DOCUMENTATION AND DEVELOPMENT OF THE COLUMNS OF THE CHURCH OF ST. CHARLES IN VIENNA

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ABSTRACT

The Church of St. Charles in Vienna is flanked by two huge columns. Both are decorated with a relief showing different scenes of St. Charles Borromäus and are due for restoration work in approximately spring 2006. This paper presents how these two columns and their relief can be reconstructed from photogrammetric measurements. First in a bundle block adjustment all photos and control point measurements are used simultaneously to derive the photo orientations and the defining parameters of the columns' surface (e.g. a cylinder). Afterwards the columns' surface is developed and the texture from each photo is transferred into the geometry of this development. This result corresponds to an ortho-photo of the developed column surface, which will be used several times in the restoration phase: for documenting the current state of damage, for supporting the financial calculations of the companies who are interested in taking over the restoration work (as this work will be contracted out) and finally for the restoration work itself, as the working restorers of the authorized company are obliged to record all their work precisely in this ortho-photo. In order to achieve the required high resolution of 1mm on the entire column (size: height 40m, diameter 5m) in this ortho-photo, the arrangement of the cameras has to be planned in detail. After completing the restoration work the post-restoration state of the columns will be surveyed again using photogrammetry. This way not only the consistent documentation of the historical evolution of the building material is guaranteed, also a quality control of the restoration work is possible by comparing the pre- and post-restoration states with the recordings of the restorers.

1. INTRODUCTION

Prerequisite for the restoration of any architectural object is the documentation of the object's condition on the basis of a defined geometry. Photogrammetry has a long tradition in providing this information: It allows the determination of the object's geometry and further gives a contemporary document of the object's condition due to the colour information of the photographs.
This article deals with the photogrammetric documentation of the relief of the two columns of the Church of St. Charles in Vienna, see figure 1. The columns are formed by cylinders or perhaps very steep cone frustums and are therefore developable. Consequently the best documentation of the relief of each column is an ortho-photo mosaic in the geometry of the column's development.
The article is structured in the following way. Section 2 gives a short overview on the history of the Church of St. Charles in Vienna. Section 3 describes first photogrammetric work, that was done in order to assess the possibilities of the available measurement systems (i.e. photos and laser scanning). Section 4 follows, which describes the planned surveying strategy, which is matched with the authorities responsible for the restoration. In section 5 the usage of the ortho-photo mosaic in the restoration phase is described, and section 6 gives a summary.

2. HISTORY OF THE CHURCH OF ST. CHARLES

In 1713 the Black Death started to came over Vienna for the seventh time in two decades and thousands of people died. The Austrian Emperor Charles VI vowed to build a glorious church in honour of Charles Borromäus the saint of the plague, if only God would liberate the town from this horrible disease. After the plague vanished and the financing was arranged, the foundation of the church began in February 1716 based on the construction planes of Johann Bernhard Fischer von Erlach. After his death in 1723, his son Joseph Emmanuel Fischer von Erlach took over the construction management and completed the church in 1737; [Missbach, 2003].
The Church of St. Charles in Vienna is regarded as one of the greatest and most important baroque churches in Europe. Due to the architect Johann Bernhard Fischer von Erlach the church represents a perfect symbiosis of classical architecture of Rome, Greece and Orient with baroque visions; e.g. the main entrance is formed by a Greek temple portico, whereas the two columns on the side are based on the Trajan's Column in Rome, see figure 1.

Figure 1: The Church of St. Charles in Vienna.

The association "Verein der Freunde und Gönner der Wiener Karlskirche" (*friends and patrons of the Church of St. Charles* *in Vienna*, VFGWK in the following), founded in 1966 by the architect Clemens Holzmeister, has the intention to preserve the church in its original state and to undertake the necessary restorations and renovations. This work is largely (ca. 70%) financed by dues from tourism and 30% by the general public and the Austrian State Office for Historical Monuments.

After nearly completing the restoration of the interior parts of the church, the restoration of the two columns at the main entrance is among the coming tasks. The two columns are highly responsible for the entire impression of the church. Each column has a height of approximately 40m, a diameter of approx. 5m and is decorated by a coiling relief created by the artists Mader, Straub and Schletterer. The relief shows events in the life of St. Charles Borromäus.

