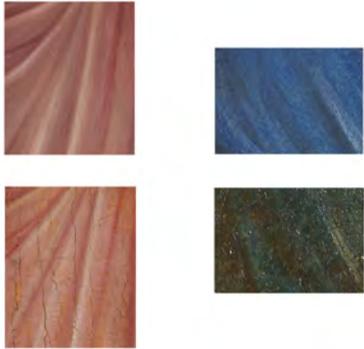
This reconstruction made it possible to enrich the project with a whole new dimension, documenting 14th century painting techniques. NCMA art conservator Bill Brown and curator David Steel were excited by this new angle. In the Spring of 2012, David and Charlotte collaborated to design the ninth panel; in the Fall, Charlotte painted it, and large portions of the whole process were filmed, so that a documentary could be prepared to accompany the planned exhibition of the now once again completed altarpiece. The new panel, once finished, did not disappoint – it certainly gave a vivid demonstration of how wonderfully bright and sparkling these altarpieces were in their own time.

But once it was finished it became obvious that the new Caspers panel could not simply be displayed in its natural position in the altarpiece frame, next to the 8 other panels – they, the authentic and original panels, would look mostly dull and faded next to this more sparkling and vivid non-authentic newcomer ...

IMAGE ANALYSIS TO THE RESCUE

Our image analysis group could help with this, however! By studying the old as well as the new panels, we could “virtually age” the new panel – i.e. make a digital copy in which the gold would look duller, the colors would be altered to mimic 650 years of aging of the pigments, small cracks would be added. A printout of this virtually aged panel could “complete” the

¹But the story of that collaboration is for another time ..



Two segments of the robes of St. John, from the 21st-century reconstruction of the missing panel (top), and from the 14th-century Ghissi panel (bottom) that inspired the modeling of these two particular segments. The same pigments and painting techniques were used for both; the difference is due to aging.

Cutouts of the same personage in panels 8 (old, on right) and 9 (new, on left); although the vermilion of the robe's outside has changed little, many other pigments have become much darker, or changed color (e.g. the highlights on the folds of the robe) due to aging.

Reunited Ghissi Altarpiece, without distracting from its authentic siblings, and the new panel could be exhibited separately, showing off its splendor.

This perspective opened yet new vistas: the technical analysis needed to achieve the virtual aging could also be applied in the reverse direction. Once we knew the exact correspondence between 'old' and 'new' for each pigment mixture used in the altarpiece, and we had fine-tuned the digital image manipulations to make the transition from new to old, we could just as easily take a high resolution image of the old panels, and map their old, aged color planes to corresponding 'freshly painted' versions, thus rejuvenating the 14th century panels. In order to really give a 'new' impression, we also would need to remove the craquelure – that is, use image analysis techniques to find all the cracks in the paintings, remove the corresponding pixels, and 'inpaint' them digitally – all (mostly) automatically, via appropriate programs, because it would otherwise be infeasible, given the number of cracks. This is something I knew could be done: I had collaborated with a group of electrical engineers and art historians who had done exactly this (automatic location of cracks and inpaint them) on a portion of the Annunciation scene in the Ghent Altarpiece by Van Eyck².

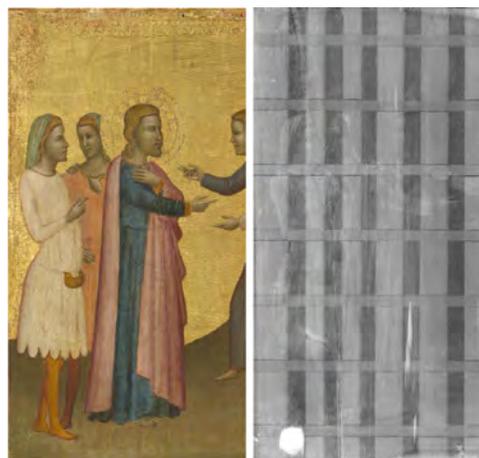
²The portion of the painting on which we carried out this crack detection and inpainting showed a book

This digital dimension of the adventure is covered by Bruno Cornelis's essay in this collection. Bruno is a Belgian electrical engineer who developed for his Ph.D. thesis a lot of the approaches needed for the crack removal in the Ghent Altarpiece project. His essay describes how we formed teams of undergraduate students, trained them in the use of the software (which they supplemented with LOTS of twists that they researched or invented on their own), and how they carried out most of the rejuvenation work on the 14th century panels, prepared to be showcased at the exhibition.

For the crack removal work on the Ghent Altarpiece, I knew that the X-ray photographs had been very useful – for those panels, cracks had been easier to trace on the X-ray pictures than on the extremely high-resolution visual-light pictures. In preparation for the crack removal project, I thus asked the NCMA conservators for the X-ray photos of the NCMA Ghissi panels; they harbored a surprise.

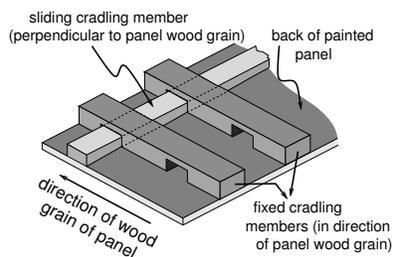
CRADLING

The most dominant feature in each of these X-ray photographs was a (to me) surprising overlaid lattice structure. At first sight, it looks like prison bars hide from view the painting and conservation repair details that one usually tries to glean from such X-ray pictures. This, it turned out, was due to the *cradle*. As Noelle Ocon explained to me then, it was fairly standard conservation practice in the 19th and early 20th century to reduce the thickness of the wood panel support of old European paintings, from their original thickness of 1 inch or more, down to 1 cm or even less. The resulting thinner board was then given increased structural integrity by attaching to the back a hardwood lattice or cradle, consisting of *fixed members* in the direction of the wood grain of the board, and *sliding members* perpendicular to the wood grain, tunneling through the fixed members.



Left: detail of one the NCMA Ghissi panels; right: X-ray photograph of the same detail.

in medieval writing, propped up on a stand. It was not clear, prior to the image analysis work, whether Van Eyck had painted only a symbolic representation of a book or had really painted an actual text. After the inpainting, based only on image analysis (without attempting text or character recognition), sufficiently many word groups could be decoded by paleographers to enable the identification of the text. (See bibliography for more details.)



Schematic diagram of a cradle



Back of one of the cradled Ghissi panels in the NCMA collection



Zoom-in on the back of a cradled panel, showing wormhole damage

There were several motivations for this practice – sometimes reducing the thickness of the original board helped in removing partially decayed or worm-holed wood; in many cases cradling was done simply to counteract the natural tendency of the wooden support to adjust its warp in response to changes of temperature and humidity. In some (fortunately rare) cases, cradled wood panels have reacted to the cradling stress constraints by developing large cracks, which can now be remedied only after removing the cradle and replacing it by a less rigid support structure that allows the panel its natural warping freedom. Most cradled paintings, conserved in museums under constant and favorable temperature and humidity conditions, are now quite stable in their cradled state, without necessitating a (costly and tricky!) physical cradle removal. Nevertheless, art conservators worldwide³ deplore how much the presence of cradles hinders their close study of X-ray pictures of old European paintings on wood panel. Prior to studying or publishing them, conservators with extensive training in PHOTOSHOP™ typically spend hours carefully removing traces of the cradling in digital versions of such X-ray

³ Another instance of X-ray pictures of cradled paintings can be seen on the exquisitely detailed high-resolution digital views of the Ghent Altarpiece polyptich on the website clostertovaneyck.kikirpa.be. Cradling is there present only on the panels making up the two wings that could be opened and closed. The front and back halves of these panels were separated in the 19th century, to enable their simultaneous viewing, and were then cradled. The cradles are clearly visible on the X-ray photos on the website – this includes the Annunciation panel for the book portion of which Bruno Cornelis and other Belgian collaborators had worked for the crack removal. If I had paid more attention earlier, cradles wouldn't have come as such a surprise to me when I encountered them on the Ghissi panels!

photographs – and they have time to do this for only a small portion of their collection.

VIRTUAL CRADLE REMOVAL

This was another opportunity for image processing to show its potential ...

The problem of identifying and developing mathematical algorithms that would make it possible to remove the trace of cradles from high-resolution digitizations of X-ray photos of paintings on cradled wooden panels became part of the Ph.D. work of Rachel (Rujie) Yin, a graduate student in mathematics working with me at Duke University. Beyond simply determining (automatically) the location of the lighter zones in the X-ray photos, and locally adjusting their intensity, it was also desirable to remove, as much as possible, all traces of the wood grain of the cradle members, without touching that of the original panels. This was a highly non-trivial task, for which we could not simply apply existing off-the-shelf techniques. Rachel contributed an essay to this collection in which she describes this in more detail.



Rachel's solution to the problem was recognized as an interesting contribution to the intellectual body of image analysis research; she presented it at a prestigious conference, and a more advanced version was accepted for publication in one of the foremost technical journals in the field. But that still didn't mean there was a workable solution for art conservators! Rachel's programs were written in MATLABTM, a language used for the prototyping of algorithms by applied mathematicians and other computational scientists and engineers – as far as its target art conservator users were concerned, it could just as well have been in Martian.

With a generous grant of the Samuel H. Kress Foundation, we then started on the next leg of the *Virtual Cradle Removal Project*. Together with Bruno Cornelis, visiting Duke for most of 2015, and electrical engineering graduate student Gabor Fodor in Brussels, NCMA conservator Noelle Ocon, Rachel and I joined forces to make the code more robust and to have it ported to an art-conservator-friendly software tool by Digital Film Tools, Inc. The end result of this process can be found on the website project-platypus.net: a software tool, called Platypus, for the removal of cradle artifacts from digitized high-resolution X-ray photos of cradled paintings on wood panel. It can be used as a plug-in in PHOTOSHOPTM, or in a stand-alone version; it is available free of charge to everyone for non-commercial use, and is provided in an open-source format so that others can add to it if they choose. In the last essay of this collection, Noelle touches upon the highly collaborative process that led to Platypus. It took weekly Skype meetings to hammer out the whole package, over a period of several months, during which decisions had to be taken, after



which participants would get their homework assignments until the next meeting.

And that concludes this overview of the art historical and digital adventures to which Bill Brown's dream of reuniting the Ghissi panels led us, an interdisciplinary and multicultural group of art historians, artists, mathematicians and engineers. I hope this collection will give readers an impression of how stimulating and satisfying our journey was. It was also great fun – and we look forward to further such adventures. ⁴

Ingrid Daubechies, July 2016

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Website:

www.dukeipai.org

⁴Now that she has climbed out of her cradle, Platypus could learn many other tricks!





FRANCESCUCGIO GHISSI AND THE ST. JOHN ALTARPIECE

DAVID STEEL

REUNITED

Reassembled for the first time in more than a century at the NCMA exhibition opening September 10, 2016, the St. John altarpiece is the most extensive ensemble of Francescuccio Ghissi's work that has survived *almost* intact. It clearly reveals this fourteenth-century Italian artist's gifts as a narrative painter and master storyteller. Little is known about Ghissi's career aside from a few signed and dated works, which document that he was active in the Marche region from at least 1359 to 1374, and only a handful of undated paintings have generally been accepted as by his hand.

We are certain of a few facts shrouded by further mysteries: These panels were originally part of the same altarpiece, painted in the late fourteenth century for an unknown church or chapel, possibly in the Marche. The central crucifixion panel was separated from the others early on and entered the collection of a member of the powerful Altieri family of Rome. The smaller lateral panels, depicting scenes from the life of St. John the Evangelist, came on the art market sometime during the first three decades of the twentieth century. Seven of them have survived: four were purchased from a private collection in Rome by the Kress Foundation in 1932 and are divided between the NCMA and the Portland Art Museum; the other three paintings were purchased from a Florentine dealer around the same time by an American collector who donated them to the Metropolitan Museum of Art in 1969.

The eighth St. John panel is the product of a collaboration between Charlotte Caspers, a conservator from Amsterdam who specializes in historically accurate restorations, and myself. We collaborated on determining the subject of the painting, its figural types, and composition. Once the overall design was decided upon, Caspers created the panel depicting St. John the Evangelist baptizing Aristodemus in the style of Ghissi, employing materials and techniques used in the fourteenth century.

RE-CREATING THE MISSING PAINTING

A historical reconstruction of a painting is typically a copy of an existing painting, which follows the original as closely as possible regarding artist materials and painting techniques. Reconstructions serve different purposes. They can help educate by simulating how the painting may have looked when new, before the paint had cracked and faded from hundreds of years of aging; complement art historical research; constitute a reference point in a scientific research project; or replace a lost original. Or, all of the above, as is the case here.

Caspers used authentic materials and techniques written about in Cennino Cennini's early fifteenth-century treatise on medieval and early Renaissance artistic practice, *Il libro dell'arte* (The Craftsman's Handbook). Pigments chosen for the painting were similar to those found in the original Ghissi panels as identified by scientific analysis.

