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Documentation and Reconstruction of the Depiction of the Virgin Mary in the 15th-Century Stained-Glass Window of the *Annunciation* from the Dominican Monastery in Kraków

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Dokumentation und Rekonstruktion der Darstellung der Jungfrau Maria im Glasfenster der Verkündigung aus dem 15. Jahrhundert aus dem Dominikanerkloster in Krakau – Zusammenfassung

In diesem Artikel werden die Ergebnisse der digitalen Dokumentation und Rekonstruktion der Mariendarstellung einer mittelalterlichen Glasmalerei vorgestellt. Das Glasfenster ist Teil der Verkündigung, die vermutlich um 1440 in der Werkstatt des dominikanischen Meisters für Marienleben angefertigt wurde. Aufgrund des schlechten Zustands der Glasmalerei (starke Korrosion des Glases, Farbschichtverluste, teilweiser Verlust der Lesbarkeit) war die Absicht, den aktuellen Erhaltungszustand zu dokumentieren und beschädigte Details der gemalten Darstellung zu erkennen. Das wichtigste war die Verwendung von Techniken, die es ermöglichen, die Lesbarkeit der Komposition zu verbessern, ohne die historische Substanz des Buntglases zu beeinträchtigen. Aus diesen Gründen wurden Techniken wie die digitale Fotografie und Photogrammetrie, RTI/PTM und das digitale Mikroskop Hirox RH2000 angewendet. Die Ergebnisse ermöglichten die Ausarbeitung einer komplexen Dokumentation zum Erhaltungszustand der Glasmalerei: die Identifizierung von Maltechniken, das Erkennen von Spuren der gemalten Komposition und schließlich die Entwicklung einer Rekonstruktion der Mariendarstellung unter Verwendung digitaler Bildverarbeitungswerkzeuge.

Documentation and Reconstruction of the Depiction of the Virgin Mary in the 15th-Century Stained-Glass Window of the Annunciation from the Dominican Monastery in Kraków – Abstract

This paper presents the results of the digital documentation and reconstruction of the depiction of the Virgin Mary in a medieval stained-glass window. The panel is part of the scene of the Annunciation, presumably made around 1440 by the workshop of the Dominican Master of the Life of the Virgin. Due to the bad condition of the panel (severe corrosion of glass, losses of paint layer, partial loss of readability of the composition), a goal to document the current state of preservation and recognize deteriorated details of the painted depiction was set. The most important was to use techniques which allowed the legibility of the painted composition to be improved, without interfering with the historical substance of the stained glass. For these reasons techniques such as digital photography and photogrammetry, RTI/PTM, and the Hirox RH2000 digital microscope were applied. The results obtained allowed for the complex documentation of the state of preservation of the panel, identification of painting techniques, recognition of deteriorated traces of painted composition, and finally, development of a reconstruction of the Virgin Mary depiction using digital image processing tools.

Introduction

In the Dominican Monastery in Kraków, many valuable works of sacred art can be found. Apart from unique works such as the Saint Hyacinth canonization banner from the 16th century and the figure of Crucified Christ with movable joints, the oldest Polish stained-glass windows are also preserved. It is worth mentioning that in Lesser Poland, only in Kraków are there three relatively substantial collections of indigenous medieval stained glass art. In the church of the Virgin Mary, 117 stained glass panels (1360-1400) and in the church of Corpus Christi 54 panels (from c. 1380 and 1420-30) are preserved.[1] The third collection of twenty-one stained-glass panels derives from the Dominican Monastery.[2] Unlike the other two, however, these works of art were taken out of the windows many years ago. Among them, the oldest examples of indigenous stained glass art from the 13th century are preserved.[3] The collection also includes a group of seven panels made by the workshop of the Dominican Master of the

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[1] Adam S. Labuda and Krystyna (eds), *Malarstwo gotyckie w Polsce, vol. 2. Katalog zabytków*, Warszawa, DiG, 2004, p. 129.

[2] Eighteen of the preserved stained glass panels are exhibited in the National Museum in Kraków and three panels are stored in the Dominican Monastery.

[3] Lech Kalinowski, "Die ältesten Glasgemälde der Dominikanerkirche in Krakau", in Lech Kalinowski and Helena Małkiewiczówna, *Ars Vitrea. Collected Writings on Mediaeval Stained Glass*, Kraków, PAU, 2016, p. 127-138. See also Lech Kalinowski and Helena Małkiewiczówna, "The Thirteenth-century Stained Glass Crucifiction Panel of the Dominican Church in Cracow", in Lech Kalinowski and Helena Małkiewiczówna, *Ars Vitrea. Collected Writings on Mediaeval Stained Glass*, Kraków, PAU, 2016, p. 139-153.