3. PRELIMINARY WORK WITH PHOTOGRAMMETRY AND LASER SCANNING

In order to assess the applicability of photogrammetric products for the restoration of the two columns, the association VFGWK in cooperation with the building authority of the archdiocese Vienna asked for some samples of possible photogrammetric products. Therefore a small part of the columns was surveyed by means of photogrammetry and laser scanning.

The following instruments were used for this first survey:

- A digital camera CANON EOS-1Ds (35,8 x 23,8 mm² CMOS sensor with 4064 x 2704 pixel) together with a 20mm and 50mm objective.
- A terrestrial laser scanner RIEGL LMS-Z420i, with a distance range of 2-800m and an accuracy of about 1cm, and an angular range of 360° (horizontal) x 80° (vertical); see also [Riegl, 2005]. This laser scanner allows the combined usage of a digital camera, which is mounted on top of the scanner. Here the very same Canon camera was used.
- A close-range laser scanner MINOLTA VIVID 900, with a measurement range of 0.6-2m and an accuracy of better than 1mm, and an angular range of 33° (horizontal) x 25° (vertical); see also [Minolta, 2005] and [3D Technology, 2005].

The following products were created from the measurements of the mentioned instruments:

- A surface model with 2cm resolution covering 3×13 m², derived from the Riegl data; see figure 2 (left).
- This surface model overlaid with texture from the Canon photos resulting in a 3D-photomodel; see figure 2 (right).
- An ortho-photo with 3×3mm² object resolution derived from the Riegl surface model and the Canon photos; see figure 3.
- A surface model with 1mm resolution, covering about 30×25 cm², derived from the Minolta data; see figure 4.

Figure 2: Left: Section (3×6m²) of the surface model with 2cm resolution derived from the Riegl data. Right: a rotated view of the respective section in the 3D-photomodel.

Figure 3: Section (size 1.3×1.3m²) of an ortho-photo derived from the Riegl surface model and the Canon photos.

4. PLANED PHOTOGRAMMETRIC WORK

In a meeting with the heads of the VFGWK, the building authority of the archdiocese Vienna and a consulting restorer these products of the preliminary work were presented. After discussing the pros and cons of these products, the requirements for the restoration work emerged more precisely, and this led to the following surveying plan.

The most important requirement for the restoration is to provide a representation of the condition of the building material of the columns' relief in a way that the restorers can document the damages and record their restoring work. This need requires the relief to be captured with photographs having very high resolution (better than 1mm on the object).

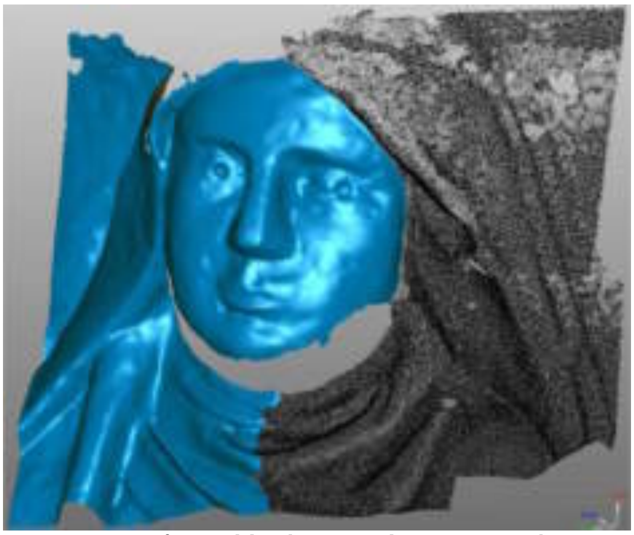

Figure 4: Surface model with 1mm resolution, covering about 30×25cm², derived from the Minolta data using ca. 125 thousand points. The left part is triangulated, the right one shows the points used.