Perhaps more challenging was identifying the likely scene on the missing panel. Considering information from the life of St. John the Evangelist in the thirteenth-century Golden Legend, I believed the missing panel depicted St. John baptizing the high priest Aristodemus.

Deriving figures from those appearing in the other panels and based on other baptismal scenes by Ghissi's teacher, Allegretto Nuzi, Caspers painted what she and I believed was a well-reasoned re-creation of the missing panel. This is likely the first time such a re-creation of a missing panel using original materials and techniques has been undertaken.

The new panel gives an impression of how bright and vivid the altarpiece must have looked when it first appeared.





THE DISPERSAL OF RELIGIOUS PAINTINGS AND ALTARPIECES IN ITALY DURING THE EIGHTEENTH AND NINETEENTH CENTURIES

CULTURAL TREASURES BROKEN APART AND SOLD SEPARATELY

The suppression of religious institutions in Italy by regional and foreign governments during the eighteenth and nineteenth centuries had a profound impact on the fates of innumerable Italian altarpieces, particularly those dating from the fourteenth and fifteenth centuries, which were removed from their original locations. The vast majority of the religious works from this period that today hang on the walls of museums had once adorned church altars, chapels, convents, and monasteries. Regional despots such as the Grand Duke of Tuscany and foreign conquerors like Napoleon suppressed churches and religious orders and confiscated their lands and property, including works of art. Over the ensuing decades, following the defeat of the French in 1815, impoverished religious institutions often sold their artistic patrimony to collectors or dealers in order to make repairs or support themselves. Such was the likely fate of Francescuccio Ghissi's St. John altarpiece, which for a few hundred years remained in its original location before it was removed, sawn apart, and sold piecemeal.

Dealers and collectors from across Europe, and much later from America, obtained these works of art at bargain prices. Over time the original locations of these works were often lost as they passed from dealers to collectors. Individual panels of dismembered altarpieces were sold to increase dealers' profits, so that today their early provenance and connection to companion paintings have often been obscured.

Nearly all the thirteenth to fifteenth-century Italian works in the NCMA's collection have suffered this detachment. They are fragments from more extensive ensembles, separated from their counterparts. In only a few instances do we know their origins and fellow paintings. One is our predella panel by Raphael, painted for the family chapel of Domenico di Tommaso di Giovanni Gavari in the church of San Domenico in the Umbrian town of Città di Castello. The panel was originally installed below the artist's Crucifixion with Saints, now in the National Gallery in London, along with another panel now in the Museu Nacional de Arte Antiga in Lisbon. The original frame for the altarpiece still survives in its original location (see image) and indicates there were originally three predella panels beneath the main panel; the missing third panel has not been discovered.

WHERE WAS THE ALTARPIECE ORIGINALLY LOCATED?

There is no firm documentary evidence linking the altarpiece to a specific church. No mention of it has yet been found in the various archives of religious institutions in the region of the Marche, its most likely locale, since we know Ghissi was active in the area. Ghissi painted in



St. Jerome Saving Sylvanus and Punishing the Heretic Sabinianus, 1502-3, oil on panel, 10 1/8 x 16 in., purchased for NCMA with funds from Mrs. Nancy Susan Reynolds, the Sarah Graham Kenan Foundation, Julius H. Weitzner, and the State of North Carolina. This was one of the three small works in a predella (framed at the bottom) for the large Altarpiece frame shown on the right. A second panel by Raphael, *The Miracle of St. Eusebius of Cremona*, now at the Museu de Arte Antiga in Lisbon, Portugal, was one of the two other small predella works; the third is missing.

(picture courtesy of NCMA)



Original frame for Raphael's Mond crucifixion altarpiece (with image of the main panel from the National Gallery London added), 1503, Gavari chapel, Church of S. Domenico, Città di Castello

the town of Fabriano, which had a church dedicated to St. John the Evangelist, demolished in the early twentieth century. The altarpiece's patron – the widow shown kneeling on the right side of the larger central panel of the Crucifixion – must have had some connection to St. John the Evangelist. Perhaps he was her patron saint, or the patron saint of the altarpiece's chapel.

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Sketch of the 14th century St. Mary on the Rock church, in Offida, le Marche, Italy. The St. John the Evangelist altarpiece by Francescuccio Ghissi may have been commissioned originally for a similar church in this region.



THE MAKING OF THE GHISSI ALTARPIECE

WILLIAM P. BROWN

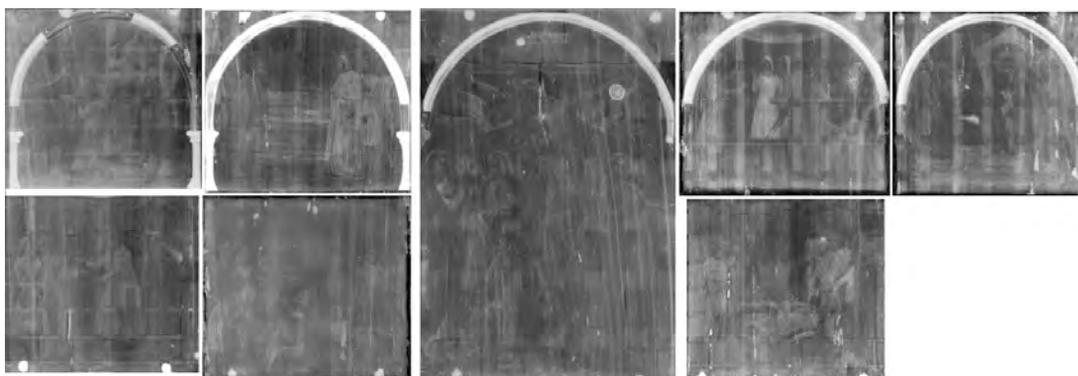
I first encountered Francescuccio Ghissi nearly 25 years ago. The NCMA's three Ghissi panels were brought to the Art Conservation Center in 1992 for research and back again to the lab in 1996 for conservation for the upcoming exhibition of the Kress collection, *A Gift to America, Masterpieces of European Painting from the Samuel H. Kress Collection*, curated by David Steel, NCMA Curator of European Art (David is the writer of the previous essay, and is the co-curator for *Reunited*). It was from this collaboration between conservators and art historians – and later mathematicians, scientists, engineers and a reconstruction specialist – that the idea for the exhibition came about. Who would have thought we would pass into the next century before the idea would come to fruition with *Reunited*?

With all the talk about the virtual, for this essay I will keep it real and talk about the actual construction of the Ghissi altarpiece, referencing medieval practices. An understanding of the object – the altarpiece – was essential in making the correct decisions regarding reunification and display of the altarpiece, and the reconstruction of the missing panel by Charlotte Caspers, whose essay follows.

All of the individual panels were restored recently, at least in restoration years – the NCMA panels 1996, Art Institute of Chicago 1978, Portland 2005, and the Met panels 1980's. This essay draws from these reports and personal examination of the paintings.

This 14th century altarpiece was originally constructed in a long rectangular shape – or dossal format – which was common in the 13th century, but not so much for the 14th century. The dossal format did provide flexibility for the depiction of narrative scenes, like with the St. John altarpiece (Keith Christiansen, *Met Bulletin*, 1982). Typically for altarpieces of both centuries, the surrounding framing and internal moldings were engaged, that is they were firmly attached to the wooden painting support with nails, then coated over with the same white gesso used to ground the support in preparation for painting. All of the frame moldings have been removed from the altarpiece, and we can surmise this was done when the altarpiece was dismembered over a hundred years ago (discussed in David's essay). Christiansen suspects that the altarpiece frame was a simple profile because there were no columns rising up between the arches to support finials or pinnacle paintings on top of the main altarpiece. The surviving five molded plaster arches, which were originally supported by pilasters, bracket the narrative scenes and give the altarpiece an updated appearance. Understanding the original format of the altarpiece was important for choosing an appropriate reproduction frame for the exhibition,

which will be discussed in more detail later in this essay. By studying the X-rays of all the panels, printed here for the first time composited together, we had confidence in our choices.



X-ray Composited by Noelle Ocon (NCMA)

The X-ray composite also gives much information on the construction of the panel. The wooden support is composed of five poplar boards with vertical grain and tangential cut. The boards join together vertically to make up the larger support plank. The construction process was straightforward, but followed a very specific order typical of medieval practice. The width of each board varies depending on location in the altarpiece; the board for the central crucifixion is about 21 inches wide, the boards to left and right of the crucifixion about 17 inches each, and the boards at the outside 16 inches. This progression is echoed in the relative sizes of the arches. Each board flanking the central crucifixion panel has a pair of scenes, one on the top row with arch, and one directly under without arch. Presumably the top and bottom rows would have been separated by a horizontal frame molding.

Much of the evidence of construction is missing, especially fasteners like hand-forged square-headed nails and wooden dowels; when the altarpiece was dismantled and dispersed to three different collections each individual panel was reduced in size, thinned and cradled (topic of other essays). Also, any signs of carpentry, like plane marks, were removed from the back. However, there appears to be subtle evidence from the X-ray of dowels down the right side of the *Crucifixion*. This would suggest that the boards were joined using wooden dowels and glue, a typical medieval practice. The plank, or maybe each individual board, was nailed through from the front into two fixed horizontal cross-battens on the back, one across the top and one at the bottom. The cross-battens provided structural strength and support for the altarpiece – the lower batten may have rested directly on the altar. The nail heads can be seen on the X-ray as white dime-sized areas, four per board – two at the top, and two at the bottom. The tops of the nail heads appear to be covered with small pieces of tin, per Cennino



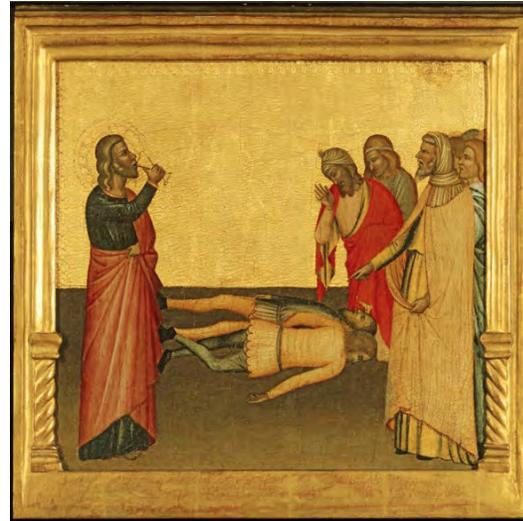
Cennini's recommendation, to prevent rust from the iron nail from penetrating through the gesso and staining the paint layer. More commonly, the nails were concealed behind the frame molding so did not pose a problem. Here they were placed well into the painted design, as can be seen in the X-ray, which may be evidence of the simplicity and modest width of the surrounding frame profile. Because the nails are evenly positioned on the ends of each board, I am wondering if the boards were nailed to the cross-battens one at a time. After the structural support was completed, all the moldings were nailed down and a layer of canvas laid down to cover over knots and other imperfections in the wood and provide a solid foundation for the gesso application. The Ghissi altarpiece does not have this canvas interlayer, which was most commonly used earlier in the 14th century, but tended to be used in strips, and less often not at all, later in the century.

To dismantle the altarpiece, the wooden moldings and cross-battens were first removed, followed by cutting apart the plank. The moldings included the surrounding frame molding, pilasters, capitals, and horizontal molding. These would have been relatively easy to pop off. The only remaining wood moldings are the short vertical strips of molding that extend down a couple of inches from the ends of the arches. Originally, where the arches met up side to side, the ends were supported by a single capital and pilaster which extended to the bottom of the altarpiece. In the X-ray, these areas are more transparent to X-rays than the denser plaster of the main arch – also you can see the two hand-forged nails used to attach each piece. Following the removal of the molding, the altarpiece would have first been sawn apart following the joints between boards, followed by a separation of the upper and lower scenes. Matching up the wood grain on the X-ray, confirmed that *Poisoned Cup* (lower level) was painted on the same board as *Acteus and Eugenius* (upper level), and in fact all the panels were properly placed as proposed by Christiansen. This left the bottom right corner as the missing panel, and the proper placement for Charlotte Casper's reconstruction of *The Baptism of Aristodemus*.

