

DIGITAL PHOTOGRAMMETRIC METHODS FOR DOCUMENTATION OF WALL PAINTINGS ON THE KARLŠTEJN CASTLE

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Abstract:

Karlštejn Castle was founded in 1348 by the Czech king and Holy Roman Emperor Charles IV as a place for safekeeping of the royal treasures, especially Charles's collection of holy relics and coronation jewels of the Roman Empire.

Since 1999, documentation work has been in progress at the castle. One part of this work concerns the documentation of the unique 14th-century wall paintings in the castle area (the Marian Tower, the Great Tower). The stipulation was to produce an exact digital base for current and further conservation works. In addition, this documentation should also be able to accept historical documentation (plans, images, reports). We chose the close-range digital photogrammetric method. The metric images were taken by calibrated professional semi-metric digital camera.

This report describes our methods of preparing the digital photoplans and their accuracy analysis. The paintings involved both "flat" wall frescos (Church of Our Lady, Chapel of St Catherine, the "staircase paintings" – the legends of St Wenceslas and of St Ludmila) and also rectified plans of soffit paintings in the window niches (Chapel of the Holy Cross) or the painting on the Gothic vaulting in the St Catherine chapel. The key impulse behind our work was to find the easiest method of use for specialists who do not have experience in photogrammetry or CAD. Thanks to this project, complete documentation of Karlštejn's unique fresco work from the culminating era of Gothic painting in Bohemia is now available.

1. INTRODUCTION

1.1 Karlštejn Castle

Karlštejn Castle occupies an exceptional position among the many Czech castles. It was built by the Czech king and Holy Roman Emperor Charles IV as the site for protection of the royal treasures, particularly the imperial coronation regalia and a collection of holy reliquaries. For over 200 years, it also guarded the Czech coronation regalia.



Figure 1: Karlštejn Castle, View from SW. Photo: J. Vidman, 2008

Karlštejn Castle was founded in 1348 on a limestone outcropping beside the river Berounka (Figure 1). Its construction was completed in 1365, with the consecration of the Chapel of the Holy Cross. After 1480, the castle was rebuilt in late-Gothic style, and in the final years of the 16th century in Renaissance style. At the end of the Thirty Years' War, in 1646, the castle was seized by Swedish troops and from that point on left to decay. Greater attention was devoted to it only at the start of the 19th century, as part of the Czech 'national revival'. The current appearance of the castle is the result of extensive rebuilding in the spirit of historical purism, undertaken in 1888-1904 under the guidance of architect Josef Mocker. Even despite its current exterior corresponding to the preferences of the 19th century, the castle has been relatively untouched by structural alterations, and has retained its unique painted decoration of 14th century date, primarily the set of 129 Gothic paintings from the workshop of Master Theodoricus and the frescos on the walls of the Church of the Virgin Mary, the Chapel of St. Catherine and the "staircase cycle" depicting the legend of the Czech national patrons St. Václav (Wenceslas) and St. Ludmila.

Since 1918, the castle has been a property of the state. Today, Karlštejn is an important national cultural landmark and one of the most visited Czech castles.

2. DOCUMENTATION

Since 1999, extensive documentary work has been underway. This paper describes the documentation of the interior paintings in the castle in the period 2005-2010, for which the selected method was terrestrial photogrammetry, with a decisive share carried out using digital technologies.

2.1 Documentation of the Church of the Virgin Mary

In 2005-2006, documentation was undertaken of the Church of the Virgin Mary, situated in the 'Marian Tower', the castle's smaller one. Preserved in the church are highly valuable frescoes with Biblical scenes as well as 'reliquary images' in which Charles IV is shown receiving and preserving the remains of saints. The

author of these paintings is most likely Mikuláš Wurmser of Strasbourg. The church has a rectangular floor plan with dimensions of 10.7x9.4m and a wall height of nearly 6m.

The goal of the documentation was the preparation of a photomap of all walls, including niches, in 1:20 scale. The basic skeleton of the walls, including the ground control points, was measured geodetically, with the shots for the photoplan taken using a calibrated digital camera Nikon D70 with lenses Nikkor 18-70mm and Nikkor 1.4/50mm. In total, over 200 digital photographs were taken with resolution of 6Mpx. After the ortho-rectification of the images, photo-plans were prepared of the individual walls, with the size of the image pixel at 2mm (Figure 2).



Figure 2: Church of the Virgin Mary, photomap of the south wall, mosaic from 18 images, pixel 2mm

2.2 Documentation of the Chapel of St. Catherine

Immediately adjoining the Church of the Virgin Mary on the second floor of the Marian Tower is the small chapel of St. Catherine, built into the width of the southern tower wall and serving as the private chapel of Charles IV. The walls of the chapel are lined with gemstones set into gilded stucco; above the entrance is a double portrait of Charles IV and his third wife, Anna Svídnická (Figure 3). The chapel has a rectangular plan with dimensions of 4.0x2.4m and a wall height reaching 4.2m.



Figure 3: Measuring in the Chapel of St. Catherine. Photo: S.Pomahač, 2006

In 2006-2007, complete documentation of the chapel was undertaken. On the basis of prepared analyses of precision (for the desired printing scale of 1:10), photogrammetric imaging was performed using a camera UMK 10-1318. After this, photographing of textures for the photo-plans was performed with a digital camera Nikon D70 (6MPx) with Nikkor 18-70mm and 1.4/50mm lenses. During the photographing, a professional flash device was used with dispersal surfaces, to limit the high degree of reflection from the gilded surfaces and the surfaces of the polished gemstones. In total, over 500 black-and-white as well as colour photographs were taken. During photographing, the greatest problem was caused by the cramped dimensions of the chapel, and thus the requirement of taking a great quantity of photographs from only a short distance. After this, using the Leica total station, around 100 ground control points were measured on the walls and ceiling of the chapel. Using standard photogrammetric methods, raster images were calculated for part of the walls using individual selected photos. These images were further treated, the colours adjusted and final mosaics created (Figure 4). The resulting photo-plans of the individual walls were prepared with the size of the image pixel set at 1mm.