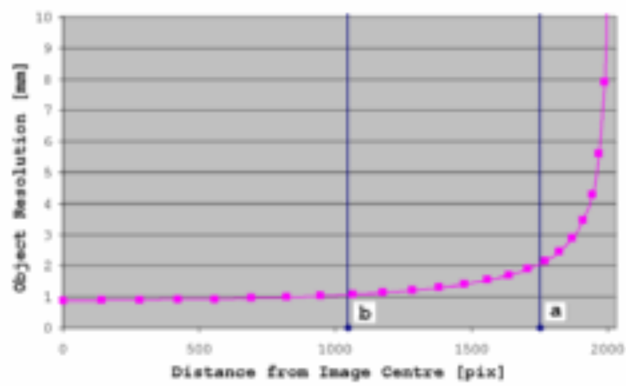

Figure 5: Size of an image pixel on the object as function of the pixel's distance from the image centre based on the camera arrangement of figure 6. The line **b** represents the border of the central image part with object resolution better than 1mm + 10%. The line **a** represents the object resolution for triple tie points seen from the 1st and 2nd photo in figure 6.

With this required object resolution of 1mm and the natural target of minimizing the needed number of photos, one can set out to plan the arrangement of the camera positions. Because of the curved surface each pixel in the image will correspond to a different resolution on the object. In order to restrain the degradation in this object resolution, we use only that central part of each photo, which does not exceed a degradation in object resolution of 10% at maximum; see also figure 5.

If we use the Canon camera EOS-1Ds with the 50mm objective and a round image scale of 1:100, then the optimum object pixel is about 0.9mm and the camera distance would be 5m. If we further demand that the photos overlap sufficiently to get triple tie points for better reliability of the results, then 8 photos are required to cover the cross section of each column, see figure 6, and the central part of each image would cover approx. 2×3m² on the object.

With this photo arrangement and a 20% overlap between the photos of neighbouring cross sections in total 144 images would be needed for a column of 40m height and 5m diameter. The actual number, however, will differ somewhat because about 20% of each column is covered by the main building block of the church and is therefore not accessible. To picture the regions close to these occluded parts, some oblique small-angle images will be necessary.

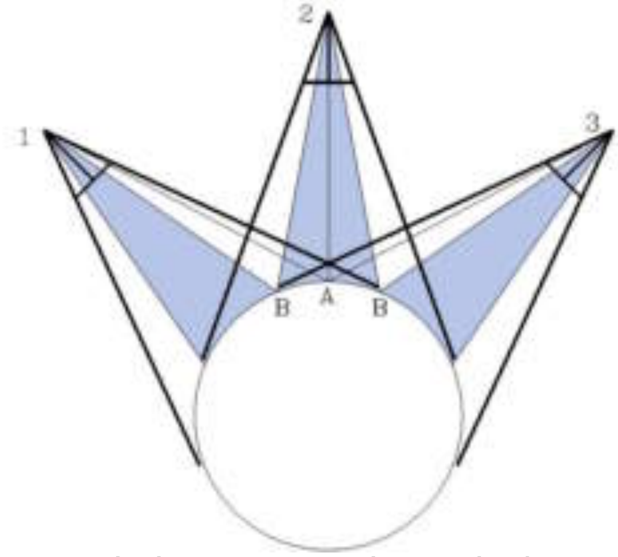

Figure 6: Planed camera arrangement and image overlap. Shown are three of the eight symmetrically arranged photos around the cross section of the column. The shaded area represents the central part of each image covering the object with a resolution of better than 1mm + 10%. Point A marks the optimum resolution with respect to image 2 and B marks the border of the central part. Double tie points are best placed close to B and triple tie points are best placed in A. Compare also with figure 5.

For accessing the higher parts of the column a simple lifting platform will be required and in order to acquire the photos from the planned camera positions (so that the resolution and coverage on the object is guaranteed), the movement of the platform needs to be guided on site by a tachymeter.

Furthermore, since the photographed texture is of highest importance, equal lightning conditions must be guaranteed. This can only be achieved if spotlights are mounted on the lifting platform and directed parallel to the viewing direction of the camera.

Before these original photos can be used for the designed task of documenting and recording the restoration work, the distortions inherent with central perspective views have to be removed from the photos by a rectification with respect to a suitable geometry. Due to the curvature of the object the best geometric reference for these rectification is the development of the columns; see figure 7 and [Kraus, 1997]. Further related work on differential rectifications of curved surfaces can be found in e.g. [Kraus and Tschannerl, 1976] or [Vozikis, 1979].