From the X-ray, you can see the approximate location of loss to the altarpiece. This is indicated by the narrow white spaces between panels. I suspect that when first cut apart the amount of loss was approximate to the width of the saw blade kerf, or approx. 1/8 inch for each cut. Sometime after the panels were cut apart and dispersed, they were likely further reduced in size when cradled by restorers for their respective owners. The panels which are closest to their original sizes are the three in the Met collection. When the two arched panels located to the right of the crucifixion are brought together, the two halves of the figure of St. Louis of Toulouse in the spandrel come together without significant loss. Compare this to the arched panel to the left of the crucifixion; when the two halves come together a considerable part of the proper right side of St. John's face is missing. The largest loss is about an inch on either side of the crucifixion panel, below the ends of the arches. Although, there appears to be very little actual loss to the gilded or painted design throughout the altarpiece – most of the losses



The Portland Ghissi panel, *The Resurrection of Drusiana*, in its frame with velvet liner, as designed for the 4 Ghissi panels when they were together, in the collection of Samuel H. Kress. (Image credit: Portland Art Museum.)



One of the NCMA panels, *The Poisoned Cup*, in its inner frame (velvet liner removed by NCMA), as designed for the 4 Ghissi panels when they were together, in the collection of Samuel H. Kress. (Image credit: NCMA)

are unpainted areas where the engaged frame molding was attached. This is most apparent with the *Poisoned Cup* located just under the Met's panel closest in to the crucifixion; the 15 3/16 inch width is the narrowest of the four panels located next to the crucifixion. The narrow width led to confusion on my part that the panel should be one slot over in the bottom right corner (the X-ray would prove me wrong). This difference in size between panels made sizing the reproduction frame, to be constructed for the exhibition, really challenging.

In addition to the reduction in size when cradled, another curious alteration is present with the four Kress Collection panels. The two arched panels to the left of the crucifixion were given short twisted columns and replacement capitals to complete the panel. These were made of plaster and are permanently attached. Also, the unpainted left and right edges for *Acteus and Eugenius* in the bottom left corner, were over-painted by the restorer to extend the painted design out to the edges, making it approximately the same width as *Poisoned Cup*, in the bottom right, next to the crucifixion. In addition, both panels were given frame liners which imitate the same column motif used in the arched panels. All the panels were framed with green velvet liner, popular for the 1930's. The panels must have looked very stylish in Samuel Kress's Fifth Avenue, New York City penthouse overlooking the Metropolitan Museum of Art, where his extraordinary collection of period furniture, decorative arts, carved chests and marble



Samuel H. Kress Residence, Venetian Sitting Room, 1925.

(Image credit: Department of Image Collections, National Gallery of Art Library, Washington, DC)

floors evoked the feeling of the Renaissance.

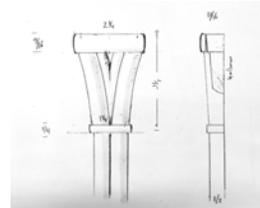
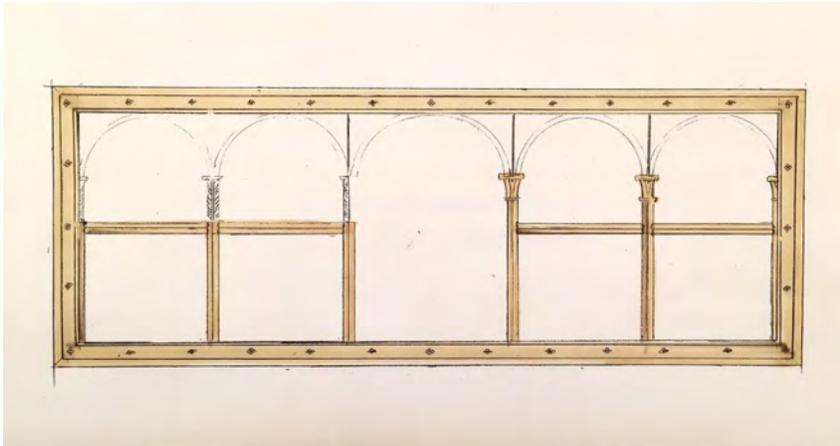
The reproduction frame for the altarpiece was constructed locally by furniture maker Evan Lightner. The design for the frame was a collaboration between myself, David, Evan, and George Bisacca, Panel Conservator at the Met. Inspiration was drawn from an early polyptych from the same region, the Marches, where Ghissi was active. It was painted about 40 years earlier than the Ghissi altarpiece, but has similar spandrels that bridge across between scenes and a pilaster profile we thought appropriate for the reproduction frame (top, altarpiece by Maestro del Polittico di Ascoli, Pinacoteca Civica, photo courtesy of George Bisacca). George also provided another photo (bottom) of an early Italian polyptych from which we borrowed the relief carved rosette motif for the outer frame.



(Image credit for both: Goerge Bisacca)



Below is the design which Evan drew up for the display of the Ghissi panels for the *Reunited* exhibition, with details of the capitals. The capitals are a Doric derivative with square abacus.



(Image credit for all three images: Evan Lightner.)

And here is the final altarpiece frame, gilded and ready for installation of the individual Ghissi panels.



(Image credit: Conservation Department, NCMA.)



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RECONSTRUCTION OF A LOST 14TH CENTURY PANEL

CHARLOTTE CASPERS

WHAT IS A 'RECONSTRUCTION'?

A 'reconstruction' signifies for me a '(re)creation of a historical painting that follows as closely as possible the original layering and painting techniques, using the same materials'. To achieve this, one needs not only the ability to paint, but also extensive information about the object to be reconstructed. This means, in particular, that this is not a project on which to work in isolation; it is best to maintain a close collaboration with others (such as scientists, art historians, art conservators), and – if possible – to be in close proximity to the original object.

THE GHISSI ALTARPIECE



panel 1 (*The Resurrection of Drusiana*) is in the Portland Art Museum, Oregon, USA, as part of the distributed Samuel H. Kress collection; panels 2 (*St. John the Evangelist Reproving the Philosopher Crato*), 3 (*Acteus and Eugenus Implore St. John the Evangelist to restore Their Wealth*) and 8 (*St. John the Evangelist and the Poisoned Cup*) are in the North Carolina Museum of Art, Raleigh, USA, likewise as part of the distributed Samuel H. Kress collection; panels 4 (*St. John the Evangelist raises Satheus to Life*), 6 (*St. John the Evangelist with Acteus and Eugeneus*) and 7 (*St. John the Evangelist Causes a Pagan temple to Collapse*) are in the Metropolitan Museum of Art, New York, USA, donated by Mrs. W. Murray Crane; finally, the larger panel 5 (*Crucifixion*) is in the Mr. and Mrs. Martin A. Ryerson collection in the Art Institute in Chicago, Illinois, USA.

(Image credit for each panel is with the Museum to the collection of which the panel belongs.)

The 'Ghissi Altarpiece' is attributed to Francescuccio Ghissi; it was created in the Marche

region (near the East coast of Italy) around 1370. Little is known about the altarpiece and its painter. It was executed in egg tempera and gold leaf on a support of European poplar; originally it consisted of 9 scenes, mounted together in a huge frame – a central crucifixion, surrounded by 8 smaller depictions of episodes from the life of St. John the Evangelist. In the course of history, the 9 panels were removed from their original frame and separated, after which the small panel chronicling the last illustrated episode from Saint John's life disappeared from the known records. The panels 1 through 8 are now distributed over four different art collections, as indicated above.

In 2012 I reconstructed this missing panel, while I was an Artist in Residence at Duke University (North Carolina, USA). The reconstruction was commissioned by the North Carolina Museum of Art (NCMA).



The reconstruction was made in preparation for the Fall 2016 “Reunited” exhibition, then still in the planning stages. Mounted together in a reconstructed frame, the eight still existing panels, reassembled for the duration of the exhibition, already present viewers with a more vivid impression of the original splendor of the altarpiece. Complementing this, a documentary movie about the creation of the reconstructed ninth panel, and the reconstructed panel itself, displayed alongside the other panels, inform the visitors to the museum about the historical creation process and techniques, and make it possible to imagine what the whole altarpiece possibly looked like when it was new, in the late 14th century.

sible to imagine what the whole altarpiece possibly looked like when it was new, in the late 14th century.

CREATION PROCESS

This project differs from the reconstruction projects I usually undertake, in that it concerned the reconstruction of an 'absent object', for which no visual documentation whatsoever was or would be available. The first and most formidable challenge was to determine the likely nature and composition of the missing scene from the legend of John the Evangelist. The other seven panels follow faithfully the text of the 'Legenda Aurea', a bundle of hagiographies penned by Jacobus de Voragine (†1298). Based upon this text, it was determined that the most likely final scene was the baptism of high priest Aristodemus and the proconsul with his family. Next, and after studying baptismal scenes in paintings contemporary with the Ghissi

altarpiece, a compositional drawing was made, based on pictorial elements (faces, draperies etc.) of the other seven small panels. It required quite some self discipline to maintain the stiff poses of the figures, without 'improving' on them. The three panels from the NCMA collection, together with the corresponding research results, were the most important source of information; where necessary, this was complemented by instructions from the medieval painting treatise by Cennino Cennini.



The description and figures below document the preparation of the support and the water gilding rather than the actual painting process; the latter is illustrated in more detail by a documentary video made by NCMA.

PREPARATION OF THE SUPPORT

1. For the wooden support I used a panel of $38.6 \times 35.3 \times 2.6$ cm in linden wood, since at the time of the reconstruction no panel of the right dimensions was available in poplar. X-ray photographs had shown that the altarpiece support consisted originally of five vertically oriented joined panels, later sawn apart. The missing panel would have been at bottom right. The width of the reconstructed panel is identical to that of the panel above it, depicting the scene in which St. John's prayers cause a pagan temple to collapse.



2. Meticulous preparation of the support is essential for a panel on which water gilding will be applied. This starts by covering the panels with layers of glue, which isolate the later layers from the underlying wood, and help in attaching the priming layers. For this reconstruction three layers were applied of different concentrations of rabbit skin glue, heated au bain marie.





3. Early-Italian panels are typically prepared with a so-called gesso priming; the gesso ground layer can be further distinguished into first a *gesso grosso* layer, and several subsequent *gesso sottile* layers. Here the *gesso grosso* layer is being applied with a palette knife. This layer consists of gypsum ($\text{CaSO}_4 \cdot 1/2 \text{H}_2\text{O}$), which, after water is added, sets to a hard consistency; mixing in some rabbit skin glue adds extra solidity. This hard and solid ground layer was essential for large panels. The challenge in this stage of the reconstruction is to mix the gypsum with the water (and glue if added) on a glass plate (it would have been a rubbing stone in medieval times), and then apply the mixture uniformly to the panel, all within the time span allowed by the chemical reaction that 'sets' the gypsum.



4. In his treatise, Cennino Cennini spends a lot of time on the preparation of the panels, describing in great detail how to prepare the gypsum for the *gesso sottile* layer. First the dry gypsum is mixed with a large quantity of water. It then has to stand for at least a month in water, during which time it gets stirred daily. This process leads to a very fine gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), which, in preparation for the *gesso sottile*, gets kneaded through a bowlful of rabbit skin glue. The resulting priming mixture has the consistency of a pancake batter; the first layer is massaged by hand into the already dry *gesso grosso* layer. Next follow at least six layers applied (alternatively horizontally and vertically) with a hog hair bristle brush.



5. When finished and dry, the priming layer is rubbed with charcoal, and then smoothed all over with a steel scraper. The charcoal serves to indicate the spots that have been insufficiently scraped. The result is a smooth ivory-like ground layer of sufficient elasticity to allow polishing and punching of the gold leaf.



6. This picture shows how the first red bole layer (from a total of six layers) is being applied on the parts that will be covered by gold leaf. Following to the instructions by Cennino Cennini, the bole has been bound with a mixture of egg white and water. To ensure that the bole is applied in the right places, an underdrawing must be made first. In this reconstruction, this was done with a watery paint consisting of gum Arabic and lamp black (corresponding to observations of the original Ghissi panels via infrared reflectography (IRR)). Contours that border the gold leaf are incised with a sharp object, so that they will retain good visibility after the gold leaf has been applied and polished.

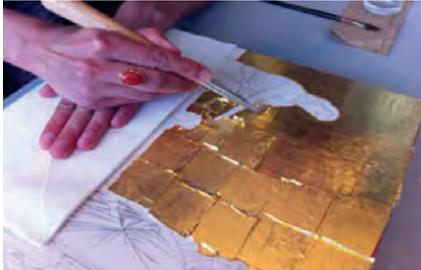


7. It is important to keep the bole layers completely free from grease, to ensure that the gold will attach well. After applying "gilding water" (a mixture of water and ethanol that activates the binder), the gold is 'laid down' on the bole layers. Medieval gold leaf was much thicker than what is available nowadays, and therefore easier to handle. Cennini describes, for instance, that the gold can be picked up with tweezers; with present-day gold leaf this would lead to instant tearing.