Life of the Virgin.[4] They depict *the Throne of Grace*, scenes of *the Annunciation*, the *Coronation of the Virgin* and the *Adoration of the Magi* (each scene consisting of two panels).

The scene of the *Annunciation* consists of a left panel representing the Angel[5] and a right panel depicting the Virgin Mary[6] (fig. 1). Probably they originally decorated the windows of the chapel of the Annunciation (currently the Rosary Chapel), erected around 1440. However this cannot be verified due to the lack of any information about the appearance of the Gothic chapel.[7] Presumably in the 17th century the stained-glass windows were moved from church windows to the cloisters windows.[8]

Fig. 1. Kraków, National Museum and Dominican Monastery, stained-glass panels depicting the Angel and the Virgin Mary at the Annunciation, c.1440. D. Podosek, © Corpus Vitrearum Polska.

From the 19th century, there have been two major renovations of the stained glass panel depicting the Virgin Mary. The first, at the turn of the century, involved the realization of the project of Stanisław Wyspiański (the famous Polish Art Noveau artist), who proposed the reconstruction of the missing fragments of the panel and closing the original oval composition into a rectangle with an ornamental border. The second renovation was to take place after the Second World War, when the severely damaged panel was handed over to the stained glass studio of S. G. Żeleński in Kraków. However, this work was not carried out and the panel perished. Between 2016 and 2018, that is over 60 years from its disappearance and 30 years since its rediscovery, the necessary conservation treatment was carried out.

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[4] Dobrosława HORZELA, "Piętnastowieczny witrażowy cykl maryjny i jego miejsce w wystroju kościoła Dominikanów w Krakowie", in Monika JAKUBEK-RACZKOWSKA and Juliusz RACZKOWSKI (eds), *Claritas et Consonantia. Funkcje, formy i znaczenia w sztuce średniowiecza*, Toruń, Wydział Sztuk Pięknych Uniwersytetu Mikołaja Kopernika w Toruniu, 2017, p. 149-174.

[5] Stained glass panel depicting the Angel is exhibited in the Gallery of Decorative Art in the National Museum in Kraków.

[6] Stained glass panel depicting the Virgin Mary is stored in the Dominican Monastery in Kraków.

[7] HORZELA 2017.

[8] Danuta CZAPCZYŃSKA-KLESZCZYŃSKA and Tomasz SZYBISTY, "Korpus witraży z lat 1800-1945 w kościołach rzymskokatolickich metropolii krakowskiej i przemyskiej. Tom I. Archidiecezja krakowska, dekanaty krakowskie", in Wojciech BAŁUS and Tomasz SZYBISTY (eds), Kraków, Imedius, 2014, p. 152.

The Virgin Mary Annunciate

The stained glass panel was painted with glass-paint on clear, yellow and light violet glass contrasted with flashed red glass. The Virgin Mary is presented in a kneeling pose against a background of red fabric, surrounded by two ornamental borders (medieval and early 20th century).

The current arrangement of the figure kneeling and facing the angel, who is announcing the message from God, is the result of arrangement proposed by Stanisław Wyspiański at the end of the 19th century. It is certain that the stained glass panel was already in a bad condition. The only surviving documentation – a watercolour made by Ludwik Łepkowski between 1864-1865, shows significant destruction of the panel. Numerous interventions consisting of the replacement of broken panes with glass panes removed from other stained-glass windows rendered illegible the composition and iconography of the Virgin Mary. Moreover, the glass pane depicting the Virgin Mary's hands came from another panel, placed there for a restoration. On the Łepkowski's watercolour it is located in the panel presenting the image of the Angel at "the Annunciation". The fragment closest to the original arrangement of glass pieces is the upper part of the stained-glass window, which depicts the head of the Virgin Mary with a nimbus and a dove symbolizing the Holy Spirit above.

Research Goals

As mentioned, between 2016 and 2018 conservation treatment and instrumental analysis of the panel depicting the Virgin Mary was performed. The chosen analytical techniques, such as X-ray Fluorescence scanning (MA-XRF), Scanning Electron Microscopy – Energy Dispersive Spectrometry (SEM-EDS), X-ray Powder Diffraction (XRPD), led to the recognition of the state of preservation of glass and paint layers[9]. As a result of conservation, the construction of the panel was stabilized, cracks bonded, glass losses filled with glass infills, corrosion processes slowed down. Infills of medieval glasses were painted neutrally using vitreous paints. A significant part of the lead matrix has been replaced as well as two saddle bars and titanium-zinc frame were installed, which improved the stability and stiffness of the construction of the stained-glass window.