For getting a textured representation of the entire relief (as an ortho-photo mosaic) all photos must be rectified with respect to this geometry of the development of the columns; cf. figure 7.

For computing the development of the columns, at first their geometry has to be reconstructed. For this task, the first choice would be the use of the mentioned laser scanners. However, due to financial and cityscape reasons the entire columns shall be scaffolded only during the actual restoration work, where permanent physical contact to the building material is required, and not during the other phases of the project (e.g. the surveying work). This limiting condition impede a reasonable usage of the mentioned Minolta laser scanner. Apart from its required close distance to the object (which is impossible without a scaffold) the usage of the Minolta scanner would be further hampered by its narrow field of view (thus requiring a huge number of scans) and its dependency on perfect lightning conditions (which are difficult to realize for outdoor objects). However, for certain limited regions this scanner could deliver valuable high-resolution 3D data (as seen in figure 4).

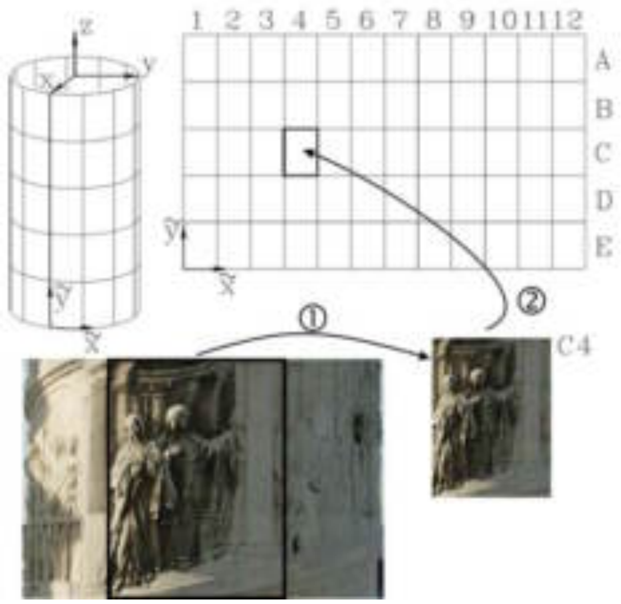

Figure 7: Development of a cylinder surface. In the geometry of the development a sheet line system can be defined, where each sheet corresponds to the central part of a certain photo. At step ♍ the central part of the original image is taken and transformed into the geometry of the development, then in step ♎ this sheet is placed in the entire mosaic of the relief; e.g. sheet C4.

The Riegl laser scanner does not suffer from these limitations as it has a very long measurement range, a large field of view and is practically independent on the lightning conditions. A few parts of the columns, however, are not very easily accessible with the scanner. Therefore at least a lifting platform would be required at some points, which, however, would complicate the surveying of the entire columns (at least from a financial point of view), as that platform would need to be very stable, otherwise – because of a swinging platform – systematic errors would be induced during scanning time. This is opposed to the lifting platform needed for the taking the photos, which has no special requirements on the stability because of the very short times of exposure. Therefore, reconstructing the entire columns and their relief variations using laser scanning would be a considerable effort by itself.

The question is, if each entire column needs to be fully reconstructed at all for the mentioned purposes of the restoration work, or if an averaging cylinder or cone frustum can be used instead. The relief has a small variation of about 10cm (compared to the diameter of about 5m). If this variation is neglected for creating the ortho-photo mosaic in the development, a displacement of ca. 6cm at maximum is induced. Usually such a displacement in an ortho-photo mosaic would cause certain parts of the object (which protrude the averaging cylinder) to disappear in the mosaic. In our case, however, this can be avoided by using a circumscribing cylinder instead of an averaging cylinder and the parts, that would be lost in the former case will then appear twice in the mosaic.

In case the mentioned displacement can be accepted for the restoration purposes, then the full 3D reconstruction of the relief is not required. If the displacement are of concern, then the relief needs to be reconstructed. But for this the extra work of laser scanning is not necessary: The photos, which are essential to get the high texture resolution (as described in the beginning of this section), can be used anyway to derive the relief by means of image matching.