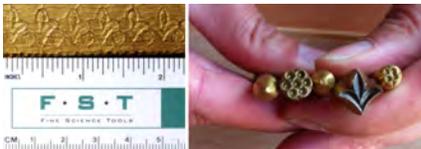




8. A few hours after being laid down, the gold leaf can be polished; it is preferable to do this the same day. In this picture one can see how gentle polishing with an agate, gradually increasing the pressure, produces a surface as smooth as a mirror. This process makes the gold surface less vulnerable, although it will remain delicate, and sensitive to water. Note that these mirroring gold surfaces are very hard to photograph; in reality the polished surface looks not as streaky as in this picture (or some of the further ones), but closer in aspect to the reflective surface in the figure below, where I am applying the punchwork. The original panels no longer present such mirroring reflections: the varnishing of the paintings, at some point in their history, including that of the gold surfaces, already removed this property; cracks due to aging disturbed this further.



9. This picture shows the 'punching' process: with a small hammer I hit small stamps into the fields of gold. In these stamped patterns, the gold leaf edges towards the (slightly) deeper-lying stamp-pattern bottoms, which affects how light gets reflected, providing local sparkling accents. When they later get clogged with dirt and the remains of varnish layers, these regions become more light-absorbent (and thus look darker) than the surrounding gold, so that the effect gets reversed through aging. Punches (and their patterns) constituted a finely manufactured, precious resource, and were studio-specific. In some cases, it is possible, by comparing punch work in early-Italian paintings, to determine to which studio a painting can be attributed. For this reconstruction special punches were made with motifs that appear in the Ghissi panels.





10. After X-ray and microscope examination of the NCMA panels, I could start painting. Since we were not allowed to carry out physical paint sampling, the pigments used were determined via X-ray fluorescence (XRF). X-ray pictures indicated the extent of lead white additions; occasionally IRR gave information about additions of carbon black to the paint mixtures. The pigments and painting techniques correspond to practices in general use in the Middle Ages. The paints for this reconstruction were prepared according to the instructions of Cennini (equal parts of egg yolk and water). As for the original Ghissi panels, the background (in this case the floor) was painted first, followed by the brown-green bottom layers for the incarnates (flesh tones). A special aspect of these green layers in the Ghissi panels is that they contained, in addition to the usual pigments, also some coarse-grained azurite.



11. This picture illustrates the painting of the draperies. The pinkish purple and blue robes of John are executed according to the system of three color gradations described by Cennini: the darkest color at the start, after which the folds are elaborated with two lighter gradations, ending with highlights and darker lines, richer in binding medium, on the shadow sides. In this picture the red robes, for the group of figures in the background, are still in an initial stage. Comparable red robes in the original panels turned out not to be painted according to the 'three-valued grading system', but as uniformly red areas, with highlights that have now turned gray. For this we could also find a usable description in Cennini: painting the red robe in vermilion (as confirmed through XRF examination) with highlights in orange red lead. The pigment mixtures could be determined for all the robes, except for the mantle of the kneeling Aristodemus in the foreground. The version of this mantle in panel 8 seems to have lost its color in the course of time through the fading of a lake; additional material-technical research would be necessary to determine the correct original color. For the panel 9 reconstruction we chose to retain the neutral color of the discolored mantle.

12. Finally, here is the finished panel: all robes are filled in and fully detailed, the green underlayers are covered to provide life-like flesh colors, and the last few details and delineations have been completed.



[this essay is a translation, slightly adapted with the author's permission, of a text in Dutch by Charlotte Caspers under the heading *Historical painting techniques* in κΜ 92. κΜ or 'kunstMateriaal' is a magazine publication in Dutch on Art Materials and Techniques for visual artists and visual content providers; κΜ volumes often center around a theme – for volume 92 this was 'Licht' (Light) (see www.kunstenaarsmateriaal.nl)]

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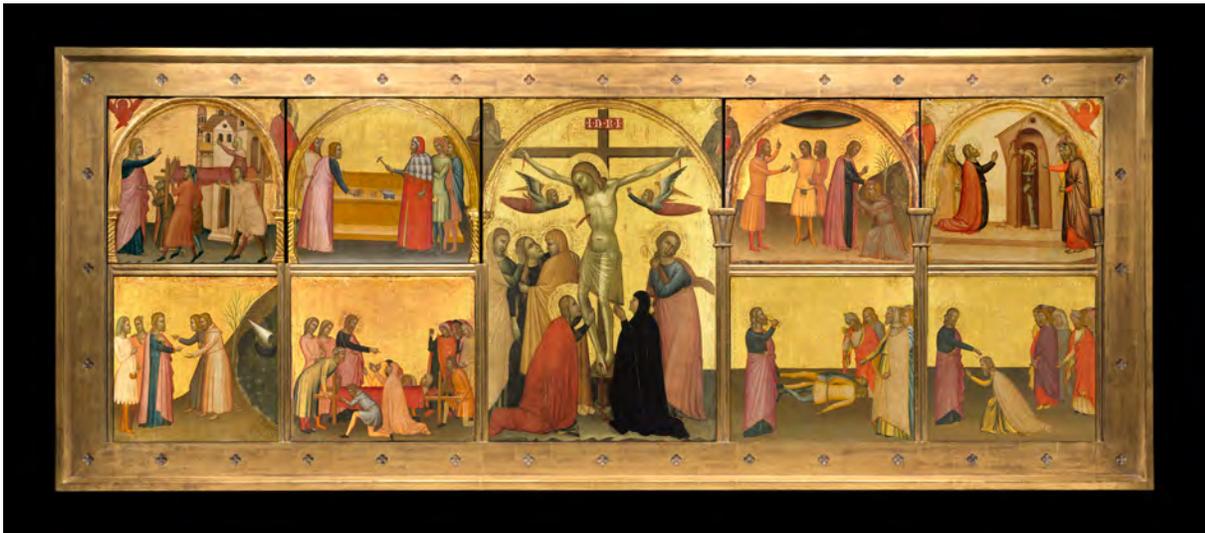


Image credit: NCMA

REJUVENATING (AND AGING) THE GHISSI ALTARPIECE:

A RESULT OF TRUE TEAMWORK

BRUNO CORNELIS

INTRODUCTION TO THE PROJECT

After Charlotte Caspers' reconstruction of the 9th panel in preparation for the reunification of the Ghissi Altarpiece, the contrast of its vivid colors and shiny gilded features with those of the other panels made us realize that it would stand out when exhibited right next to the older (original) panels. Hence came the idea to digitally process the high-resolution images of all the panels: the existing panels could, virtually, be made to look just as fresh and shiny as the reconstruction; the new panel could be virtually aged.

The differences between the older panels and the reconstruction are quite significant; due to aging the paint changed color in many places, crack patterns emerged and the gold leaf lost most of its shiny appearance. Furthermore, the original panels aged differently after they were separated, as they are now in different collections at separate locations, each with its own conservation history. Finally, the 'raw material' pictures for the digital processing consisted of (digital) high-resolution photographs, taken by a different professional photographer at each museum; the consequent unavoidable differences in lighting and other settings caused yet another way in which our digital pictures of the panels differed from each other.



The pictures of panels 1 (Portland), 3 (NCMA) and 6 (Metropolitan) show differences due to both lighting and conservation history. (Numbering of the panels is as in the essay by Charlotte Caspers.)



Details of the Robe of St. John in panels 1, 3 and 6. The difference in aspect of the red could be due to lighting differences; in panels 1 and 6, more darkening dust has been removed between the coarse azurite grains in the blue.

The image processing required to make the digitized panels more uniform in appearance is quite elaborate. We devised a workflow, consisting of several different processing steps, to gradually make the older panels look like new. Even though the steps all used powerful



state-of-the art methods, none of them were designed as completely automatic algorithms – typically, parameters needed to be picked, or other choices made, by a human operator, at several stages during each of these processes. This meant that the actual processing of the high-resolution images was still a daunting task. Therefore, we recruited a number of talented Duke undergraduate students, willing to learn image processing and with an interest in art. What follows is an overview of the various processing steps for the rejuvenation of the older panels and the aging of the new reconstruction; this essay concludes with my own impressions on managing this multi-level project, crossing the boundaries of very different disciplines.

DIGITALLY PROCESSING THE GHISSI ALTARPIECE

The interdisciplinary nature of this project necessitated an intense dialog between the people doing the technical work and art experts, in particular Bill Brown, head conservator at NCMA, whose specialty is in Italian painting and the conservation of Italian old masters. The team of Duke undergraduate students started with just two students, and was later expanded to five. In last name alphabetical order, these were Geena Gomez, Raphael Kim, Mitchell Parekh, Sam Slack and Mason Taylor. Each was assigned a specific task: the removal of crack patterns (Sam), color mapping from old to new and vice-versa (Raphael and Mitchell), the rendering of gold leaf (Geena), and the generation of new crack patterns (Mason). After we briefed them and I walked them through the different processing steps, the students familiarized themselves with the algorithms and software, exploring both their power and limitations. The results obtained were systematically shown to Bill Brown, who gave detailed feedback for further improvement.

Detection and removal of crack patterns

The crack patterns in the different panels are clearly discernible with the naked eye on the photographs taken in visible light; unlike in the earlier crack detection and inpainting project carried out for the Ghent altarpiece, we did not gain much by also using the X-ray photos for the Ghissi project. The cracks are too numerous to mark them individually by hand; from the start, it was clear we would use an automatic algorithm. However easy it is for humans to detect the cracks accurately, it is not obvious at all to construct a computer algorithm that detects *all* the cracks and *only* cracks. Most of the detection algorithms we employed took into account that on the digital image, cracks are thin, elongated structures that are considerably either darker or brighter than their surroundings. We observed that crack patterns also depend on the material composition of the paint – for the detection algorithm this meant that some color fields had denser crack patterns than others. Consequently, the algorithms were developed so that they emphasized elongated structures in the image and so that their thresholds could be tuned to each local color field separately. Because cracks are not the only elongated structures in a painting, the algorithms sometimes marked e.g. thin brushstrokes as crack candidates; we thus

also designed the algorithm so that manual intervention could overrule algorithm decisions for individual cracks when inspection of the automatically generated crack map by a human user revealed such wrong labeling. The figure below shows the resulting crack map (red pixels) for a detail of panel 3.

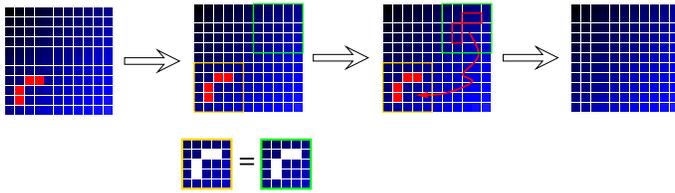


After the crack patterns are detected, they need to be removed digitally. This is done by using a *digital inpainting* method, designed to automatically fill in missing content (or, in different applications, remove unwanted objects) in images, as unobtrusively as possible. This family of algorithms requires as input the original digital image, marked with those pixels that need to be filled in. (The latter are, in our case, exactly given by the crack map generated in the first step.) The inpainting algorithm will then attempt to determine, for each marked pixel, what would be its most likely content, given the remainder of the image. That is, it searches the remainder of the image for pixels that have very similar surroundings to the pixel-to-be-filled-in, and then uses an appropriately weighted average of those other (known) pixels to “inpaint” the missing pixel.¹ If the algorithm can find sufficiently many areas that are similar and where no cracks obscure the central pixel(s) (which it usually does), then the automatic

¹ The concept of ‘inpainting’ is of course very familiar to art conservators. It is one of the many steps in a standard conservation process for paintings that have suffered paint losses, i.e. in which there are areas where the paint layer is no longer present. Conservators then draw on their extensive knowledge of painting techniques and materials used in the original, and on their close observation of the style and technique in the particular painting on which they are working, to ‘paint in’ the bare areas with the most likely color content, given its immediate surroundings. In fact, digital inpainting was first developed by image analysis experts after they observed art conservators carrying out ‘physical’ inpainting.



inpainting performs very well. The figures below illustrate the process.



Schematic representation of the pixel inpainting process: determine a neighborhood (yellow border) of the missing pixels (solid red) and another area elsewhere of the same shape (green border), in which, for the non-missing pixels in the yellow block, the colors at the corresponding spots in the green block are very similar (here they are identical); then, for each missing pixel, copy into the yellow block the color of the corresponding pixel from the green block.



Detail of Ghissi panel 3



Same detail, after inpainting of the 'crack pixels'

Color Mapping

The images of the panels look very different as each panel went through its own specific aging process. Furthermore, the high resolution images we were given have different color schemes and resolutions because they were acquired by different photographers using different cameras under different lighting conditions.

The goal of the 'digital rejuvenation' was to make each panel picture look as if the panel were freshly painted, and then photographed under the same conditions as the new Caspers panel. More precisely, two color planes on different panels that were painted in the same way, and with the same pigments, should thus also look very similar in their digitally rejuvenated form, as indeed they would have in the 14th century, just after Ghissi had completed his work. Because the high-resolution digitized photographs of the panels differed so much in their color schemes, the color-remapping scheme had to be determined separately for each panel.