However, the irreversible results of corrosion processes visible as the matt surface of the glass, discolouration, a corrosion crust covering both sides of the glass panes, still affect the reception of the work. In particular, degradation of the paint layers (numerous losses of the contour lines and almost entirely deteriorated shading) led to the loss of readability of the depiction. The significant degree of deterioration of medieval glass and paint layers contributed to the decision not to retouch the losses on the object, but to reach for digital techniques.

Several goals have been set to achieve with the use of the digital tools. The first, was to develop the most accurate digital documentation of the condition of the glass and paint layers, and to recognize painting techniques used by the workshop of the Dominican Master of the Life of the Virgin. In addition to photographs in transmitted and reflected light, macro photographs, microscopic images (Hirox RH2000) and a high resolution orthophoto map were also taken. The second goal was to make the Virgin Mary depiction clearer despite such significant deterioration. For this purpose, RTI technique was used, with its possibilities in imaging the texture of the examined objects. The obtained results of all the techniques led to the last of the goals – a virtual reconstruction of the Virgin Mary depiction. To develop the projects Adobe Photoshop graphic editor was selected.

The main conservation objective was to conduct only the necessary treatment and maintain the current state of preservation of the paint layer. Any form of reconstruction on the object itself (such as using the separate sandwich glass or retouching with cold paints) was rejected. The only reasonable option, which respected all the processes and changes that the panel was subject to and provided broad opportunities, was the virtual reconstruction. The use of digital image processing tools makes possible a treatment which cannot be physically conducted on the object itself or whose realization would affect its original substance excessively. The improvement of the readability of the composition or even the restoration of the original appearance of the stained-glass window can be achieved. These tools are increasingly used in stained glass conservation practice. Another comparable example is the 2013-14

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[9] Edyta BERNADY, Marta KAMIŃSKA, Michał PŁOTEK and Małgorzata WALCZAK, "The investigation of 15th century paint layers on two stained-glass windows from the Dominican Monastery in Krakow (Poland)", *Glass Technology - European Journal of Glass Science and Technology Part A*, 59 (2), 2018, p. 46-53.

digital restoration of the stained-glass window of "The Birth of Mary" from the Carmelite Church in Boppard (Germany).[10]

Methods

In order to prepare full visual documentation of the condition of glass and paint layer of the Virgin Mary Annunciate, photographs and macro photographs using the digital camera and microscopic images using Hirox RH2000 digital microscope were taken. Also a high resolution orthophoto map was prepared.

Hirox RH2000 microscope (New Hirox HD 3D Digital Microscope System) is an optical digital microscope equipped with a variety of lenses, as well as specialized software. It provides valuable information about the analysed material. The Hirox microscope was used mainly for surface imaging, recognition of the technology and state of preservation of glass and paint layers. However it was also helpful in reading the traces of painted composition. Instrument used for the research was equipped with two lenses: 20x-160x with adapters and a 35x-2500x revolver lens. Photographs of the dismounted glass panes were taken in reflected and transmitted light, with and without polarization.

In order to make the painted depiction easier to recognize RTI/PTM was applied. RTI (Reflectance Transformation Imaging) derived from the PTM (Polynomial Texture Mapping) imaging is a popular technique for imaging the texture of objects. This technique is increasingly used for documenting and analysing many types of objects, from paper documents to sculptures. The final image is a combination of a series of photos taken from the same point, but illuminated by different light direction. It can be prepared using two algorithms HSH (Hemispherical Harmonics) and PTM (Polynomial Texture Map). In both cases, every pixel of the image carries information about the colour (RGB) and information about the direction of light, which allows to obtain a map showing the distribution of the surface normals. The RTIViewer program enables the analysis of the obtained result with the possibility of changing the angle of the lighting and to choose proper rendering mode.[11] The possibilities of active change of the lighting and special image processing allow to detect more surface details than any photograph taken in side light. In case of the panel depicting the Virgin Mary two rendering modes worked best, the Specular Enhancement and Diffuse Gain. First mode separates the RGB colour of the image from light reflections, which allows the observation of both layers simultaneously or separately, revealing the details of the surface of the object. Second algorithm only increases the contrast of the observed image.[12]

To achieve better resolution of the final RTI image of the stained-glass window depicting the Virgin Mary Annunciate, it was divided into two parts. Canon EOS 7D camera was used, with the exposure time of 1 and 1.5 s. The angles of the lighting were determined by means of black spheres. The final images were prepared in the HSH-algorithm. Moreover imaging of three glass panes (depicting the Virgin's Head, her nimbus and part of the yellow border) was conducted. Pieces were chosen based on differences in texture characteristics. In this case, a specially designed dome and Fujifilm mirrorless camera were used. The exposure time was 1s. The final images were prepared in the PTM-algorithm.