Summarizing this section the following actions need to be done for documenting the relief of each column by means of photogrammetry:

1. Create a local system of coordinates for each column by surveying a few permanently marked points in the vicinity of the church.
2. Acquire the photos from a lifting platform equipped with spotlights by observing the planned camera arrangement.
3. From the photos select well defined natural points on the relief as control points and measure them with a tachymeter.
4. Measure some well defined tie points between pairs and triples of photos (even automatic tie point measurement might be feasible).
5. Perform bundle block adjustment and simultaneously estimate the defining parameters of the columns' shape (as a circumscribing cylinder or cone through the control points and further tie points measured in the photos); e.g. with the program ORIENT [Orient, 2005].
6. Compute the development and transfer the texture from each photo (use only the mentioned central part, which guarantees a resolution of 1mm + 10% on the object).
7. Derive a mosaic for the entire relief of each column.

5. USAGE OF THE PHOTOGRAMMETRIC PRODUCTS DURING THE RESTORATION PHASE

Both products, the ortho-photo mosaic of the entire relief and the rectification of the central part of each photo, provided in the geometry of the column's development, will be used several times in the restoration phase, which is coordinated by the building authority of the archdiocese Vienna:

1. Before the actual restoration work can begin, the present damage of the entire columns must be documented in these textured developments. This work will be done by the main-restorer.
2. The entire restoration of the columns will be contracted out. For supporting interested companies in estimating the required restoration work and thus making their financial calculations, this damage documentation will be given to these companies. To refine their calculations the companies are further invited to closely study the conditions of the columns on site.
3. During the actual restoration the working restorers of the authorized company are obliged to record all their work precisely in the textured developments, which they can access online e.g. on a laptop. This way it is ensured that the historical evolution of the building material is consistently documented; i.e. future generations can differ between original, restored and renovated material. For financial and cityscape reasons this will be the only time of the entire restoration phase that the entire columns will be scaffolded. All the other times (issues 1 and 2) the higher regions are only accessible via a simple lifting platform on demand.

After completing the restoration work the post-restoration state of the columns will be surveyed again using photogrammetry – following the very same procedure as outlined in section 4 for the pre-restoration state. This way not only the consistent documentation of the historical evolution of the building material is further improved, also a quality control of the restoration work is possible by comparing the pre- and post-restoration states with the recordings of the restorers.

Finally, by rewrapping the texture mosaic of the relief onto the adjusted geometric model of the columns a 3D-photo model of each column for the pre- and post-restoration state can be derived. These 3D-photo models can be presented easily on the internet, thereby informing the public about the result of these restoration activities and furthermore allowing to experience the columns interactively in 3D.

6. SUMMARY

This article gave an outline on the planed photogrammetric work for the documentation of the pre-and post-restoration state of the two columns of the Church of St. Charles in Vienna. The best documentation of the relief of each column is an ortho-photo mosaic in the geometry of the column's development.

In order to achieve the required high resolution of 1mm on the entire column (size: height 40m, diameter 5m), the arrangement of the cameras has to be planned in detail. Because of the curved surface each pixel in the image will correspond to a different resolution on the object. Therefore, if we allow for a degradation of 10% in object resolution, then each photo will contribute a well defined part around the image centre to the entire mosaic of the relief.

In the geometry of the development a sheet line system can be defined. There each sheet corresponds to this central part of a certain photo, which transfers its texture into this sheet.

The photo texture transferred into the geometry of the column's development will be used several times in the restoration phase: for documenting the current state of damage, for supporting the financial calculations of the companies who are interested in taking over the restoration work (as this work will be contracted out) and finally for the restoration work itself, as the working restorers of the authorized company are obliged to record all their work precisely in the textured developments.

After completing the restoration work the post-restoration state of the columns will be surveyed again using photogrammetry. This way not only the consistent documentation of the historical evolution of the building material is guaranteed, also a quality control of the restoration work is possible by comparing the pre- and post-restoration states with the recordings of the restorers.

From the current state of affairs, the first survey (pre-restoration state) will take place in autumn 2005.

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