As illustrated in the introduction, some pigment mixture colors had changed very little over the centuries (e.g. bright vermilion), while others had altered significantly (e.g. azurite blue robes looked almost black in some of the panels). This meant that within each panel, areas of different colors also had to be treated separately. A first step consisted therefore of *color segmentation*: within each panel, zones or segments of similar color were identified². The

² The segmentation was *not* simply an automatic Photoshop selection of those pixels that had the same color. Within one of our segments, there typically might be many different shadings, as a result of highlighting or the presence of slightly darker mixtures to indicate shadow zones – these would correspond to different

figure on the right illustrates the identification of one such zone (bordered in black) on (a detail of) Ghissi panel 3, and the result after mapping its color to what had been determined (after XRF analysis of the pigments) as its likely color in the 14th century.

It was not immediately clear what procedure to follow for the color-remapping of each segment. The original intention was to use an Adobe Photoshop plug-in called Powerstroke. In the end, and after much experimentation, Raphael and Mitchell developed an ad-hoc technique within the Adobe Photoshop framework that produced luminous colors, gratifying to the art conservators, while at the same time respecting the original highlights and shadow regions, as well as preserving crisp borders.

It was important to our whole team that every stage of the image processing intended to remain 'true' to the historic panels, and to use techniques that would produce the best possible results, in accordance with the knowledge of the art historians and conservators, within our framework of human-assisted automatic image processing tools, without 'inventing' features. In particular, our color mapping does *not* add new content, such as brushstrokes, to the painting.

The goal was to preserve the brush-stroking and painterly buildup of the painting, to the extent these could be seen in the high-resolution photographs, but to adjust for the color alterations that had taken place over time. This naturally led to shortcomings at every stage in the image processing: even our very sophisticated crack removal and inpainting algorithms missed some of the cracks; in areas where the painting has lost some contrast due to fading of colors, it was decided, after consultation with the art conservators, not to try to 'recreate' highlighting brushstrokes if they could no longer be seen on the faded painting. (This is similar to the decision made by Charlotte Caspers in the reconstruction of the 9th panel, with respect to the robe of the kneeling Aristodemus – having insufficient evidence about the correct color from the panel preceding it in the chronology of the altarpiece scenes, she kept it similar to the neutral, faded color from that panel.)

Sustained communication with Bill Brown, and occasionally with Charlotte Caspers, was a very important part of the project. The students on the team were encouraged to contact them often, whenever they had questions that required choices. This was especially important in order to end up with color schemes that were consistent with all the evidence and with the

pixel colorations. On the other hand, there might well be, within the picture, pixels that had identical colors in the high-resolution digital photograph of the panel, but that belonged to different segments, with different pigments, and thus likely needed to be colored differently in the rejuvenated version.



Left: detail of Ghissi panel 3; middle: one zone is segmented (as indicated with a black border); right: this zone has been color-remapped.

experience of the conservators. The figure below shows the full color scheme remapping for panel 3, of which a detail was shown above. (Note that the gold leaf segment is removed; rejuvenating the gilded portions was not part of the color-remapping sub-project; we'll come back to it below.) Note in particular the difference in the faces of the personages. The robe of the leftmost figure (which was shown in the detail above as well) is one example that stands out by its lack of apparent modeling. In this particular color, fading is very pronounced and the modeling highlights and shadows can no longer be distinguished, although their earlier presence can be guessed from the underpainting that now shines through the paint layer (as it probably did not yet in the 14th century), indicating where modeling strokes were to be painted.



Left: scene on Ghissi panel 3 after the cracks have been detected and inpainted; right: the same scene after all the colors have been remapped. In both scenes, only the painted surfaces are shown, without the gilded background. In the gilded painting, a circular gold halo (with punchwork) surrounds the face of St. John, obscuring part of the head of the second figure from the left.

Rendering gold leaf

In the images of the old panels the gold leaf background has a completely matte appearance, with a very dense crack pattern. Rejuvenation was in order! On the other hand, even the photographs of the new reconstruction do not do justice at all to the beauty of the gilded surface, reflective and shiny, with its sparkling punchwork. In photographs, we recognize metallic surfaces because they show reflections of their surroundings, suitably deformed in accordance with the shape of the metallic object. In a movie, the reflections also change as the viewer (or camera) changes position. It dawned on us that to give a good impression of



a truly reflective surface, we needed to go beyond 2D image processing and use 3D computer graphics. On the advice of professor Anselmo Lastra at the University of North Carolina (UNC), Geena studied the 3D modelling and rendering program Maya. Using Maya, she first made virtual 3D panels, on the top surface of which she put the inpainted and color-remapped painted surfaces. The remainder of the top surface then needed to be filled in by a model of the gilded complement on that top surface. By experimenting with different parameters, she identified how to make the surface look like polished gold leaf, together with its small imperfections; she then proceeded to render the slight stamped indentations corresponding to the punch marks, the shapes and locations of which we had ‘lifted’ from the photographs of the panels. For this last component, Geena was helped enormously by Ed Triplett, of the Wired! lab in the Department of Art, Art History and Visual Studies at Duke.

At the start of the project, Ingrid Daubechies and I had a pretty good idea of how the crack detection, crack inpainting and color-remapping sub-projects could be tackled. Many of the details still had to be pinned down, and some aspects (such as the color mapping) finally did use a direction quite different from what was initially planned, but we felt confident we could do it all. The gold rendering was more challenging in that it really went beyond what was familiar to us. We are grateful to Anselmo Lastra for helping us in mentoring Geena and to Ed Triplett, who suggested more efficient ways to transfer the punchmarks to the gold surface, and who then worked with Geena to render them. The assistance of both Anselmo and Ed was crucial in bringing this part of the project to a successful conclusion.

Generating new crack patterns

The goal of the project was not only a virtual rejuvenation of the older panels but also a virtual aging of panel 9, as reconstructed by Charlotte Caspers – indeed, the virtual rejuvenation plan had emerged only after it had been decided to undertake the virtual aging of panel 9.

To age a digitized version of panel 9, a first step was to color-remap the ‘new’ colors to their ‘aged’ version – this consisted simply in reversing the color-remapping used for e.g. panel 8. Introducing cracks was, however, a step that could not be viewed, at least in its technical image analysis implementation, as a natural inverse of the crack detection and inpainting we had carried out for the old panels. Instead, we had to devise a method to generate crack patterns that look like those found in the original panels.

For this sub-project we looked first into a numerical method inspired by the physics underlying the cracks. One of the most important causes of cracking are changes in climate conditions, such as shifts in temperature or variations in humidity level, which cause the wooden support to expand or shrink. The movement of the wood panels generates stresses within the paint and gesso layers; when these stresses exceed what these layers can absorb elastically, cracks form. Our numerical method, although heuristic in nature, meant to mimic this phenomenon computationally (without, however, constructing a true physical model for the whole structure,



which would have been a much more complex task). The paint surface is divided into small triangles (in technical terms this is called a *mesh*), each associated with a particular stress component that is manually defined. Because different pigment surfaces in e.g. panel 8 corresponded to different crack widths and density, this would be a segment by segment process, using the same segmentation as for the color-mapping: assigning different stress levels and stress orientations to each color segment would result in different crack patterns per painted segment.

Although the method gave interesting results, and we still hope to perfect it further for some other project, time pressure finally pushed us to a more ad-hoc method, in which we extracted crack patterns from the gilded part of images of old panels (it was easier to extract them there than in the painted portions), and used them (after coloring them appropriately for the different color planes) as an overlay.

A TRULY COLLABORATIVE PROJECT

The rejuvenation of the Ghissi altarpiece was one of the most interesting projects I have had the opportunity to work on; it involved not only interesting technical challenges but also very interesting management and communication issues among people from very different backgrounds. It started off as a “simple” project (which we underestimated greatly) but quickly grew in scale. The high resolution images we received as our ‘input’ were challenging, coming from very different sources; rejuvenating them and making them look more uniform required great attention to detail. We realized quite early on that we would need extra ‘bodies’, and we were fortunate to find undergraduate students with great interest in the particular combination of image processing and art. Geena, Raphael, Mitchell, Sam and Mason were introduced to advanced scientific and graphics tools that are currently very relevant (and will likely remain so in the future) and quickly became proficient in their use; they remained excited about the project throughout. A large part of the project relied on communication between different parties; communication between the students and myself, communication amongst the students themselves, and, crucially, also with various experts from the art community. Those students who joined our little group after the initial start were smoothly briefed by the “veterans” and quickly started producing results of comparable high quality. Interacting with Bill Brown and Charlotte Caspers went very smoothly as well. Whereas I initially was in charge of liaison with the art conservation studio at NCMA, the students quickly took the initiative of seeking contact themselves with Bill Brown, between our weekly update meetings, and diligently took his advice into account. Although the dialog between people of different background is not always straightforward, and it sometimes took a few exchanges before everything was clear to everyone, sustained communication and seeking common ground proved to be key to the successful realization of the project.



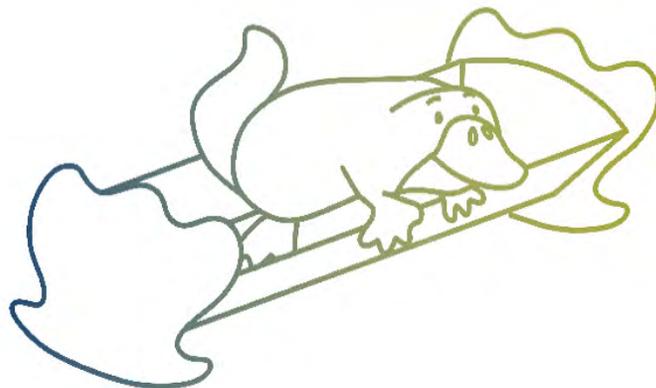
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platypus



VIRTUAL PROBING OF REAL MASTERPIECES:
REMOVING CRADLE ARTIFACTS FROM X-RAY PICTURES OF
PAINTINGS ON WOOD PANEL

RUJIE YIN

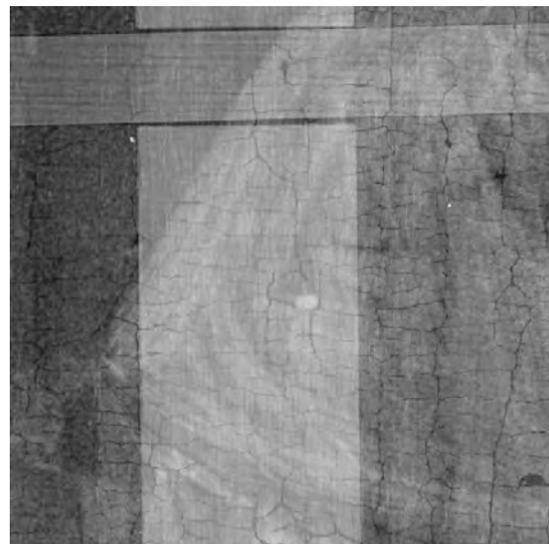
FRAMING THE PROBLEM

What can be seen in an X-ray?

An X-ray photograph of a panel painting shows layers of paint content supported by the wood panel, including both original brush strokes and retouches by conservators, as well as damage, e.g. cracks and worm holes, present in the paint layers or the wood panel. For cradled panel paintings, the much thicker wood mass, to be penetrated by the X-rays in locations where cradle members are present, causes very visible artifacts on the X-ray photograph that obscure the reading by experts of the details they want to see in the high resolution X-ray photographs, such as fine details of brush strokes and past conservation retouches. The X-ray photos also contain wood grain from both the panel and the cradle attached to it.

What should be taken out?

Since the X-ray pictures are used by professional conservators at museums to study the condition of panel paintings, they should be kept as 'authentic' as possible. Therefore, only the components from the cradle that impair the reading of the X-ray pictures should be removed, *without introducing extra artifacts*. It is *not* about prettifying the X-ray pictures!

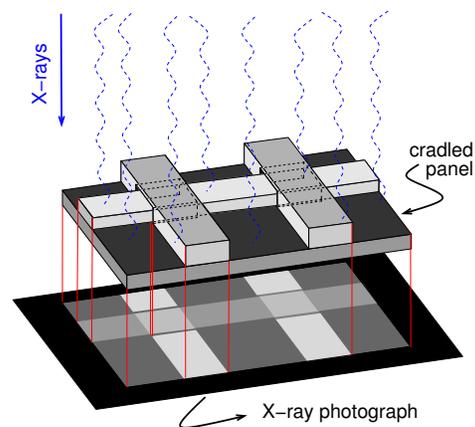


Detail of the X-ray picture of Ghissi panel 2, centered around the bottom left corner of philosopher Crato's cape. A fixed (nearly vertical) and a sliding (nearly horizontal) cradle member intersect; both are slightly tilted with respect to the axes. A small paint loss area (dark) is visible near bottom right. Wood grain of both panel and cradle members can be seen throughout; that of the sliding member is particularly pronounced.