Results

Elaboration of the digital documentation was initiated by taking photographs of the panel's condition before conservation. Photographs and macro photographs in transmitted and reflected light were taken. Partial dismounting of the lead matrix executed during the treatment, allowed for detailed microscopic analysis of several medieval glass panes. Preparing the orthophoto map and RTI was the last part of the documentation, made after conservation.

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[10] Boppard Conservation Project - Glasgow Museums, "A Digital Restoration of the Birth of the Virgin Panel", 2014, https://boppardconservationproject.wordpress.com/2014/09/24/a-digital-restoration-of-the-birth-of-the-virgin-panel/, [August 28, 2019].

[11] Gianpaolo Palma, Massimiliano Corsini, Paolo Cignoni, Roberto Scopigno and Mark Mudge, "Dynamic Shading Enhancement for Reflectance Transformation Imaging" *ACM Journal on Computing and Cultural Heritage*, 3 (2), 2010, http://culturalheritageimaging.org, [March 18, 2018]. See also "Cultural Heritage Imaging | Reflectance Transformation Imaging (RTI)", http://culturalheritageimaging.org/ Technologies /RTI/ [August 28, 2019]; and Alexander M. Dittus, "Reflectance Transformation Imaging of Glass Objects", in Hannelore Roemich and Lauren Fair (eds), *Recent Advances in Glass and Ceramics Conservation*", Paris: International Council of Museums - Committee for Conservation (ICOM-CC), 2016, p. 145-154.

[12] "Guide to RTIViewer", 2010, p. 11-14, http://culturalheritageimaging.org/What_We_Offer/Downloads/rtiviewer/RTIViewer_Guide_102.pdf [March 18, 2018].
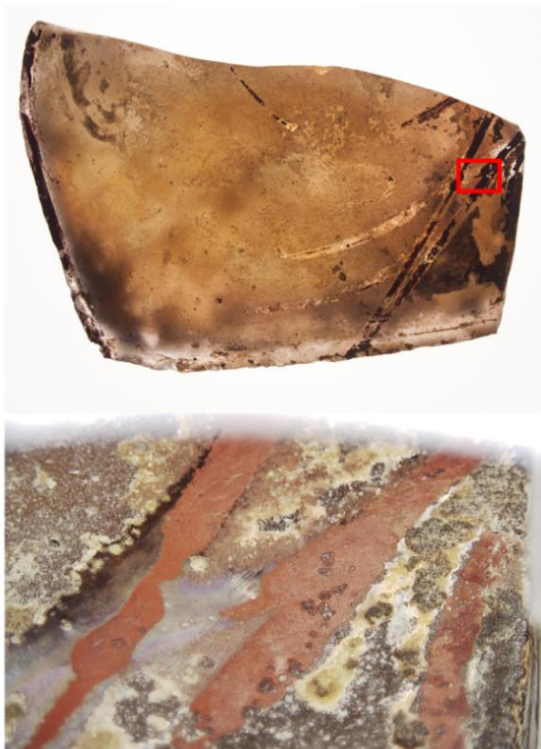
Fig. 2. Microscopic image in reflected light of medieval paint layer (Hirox RH2000 digital microscope with revolver lens). E. Bernady, M. Momot.

For the microscopic analysis using the Hirox RH2000, heavily corroded glass panes with almost illegible paint layer were chosen. The observations revealed a lot of valuable information about the condition of glass and the paint layers. They showed the extent of glass corrosion under the paint layer and allowed to measure the depth of corrosion pits into the structure of glass, among other things.

The possibility of observing the glass panes in reflected and transmitted light was crucial to show surface features of the analysed pieces. Partially preserved contour lines and traces of shading paint were accurately documented (fig. 2). Figure 2 also shows the corrosion pits going through the trace line paint.