Figure 4: Chapel of St. Catherine, photoplans of south wall (left) and west wall (right), pixel 1mm

2.3 Documentation of the niches in the Chapel of the Holy Cross

The quite well-preserved Chapel of the Holy Cross is the most important space inside the Great Tower and the entire castle, once the depository for the coronation regalia of the Holy Roman Empire as well as the Czech lands. The imposing ornamentation of the chapel, with many gilded surfaces and semi-precious stones, is supplemented with two fields of cruciform vaulting with the illusory image of a star-filled night sky. The walls are covered with panel paintings by Master Theodoricus.

Documentation work in the Chapel of the Holy Cross focused on the preparation of photo-plans for the three window niches (Figure 5). Because these are vaulted in form, it was necessary for the preparation of unrolled surfaces to capture each individual section of the vault. Work was performed in 2007.

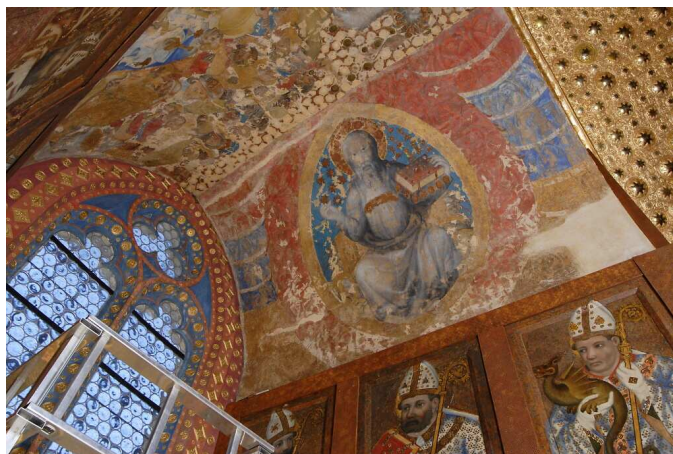


Figure 5: Chapel of the Holy Cross, window niche Nr. 1. Photo: J.Vidman, 2007

First, measurement photographs were taken for each niche using a Rolleimetric 6x6cm camera, followed by texture photographs for photo-plans with a digital camera Nikon D200 with resolution of 10MPx. Ground control points were again measured geodetically.

Geometric processing: From the measurement photographs, the 3D coordinates of the detailed points of the ceiling were evaluated stereoscopically, from which a three-dimensional digital model was prepared of the ceiling, separately for each niche. On the basis of these confirmed spatial relations, the geometric surfaces were determined for rolling them out flat. In contrast to the original expectation, these did not form a cone, but a cylinder with a leaning axis, and a radius of c. 1.70m. In each niche, therefore, a pair of cylinders was planned and positioned to minimise the deviations of the measured detailed points from the theoretical geometric surface – using the smallest-square method. After this, raster images were calculated from the selected digital images for individual sections, and these directly onto the flat surface created through unrolling the cylindrical surfaces (Figure 6). For this calculation, we used our own mathematical approaches based on the method of indirect geometric transformation. The resulting photo-plans of the unrolled surfaces were prepared with the size of the image pixel as 1mm – for an assumed printing scale of 1:10.



Figure 6: Chapel of the Holy Cross, Window niche Nr. 1, Scene: God of the Apocalypse.
Photoplan of the unrolled cylindrical surface, mosaic from 6 images, pixel 1mm

3. RESULTS

3.1 Use and presentation of prepared documentation

The resulting photo-plans of the paintings were submitted both in digital and printed form.

Digital photo-plans were saved in the format TIFF + TFW. For presentation and printing, drawings were prepared in PDF format, with raster resolution of 300dpi.

Printed plans were prepared using a large-format HP DesignJet 130gp printer with colour calibration on semi-matte photographic paper of 180gr. For improving longevity, the prints were then laminated.

The prepared documentation is and will be used for the following purposes:

- As the basis for restoration work,
- For scientific and research purposes for art historians and historic preservation experts,
- For presentation of Karlštejn Castle to the professional and lay public,
- For future preparation of a 3D model and virtual tours of the castle.

For greater use of the prepared documentation, very good results were found with the format Adobe PDF, a program now easily accessible (the free viewer Adobe PDF Reader) and not particularly demanding for computer equipment or for user knowledge.

3.2 Evaluation of precision

The geometric precision of the prepared photo-plans is, according to the control measurements performed, around 1-2 cm. These findings have confirmed our original idea that digital photography cameras can be used for surface photography, even for work requiring very high precision levels, but only if the following specific conditions hold true:

- Good calibration of the optical apparatus,
- Use of the very best lenses of a professional series,
- Correction of optical defects of the lenses (especially radial distortion) through the use of special numerical modules,
- Performance of ortho-rectification of the images including the influence of depth articulation (digital model of the “terrain”).

If these conditions are met, it is possible to use even extremely wide-angle lenses with an image angle of >120deg.

During the processing, software packages and modules were used from the companies Adobe, PCI Geomatics, Racurs, Photomodeler and above all the Czech programming systems TopoL, PhoTopoL and ATLAS DMT. For processing certain specialised tasks, we used or developed our own programming modules – primarily for correction of lens distortion and for orthorectification of images on a rolled-out cylindrical surface.

4. CONCLUSIONS

The results of preparation fully confirmed the correctness of implementing the methods of terrestrial photogrammetry for documentation of wall paintings. For work with very high precision, it is moreover possible to use high-quality digital cameras.

5. REFERENCES

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