[Note: This does not mean that additional image processing tools, enhancing certain features, don't have a place in the study of these X-ray pictures. Indeed, art conservators often use image processing to enhance certain aspects, e.g. within Adobe Photoshop™, in order to refine their understanding of puzzling features in the X-ray photos, or to make details more apparent for publication. However, we saw the goal of *this* particular image processing tool as the (semi-automatic) removal, as best possible, of the impact of cradle artifacts from the digitized high-resolution X-ray photos, without impinging on any of the other features present in the photo. In particular, this meant that the algorithm would not make *any* changes to areas of the photo where no cradle member was present. Any subsequent desirable image processing (e.g. to brighten dark, over-exposed areas) was left to the art conservators using of the output of the algorithm, who were better placed than we to judge what enhancements would most benefit their subsequent art historical study.]

STEP 1. ADJUSTING BRIGHTNESS IN REGIONS WITH CRADLE

X-ray pictures of paintings are taken by *transmission*: the X-ray source is on one side of the painting, and it sends X-rays through the painting to a film or detector located on the other side, typically in close contact with the back of the painting support. An X-ray that makes it through causes a dark spot on the film or the detection screen; locations where X-rays are absorbed to some extent are thus rendered as regions on the X-ray photo that are brighter. Features become visible on such X-ray photos because of their different absorption rates for X-rays. Where cradle members are present, the much thicker layer of wood traversed by the X-rays causes much greater absorption, so that these regions look much brighter on the X-ray photos than cradle-free regions. The extent of the change of brightness is closely related to the thickness of each cradle member.



A schematic representation of X-raying a cradled panel, with brightness on the X-ray photograph corresponding to the total thickness of the wood layer absorbing the X-rays at that location.

When X-ray photographs of paintings on cradled wood panels are taken, an X-ray with uniform beam intensity is used to illuminate the whole panel. The difference in absorption between cradled and cradle-free regions is such that the operator typically has to balance between the degree of under-exposure of the cradled regions with the over-exposure of the cradle-free



regions. In most examples we have seen, the effect is strongest in the cradle-free regions; as a result, these tend to have smaller contrast because they are over-exposed.¹

To correct the brightness in the cradled regions, the X-ray picture first needs to be segmented into pieces, typically rectangle-shaped (or rather, slightly parallelogram-shaped; see below), that are either cradle-free or cradled; the latter are still distinguished in having a fixed cradle member, a sliding cradle member, or an intersection of both.

The adjustment within each cradled piece is estimated by an effective mathematical model that observes and then incorporates the brightness of neighboring cradle-free pieces.

Angle of cradle members

At the very high resolution of the X-ray images on which we work, cradle members are rarely perfectly aligned horizontally or vertically – they are tilted by fairly small angles with respect to the horizontal or vertical axes in our digital rastered images. These angles need to be estimated accurately, so the exact location of the cradle members can be taken into account in the segmentation.

Cross section profile

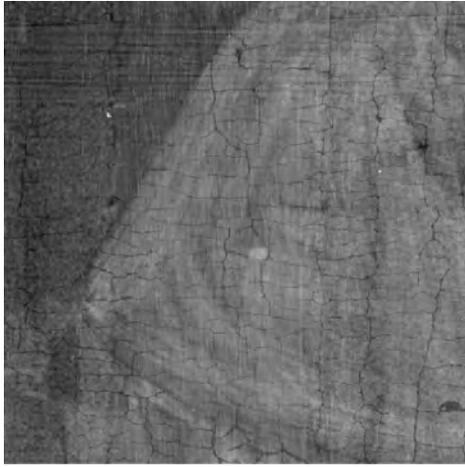
The cross sections of cradle members from the same painting are typically the same, but they can be different across paintings. The cross section profile determines how the brightness changes in the cradled region; we designed the mathematical model so it could adapt to various profiles.

STEP 2. REMOVING WOOD GRAIN FROM THE CRADLE

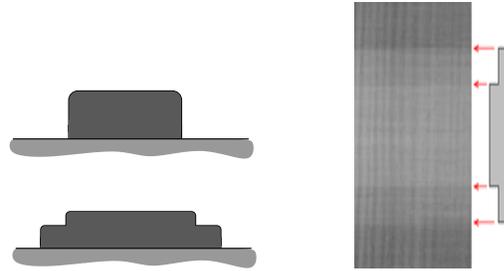
Although the X-ray pictures are already more interpretable after the brightness adjustment, the art conservators (at NCMA, at the Prado Museum in Madrid, and at the Royal Institute for Cultural Heritage in Belgium) with whom we discussed desirable features of our algorithms (as we were building them) wondered whether we could also remove the wood grain of the cradle members, while leaving the wood grain from the original panel untouched – a much more delicate image processing task, requiring a very different approach.

Wood grain does not have a completely regular pattern within one piece of wood; its texture

¹ Since the effect of our image analysis tool is to remove the visible artifacts of the cradle, and we don't want to touch the cradle-free regions (see above), this means that the output of our tool typically looks 'too dark', since the cradled regions will be brought to an average level similar to that of the cradle-free regions. This can then be remedied by further image processing/enhancing by the art conservator. It should be noted, however, that the loss of subtle contrast due to under- or over-exposure (depending on the region) inherent to the original X-ray photos will persist, and cannot be undone without additional information.



The result after *step 1* (brightness adjustment) on the same X-ray picture detail from panel 2. Note that the wood grain of the horizontal cradle member is still very much present.



Two different cross-section profiles: a standard regular rectangle profile (with rounded corners), as used in e.g. the cradles of the Ghissi panels, and an inverse “T”-shaped profile, used in e.g. the Ghent Altarpiece by Van Eyck. The small X-ray photo detail on the right shows a portion of a sliding member with a T-profile, from the *Joos Vijd* panel of the Ghent Altarpiece. Note also the very pronounced *panel* wood grain in this X-ray picture.

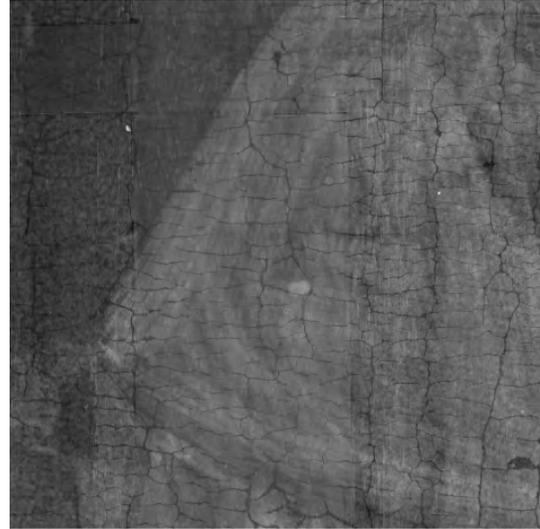
also varies a lot across the different types of wood used for cradling. Reliably identifying the wood grain component would thus not be straightforward. The aim of removing *only* cradle wood grain made this task extra challenging, since cradle wood grain was never observed ‘in isolation’: cradled regions contain the wood grain of both panel and cradle, while cradle-free regions contain wood grain from only the panel (which would, however, not have a pattern *identical* to that of the panel wood grain in neighboring cradled regions, because of the local variability of wood grain).

To deal with this part of the problem, we used several recently developed machine-learning algorithms. Basically, we used them to *observe* the different wood grain patterns, which helped us separate wood grain from other fine-scaled features (such as brush strokes) within the image. For the wood grain texture, the algorithms then had to separate, when working on a section with wood grain from a combination of cradle and panel, the features into those more likely to pertain to the panel and others more likely from the cradle.

This turned out to be a very challenging machine learning task: learning the different types of wood grain is hard, and it is delicate to then separate them. In practice, this second step of the procedure takes *much* longer than the brightness adjustment step: it requires hours rather than the few minutes (or even less) needed for that first step. ²

² Fortunately for us, art conservators are, of all possible users for image processing tools, the most tolerant of lack of speed – maybe because they often have to be extraordinarily patient in their work, e.g. when cleaning painted surfaces using nothing but Q-tips and distilled water! On the other hand, we found they also

Again, the guiding principle was to obtain the best possible result without removing any content that would be meaningful for further examination by art experts. When the cradle wood grain is too similar to features present in the panel, there is no guarantee that the algorithm will remove it. In practice, this means that cradle wood grain removal is often more successful for the sliding cradle members (the wood grain of which is perpendicular to that of the panel) than for the fixed cradle members (which have wood grain parallel to that of the panel). In addition, when the same type of wood is used for the cradle as for the panel (as in e.g. the Ghent Altarpiece, where both panel and cradle use Flemish oak), it turns out to be impossible to extract and remove the cradle wood grain in regions with a fixed cradle member: although it is often clear that the wood grain is denser (because it comes from both cradle and panel sources) than in cradle-free regions, it turns out to be impossible to separate the two.



Result for the same X-ray picture detail again after Step 2 of the algorithm – the wood grain of the horizontal sliding member is now removed.

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Website:

[services.math.duke.edu/~rachel/
project-platypus.net](http://services.math.duke.edu/~rachel/project-platypus.net)

have an extraordinarily high standard when judging quality of results.

WORKING WITH PLATYPUS

NOELLE OCON

Two Belgians, a Hungarian, an Asian and an American walk into a room!

That is not the start of an inappropriate joke, but rather the beginning of a wonderful relationship between the North Carolina Museum of Art and Duke University. And along the way we lassoed the Free University of Brussels and Digital Film Tools into our platypus family.

Over the course of my conservation career, I have enjoyed working with those in the sciences, and I have found that scientists are very excited when their knowledge and skill-set can be used in new and interesting applications. How we find each other is often serendipity, as are the projects that might result from such a meeting. This is how the Platypus project took shape.



Analyzing the NCMA's 14th-century *Crucifixion* by Puccio Capanna, with a pump-probe laser in the lab of Dr. Warren. (Photo credit: Bill Brown)

Our strong relationship with Duke University started fortuitously in 2010, when Professor Warren Warren, Director for the Center for Molecular and Biomolecular Imaging (CMBI), met with Bill Brown to discuss the possibilities of a collaboration with the Art Conservation Center. A follow-up meeting between Dr. Warren, his science colleagues from Duke, and Museum conservators and curators resulted in an image analysis and processing collaboration, the *Art + Science Initiative*. That initiative assisted in the research of important paintings from the Museum's European collections, with fascinating results. For instance, the pump-probe laser analysis illustrated in the picture revealed that the Madonna's blue robe in Puccio Capanna's *Crucifixion* was painted with ultramarine (from lapis lazuli), the costliest blue pigment available (rather than azurite, still expensive but less so), suggesting the painting was more important than previously realized. (More details can be found in the *Proceedings of the National Academy of Sciences* paper listed as reference below.)

At a meeting organized by CMBI that was showcasing some of these results, we had the good fortune to meet Ingrid Daubechies and her team. As Ingrid described in the introduction, this led to several collaborative projects, and in particular to the development of PLATYPUS, a software tool with which art conservators can remove cradle artifacts from X-radiographs of paintings on wood panel.¹

The most rewarding part of working with team Platypus has been the intersection of art and science. Using mathematics as a way to help the field of conservation is exciting.

So how is Platypus working in real life?

X-radiographs are useful for the conservator to assess condition, construction, materials and technique of the artwork. For example, in the X-radiograph detail below left, the brushstrokes are still visible even with the cradle pattern, but the pronounced cradle artifacts are so distracting that it can be hard to decipher the artist's style and technique.

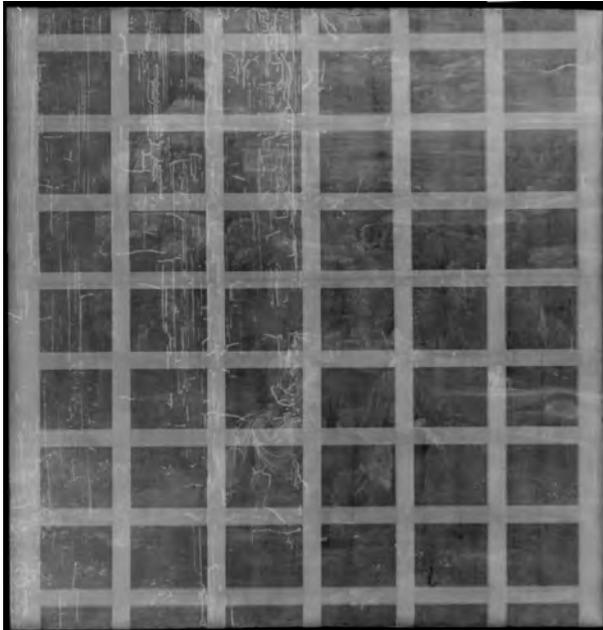


X-radiographic detail of *The Pentecost*, circa 1530, Follower of Bernard van Orley, 37 1/2 x 43 3/4 in. (95.3 x 111.1 cm), oil on panel Purchased for NCMA with funds from the State of North Carolina, 52.9.90.