To document the condition of the painted depiction of the examined panel, the use of revolver lens was also very helpful. Changing the angle of observation and rotating of the lens allowed for highlighting the traces of paint layers preserved on the surface of the glass.

Besides the documentation of the state of preservation of the panel, the Hirox RH2000 microscope led to recognition of the painting techniques. Despite the numerous losses of paint layers it was possible to notice some details of ornaments remaining in the texture of corrosion crust or traces of vitreous paint covering back of the glass panes. However, it was only possible to examine under the Hirox microscope pieces dismounted from the stained glass panel. Thus, important parts of the composition, such as the Virgin's face or nimbus, required the use of other techniques to recognize the painted details.

For this reason the RTI/PTM was performed. The opportunity to carry out imaging of the entire medieval part of the stained-glass window as well as individual glass panes gave significant results.

At first, RTI of the stained-glass window divided into two parts was performed. The series of digital photographs were developed using HSH-algorithm. Observations of the final images were made in the Specular Enhancement rendering mode. Changing the direction of the lighting revealed many texture details of medieval glass panes, allowing to identify the painted composition even at more deteriorated parts. An example of the obtained results is presented in fig. 3. Observation of that fragment was focused on recognizing the drawing of the border pane. RTI was able to significantly improve readability of the drawing, which was partially visible in the corrosion pattern.

Fig. 3. Photograph in reflected light and RTI SE image (HSH). E. Bernady.

Afterwards, imaging of the three individual glass panes was also conducted. As mentioned above, pieces depicting the Virgin's head, her nimbus and part of the yellow border were chosen. Final images were developed using PTM-algorithm. The obtained images were analysed in Diffuse Gain and Specular Enhancement rendering modes. Due to the high resolution of the final images, they allowed for better illustration of painting details present on selected glass panes. Despite the severe deterioration of chosen pieces, it was possible to notice more details of the Virgin's face as well as the design of the nimbus etched in the thin layer of the shading paint.

The results obtained led to the recognition of the partially preserved depiction of the Virgin Mary. A thorough analysis of all the images of the panel, together with analysis of the style of the Virgin Mary in depictions of the *Adoration of the Magi* and the *Coronation of the Virgin* (also made by the workshop of Dominican Master of the Life of the Virgin), contributed to the development of a virtual reconstruction of the deteriorated depiction. Reconstruction projects were made in Adobe Photoshop on the basis of the orthophoto map. The high-resolution image was prepared from the assembly of a series of photographs of the stained glass panel. It was possible to achieve the resolution of 0.07mm of the final orthophoto map. The virtual restoration projects were focused primarily on the reconstruction of the current composition of the panel. All historical additions have been left, including glass pieces added during the last conservation and the present shape of the lead matrix. Projects included mainly the reconstruction of the contour drawing and restoration of red colour of flashed glass (fig. 4).

Fig. 4. Digital reconstruction of the Virgin Mary: (a) orthophoto map; (b) digital reconstruction of the contour lines and restoration of red colour of background glass panes. Photo: P. Gąsior, B. Mitka, image: E. Bernady.

Conclusion

As the paper has presented, selected digital techniques have led to the accomplishment of all goals. The results allowed the preparation of complex visual documentation of the stained-glass window condition, including the degree of glass deterioration and current state of preservation of paint layers. Moreover, they led to the recognition of the illegible details of the painted composition, such as detailed features of the Virgin Mary depiction, patterns etched in the thin layer of shading paint, traces of the paint layer on the reverse of the glass panes. Together with the stylistic analysis of the other stained-glass windows from the same workshop, achievements enabled the development of virtual reconstruction projects. The use of an orthophoto map creates many possibilities for further image analysis and future museum exhibitions.

Despite the bad state of preservation of the depiction, the virtual reconstruction shows precision and attention to detail of the workshop of Dominican Master of the Life of the Virgin.

Based on the example of the stained glass panel depicting the Virgin Mary Annunciate, the potential of digital techniques as valuable tools of documentation and analysis in the hands of art conservators was shown. They allow us to document not only the state of preservation, but also the technological aspects, such as painting techniques. The virtual restoration and reconstruction give a wide range of possibilities of presenting the stained-glass windows as well as carrying out the conservation treatment, which on the physical object has to be restricted or cannot be undertaken for some reason. These methods allow us to perform actions without interfering with the original substance of the artwork. Digital documentation and virtual reconstruction are both valuable sources of knowledge for specialists, conservators or historians, but they can also be significant for education of non-specialist recipients about the importance of heritage preservation.

Acknowledgements

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