Same detail, after treatment by Platypus. The lack of contrast in areas above a cradle member (compared to the remainder of the painting) is due to the severe under-exposure of these areas in the original X-radiograph. (Image credit: Noelle Ocon, NCMA.)

¹Why is it called PLATYPUS? When the programmers of DIGITAL FILM TOOLS, the company that wrote the interface pointed out that we needed a name and a logo, we struggled with turning *Virtual Cradle X-Radiograph Artifact Removal Tool* into less of a mouthful – VCXRART wasn't very appealing as an acronym either. When I pointed out that maybe the name didn't need to have a semantic connection with its function, but rather something people would remember, "like, I don't know, 'platypus' to give a silly example", Ingrid's face lit up, and she announced, Platypus it is!



X-radiographic composite of *The Flight into Egypt*, circa 1530-1535, Master of the Female Half-Lengths, 25 3/4 x 24 7/8 in. (65.4 x 63.2 cm), oil on panel, purchased for NCMA with funds from the North Carolina State Art Society (Robert F. Phifer Bequest), G.52.9.105. (Image credit: Noelle Ocon, NCMA.)



Same X-radiographic composite of *The Flight into Egypt*, after treatment by Platyplus. The nature of the panel, constructed by joining two planks, is now much more clearly visible.



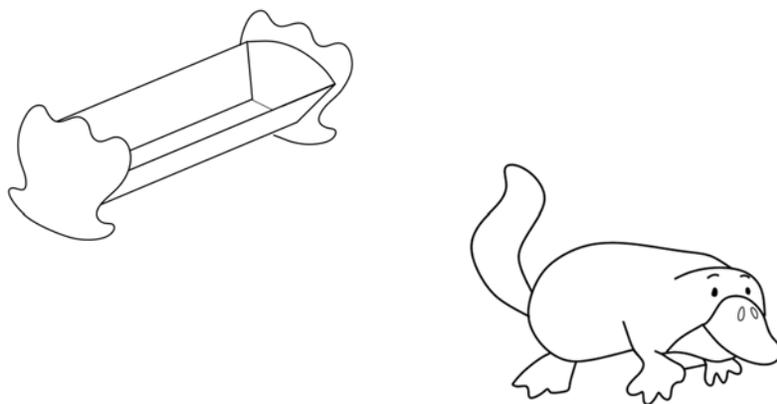
Other times, inspecting the X-radiograph can help determine the overall condition of the painting. For example, on the X-radiograph at the top of the preceding page, it is hard to see the line of demarcation between panels at first. When the cradle is removed, it is delineated by the worm-tunneling seen on the left side of the panel.

I have absolutely enjoyed working with the entire team for this project. The best part was the interdisciplinary aspect, working with people from different industries and coming together with the combined skills of all. I hope to continue our collaboration further!

Bibliography:

Tana Elizabeth Villafana, William P. Brown, John K. Delaney, Michael Palmer, Warren S. Warren and Martin C. Fischer, *Femtosecond pump-probe microscopy generates virtual cross-sections in historic artwork*, Proc. Natl Acad. Sc, vol. 111, nr. 5, pp. 17081713, DOI: 10.1073/PNAS.1317230111.

Noelle Ocon, Rujie (Rachel) Yin, Bruno Cornelis, Gabor Fodor and Ingrid Daubechies, *Digital Cradle Removal Tool in X-radiographs of Panel Paintings*, Zeitschrift für Kunsttechnologie und Konservierung, 2016/1.





Website: project-platypus.net

platypus

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CRADLE REMOVAL MADE EASY

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Platypus is a software solution that comes both as a standalone application and a Photoshop plugin. It is specifically designed to digitally remove cradling artifacts in X-ray images of paintings on panel. This project was made possible thanks to the financial support of the Kress foundation.

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ART HISTORICAL AND DIGITAL ADVENTURES AROUND THE EXHIBITION

Reunited: Francescuccio Ghissi's St. John Altarpiece

COMPARISON: OLD AND REJUVENATED PANELS

In the next set of pages, all the panels of the Ghissi St. John altarpiece are shown in two versions, on facing pages, in the 1 through 9 order, following the numbering introduced in Charlotte Caspers's.

For each pair, the left page shows the "old" version – for panels 1 through 8, these are the photographs of the panels in their present condition from which we worked to carry out the digital rejuvenation. For panel 9, this is a digitally "aged" version, obtained by following the techniques described in the essay by Bruno Cornelis.

The right page shows a "fresh" version – for the 14th century panels 1 through 8, this means they are digitally "rejuvenated" – cracks have been removed, colors remapped to what is our best determination (when it was possible) of their "newly painted" aspect, following the examination of the panels and pigment determination via XRF by Bill Brown and Charlotte Caspers. For panel 9, the painted part is from the photograph shown in Charlotte's essay.

We already mentioned that it is very hard, in still pictures of gilded panels, to simultaneously capture the polished golden background in all its splendor and the painted portion with full detail. In the exhibition, this problem is solved by showing movies of the rejuvenated panels, in which the viewing point changes, so that the changing reflections give a good impression of the gold backgrounds. For the pictures that follow, we have chosen, for the "fresh" versions, to combine the painted parts of the panels (actual for 9, rejuvenated for 1 through 8) with a "mock-up" of the background. This mock-up combines a photograph of a gold foil sheet borrowed from the Wikimedia Commons (provided under a Creative Commons license by its author, PGHCOM from the Toi gold mine in Japan) with superposed copies of the punchmarks, in their right locations. For the top row panels 1, 2, 6 and 7 the pictures include a mocked-up gilded arch on top of the gold background; in panels 1 and 2, the torsaded small columns, which are a much more recent addition (as described in Bill Brown's essay), have simply been



blacked out. For the panels from the Kress collection (1, 2, 3 and 8), the extra pieces of wood, attached to the panels when they were cradled, have been “blacked out”.

The 3-dimensional effect, and the varying reflections off their beveled edges, have been mimicked, in these mock-ups, by printing slightly shifted versions of the punchmarks in colors borrowed from the (hugely enlarged) punchmark reflections in a photograph of panel 9. Each punchmark has the correct shape and scale and is at its right location, taken from a file prepared for the 3D-modeling of the panels as part of the gold rendering process.

We stuck to the punchmark shapes that Charlotte Caspers, David Steel and Bill Brown had determined, based on their study of the 14th century panels, and for which corresponding punches had been manufactured, commissioned by Charlotte. It turns out that the top row small panels (1,2,6 and 7) and the central Crucifixion panel have a few punchmarks that do not appear in the bottom row (3,4 and 8), and that therefore had not been manufactured for panel 9. Since they were simply circles of a different diameter than one of the punchmarks we already had, it was easy to add them to our virtual punchmark collection. In total, we identified seven different punchmarks, which the image processing team called *big dots*, *lilies*, *clovers*, *flowers*, *small circles*, *medium circles* and *huge circles*, respectively; only the first five are present in the lower-row St. John panels; in addition, *medium circles* appear in only the *Crucifixion* panel. Except for *big dots*, the punchmarks are all thin outlines of a central shape that was itself not depressed by the punching; for the *big dots* the punch was (probably) slightly conical, and depressed the whole circular area of the punchmark. In addition to the punchmarks, some lines were also incised in the panels, parallel to the outer edges or to the arches (for the upper and central panels), as well as circular arcs accentuating the halos around the heads of holy figures.

Placing the punchmarks was done painstakingly onscreen, using the vector graphics picture tool *xfig*, on the basis of the high resolution photographs of the panels in their present physical condition. Initially, we had envisioned to identify their locations by simple pattern matching. Like for almost every task we have encountered so far in image processing for art conservation, it turned out that the reality was much more challenging than we expected, and this simplistic approach could not work, for many reasons. We had at our disposal one single high resolution photograph of each panel. The aging process had removed the reflective nature of the gilded surfaces, and had filled the punchmarks with dust, which typically makes them stand out on the scanned photograph as darker than the surrounding ocher-looking gold-leaf. However, they are not everywhere as clearly visible – in many places, we found they are much less obvious; often their locations could still be clearly inferred from other clues – sometimes one could detect only the darkening that elsewhere indicated the center of a



big dot punchmark, sometimes one could recognize only the characteristic shape of a larger crack-delimited gold leaf flake containing the punchmark, which mirrored (but slightly larger) the punchmark shape. Sometimes, maybe where the punch had been hammered a tad too vigorously (making the rim of the punchmark tear through the gold leaf instead of bending it down without breaking it), cracks would follow the punchmark edges itself; in some cases this had led to punchmark-shaped gold leaf loss.

We believe that it would be possible to develop a program, using machine-learning techniques, that could accurately identify and locate punchmarks semi-automatically (so that it could be used with some human assistance, for instance delineating areas where punchmarks should be found, or helping the program decide on the right shape of the punchmarks), even for challenging pictures like these. Should there be interest from the museum community for such a tool, then this could be a possible future project; we didn't have sufficient resources or time to do this in preparation for the *Reunited* exhibition, however.

Preparing the files for the punchmark locations led us to observe some interesting differences between the panels from the different museums. For many of the punchmarks, the three panels from the Metropolitan Museum collection (4, 6 and 7) turned out to be the most challenging. Part of this can be due to differences in lighting conditions when the photographs were taken, but it also looks like there is considerably more wear on the punchmarks, possibly caused by abrasion during cleaning of the background when the panels were prepared to "look their best" prior to being offered for sale to a collector.

The table below summarizes the different punchmarks.

	big dot	used at edge of panel, and in outer band of halo punch is solid (i.e. not just edge), shallow cone		lily	used at edge of panel (also in halo for large panel = nr. 5) punch is just on edges of this figure
	clover	used at edge of panel punch is just on edges of this figure		small circle	used as fill-in (very dense) between flowers in halo punch is just on edges of this figure
	flower	used in widest band of halo punch is just on edges of this figure		medium circle	used only in panel 5, in halo of angels punch is just on edges of this figure
				huge circle	these are used only in the halos of some (not all) "spandrell figures" (which got sawn in half) in the top panels (1,2,6,7)
other markings: straight lines used at edges of panel, or following arches circular arcs used in halos					



Panel 1, *The Resurrection of Drusiana*, photograph of the panel in its present physical condition.

(Image credit: Portland Art Museum)



Panel 1, *The Resurrection of Drusiana*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped. The gilded arch and the punchmarks have been mocked-up in the right locations; the torsaded columns have been blacked out.



Panel 2, *St. John the Evangelist Reproving the Philosopher Crato*, photograph of the panel in its present physical condition.
(Image Credit: NCMA)



Panel 2, *St. John the Evangelist Reproving the Philosopher Crato*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped. The gilded arch and the punchmarks have been mocked-up in the right locations; the torsaded columns have been blacked out.



Panel 3, *Acteus and Eugenius Implore St. John the Evangelist to restore Their Wealth*, photograph of the panel in its present physical condition. (Image credit: NCMA)



Panel 3, *Acteus and Eugenius Implore St. John the Evangelist to restore Their Wealth*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped.



Panel 4, *St. John the Evangelist raises Sathus to Life*, photograph of the panel in its present physical condition.
(Image credit: Metropolitan Museum, NYC)



Panel 4, *St. John the Evangelist raises Sathus to Life*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped.)



Panel 5, *Crucifixion*, photograph of the panel in its present physical condition.
(Image credit: Art Institute, Chicago)



Panel 5, *Crucifixion*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped.



Panel 6, *St. John the Evangelist with Acteus and Eugene*, photograph of the panel in its present physical condition.

(Image credit: Metropolitan Museum, NYC)



Panel 6, *St. John the Evangelist with Acteus and Eugeneus*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped.



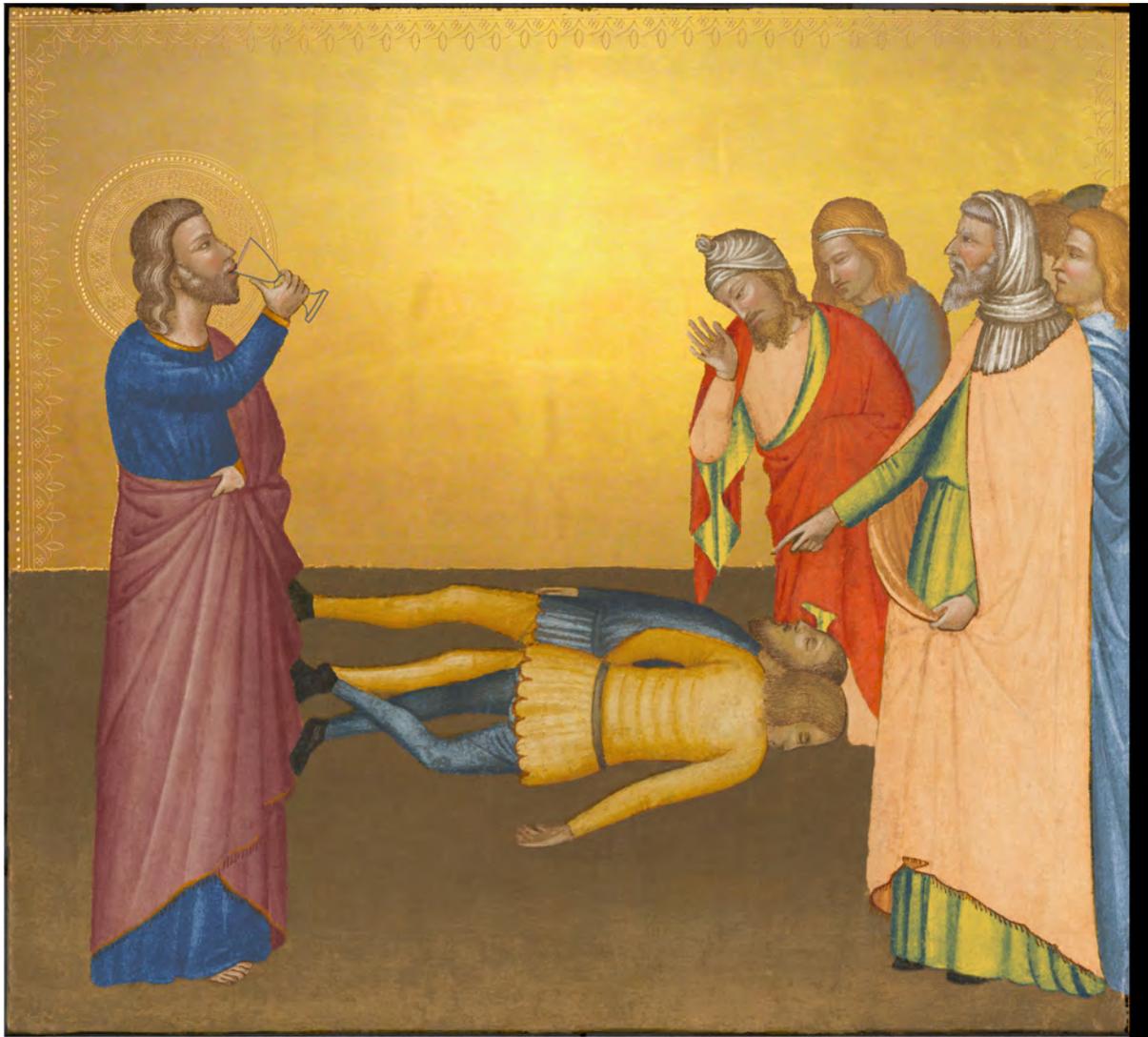
Panel 7, *St. John the Evangelist Causes a Pagan temple to Collapse*, photograph of the panel in its present physical condition.
(Image credit: Metropolitan Museum, NYC)



Panel 7, *St. John the Evangelist Causes a Pagan temple to Collapse*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped.



Panel 8, *St. John the Evangelist and the Poisoned Cup*, photograph of the panel in its present physical condition.
(Image credit: NCMA)



Panel 8, *St. John the Evangelist and the Poisoned Cup*, after virtual rejuvenation of the painted portion in the photograph on the left: cracks have been removed, and colors remapped. The punchmarks on the gilded background have been mocked-up in the right locations.



Panel 9, *St. John the Evangelist and the Baptism of Aristodemus*, virtually aged: the cracked gilding is adapted from panel 8, and the colors have been remapped to what (based on the other NCMA panels) they would look like if this had been painted at the same time, in the 14th century, and shared the history of those other 3 panels.



Panel 9, *St. John the Evangelist and the Baptism of Aristodemus*, in its present “new” condition. In this rendering, we replaced the “actual” gilding (with punchmarks) by a background similar to that for the rejuvenated old panels: an idealized image for the gold background, and punchmarks mocked-up in the correct locations. The painted part is the same as in the photograph on p. 59 in Charlotte Caspers’s essay. (Image credit: NCMA)



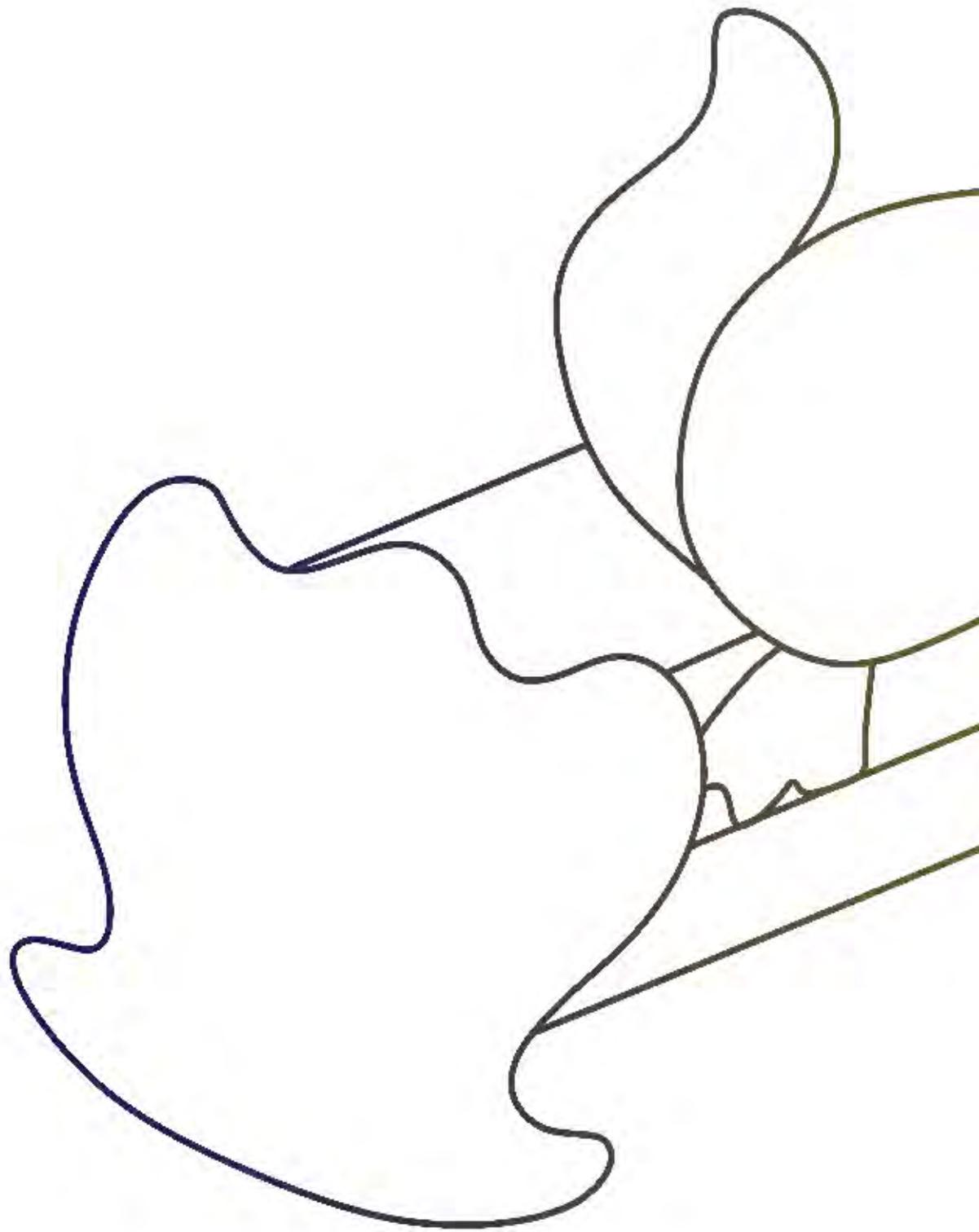
We end the comparison with two virtual montages – this one shows all the old panels, in their present condition, together with the aged version of panel 9, in the new frame. This is close to the actual reunited altarpiece at the exhibition.

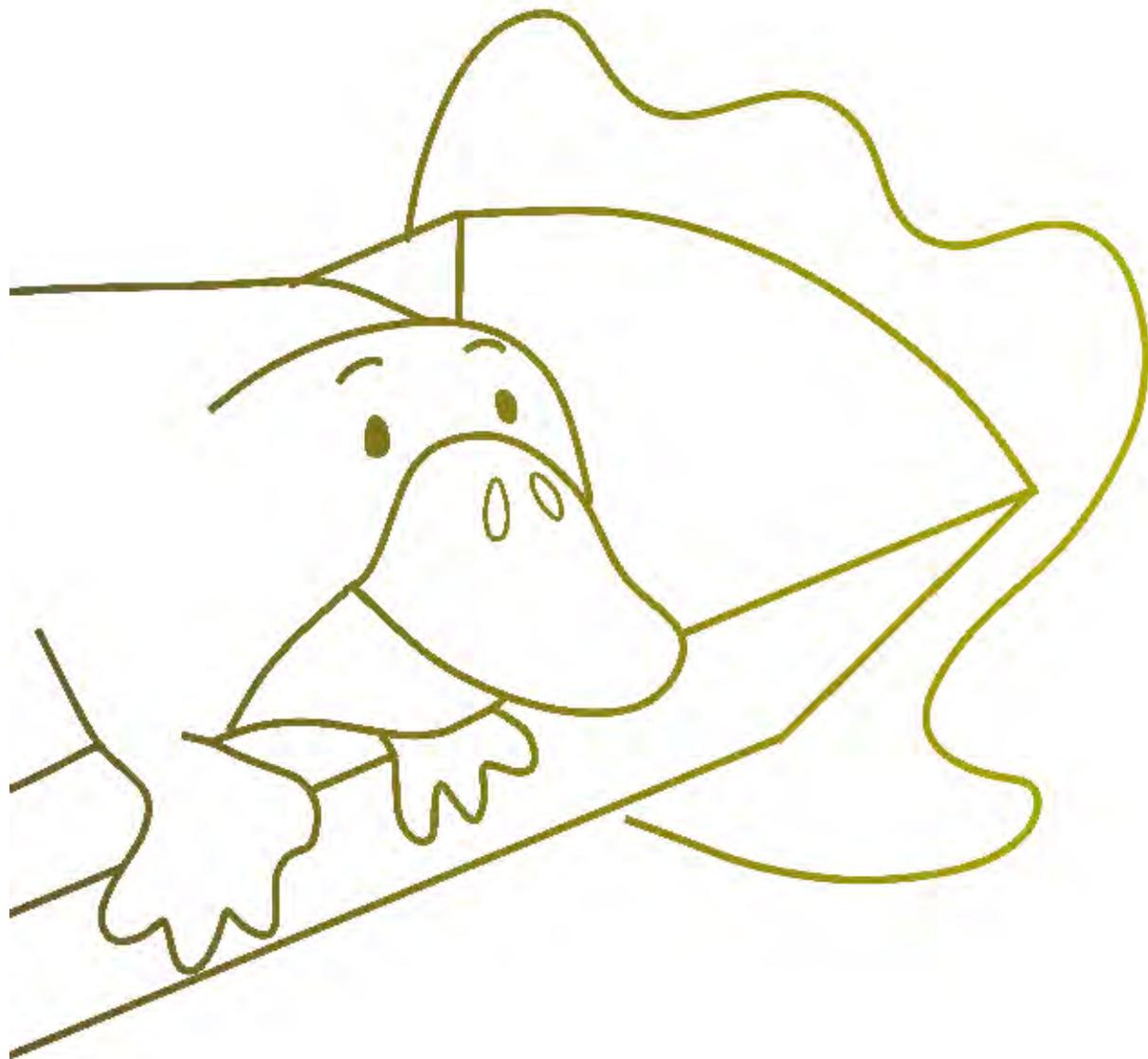
(Unlike the images of the virtually assembled panels shown earlier – on the cover, and at the end of the essay by Charlotte Caspers – the images of the panels are here simple reductions in size from the high-resolution photographs, without any enhancements.)

(Image credit: Portland Art Museum, NCMA, Metropolitan Museum in NYC and the Art Institute in Chicago.)



This side of the comparison of two virtual montages shows all the rejuvenated panels of the St. John Altarpiece by Franciscuccio Ghissi, together with panel 9 with the same virtual gilding as on p. 73; we have taken the liberty to also doctor the new frame so it can cover the space left by the virtually removed torsaded columns in panels 1 and 2.







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