HISTORIC PHOTOS AND TLS DATA FUSION FOR THE 3D RECONSTRUCTION OF A MONASTERY ALTAR ENSEMBLE

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ABSTRACT:

The basis of the photogrammetric reconstruction of the altar at the monastery / church are 2 historic photos from around 1920's as well as a 3D documentation of the church from terrestrial laser scanning. The point cloud from the laser scan was the starting point for an approximate computation of the interior and exterior orientation of that image that also contains parts of the altar area that still do exist.
Using a projection of the recent geometry into the image allowed the analysis of changes of the altar ensemble since the time of image acquisition. Those parts that are still in situ are the origin for further action. Whether fragments and parts should be used further or newly positioned was decided in the next phase of reconstruction process.
The focus of the first step of the workflow was at the outlines of the parts in the center of the altar. Using a monoplotting approach and assuming that the profiles are vertical and parallel to each other these object could be definitely compiled. Theses outlines also allowed an approximate determination of the interior and exterior orientation of the second historic photograph in which otherwise the complete connection to the recent altar area was missing.
The side parts of the altar showed to be more complicated for reconstruction. The difference in depth of the varying edges could not be distinguished any more in the images. Such, the sequence and form of the different edges was adopted, scaled and transferred from the central part of the altar to the peripheral ones. Using this geometric information it was possible to define the necessary projection planes for the monoplotting restitution of the visible outlines. A concluding rigorous control was accomplished by back projection of the geometry into both historical images.

1. BACKGROUND

The Capuchin congregation goes back to St. Francis of Assisi and was founded by Ludwig of Fossombrone in the first half oft he 16th century. In 1536 Pope Paul III confirmed the new congregation. Because of their work as predicants and missionaries, their care oft he sick and youth-education as well as their Marian devotion the order became very popular and spread all over the world. In the Tyrol, once there existed 16 capuchin monasteries, all of which followed the same architectural guidelines. The monasteries are built very simply, the convent-churches show a wagon vault without stucco-decoration or frescoes, the altars are made of wood and have their natural brown color or a gray imitation painting, the high altar is framed by panel-paintings and cover the whole reredos.

The Capuchin monastery of Kitzbühel (since 2002 a Franciscan convent) was founded in 1698 by Johann Raimund count of Lamberg, who was a capuchin monk since 1689 and son of the sovereign of the area of Kitzbühel. The capuchin church has a very simple, unadorned architecture with a barrel vault and a side chapel. The artistic value of the church is owed to the three wooden baroque altars from the beginning of the 18th century, framed by columns and pilasters, crowned by broken pediments and oval paintings, approved by a veneer painting and decorated by carved ornaments. The altarpieces where painted in 1707 by the episcopal court painter of Passau, Jakob Christoph Platzer and show the baptism of Jesus in the Jordan, the holy family and St. Antonius in front of the Child Jesus.

During World War II the monastery was closed and the church became a depot. In the years after World War II, the high altar was altered, partly destroyed and lost its characteristic appearance with a broken pediment, crowned oval painting and wings paintings. At the same time, the original church pews, the confessionals and the frames of the Stations of the cross where removed and lost. More than sixty years after the last intervention, a big restoration project started in 2013 with the focus on the artistic inventory of the church. In 2014, the inner room was painted with lime paint, the original marble pavement excavated and restored and the guidelines for the reconstruction of the high altar where found in an interdisciplinary research project of photogrammetric reconstruction by the Surveying and Geoinformation Unit of the University of Innsbruck. According to this project it will be necessary to replace the altar in the original position, to reconstruct the lost broken pediment and to create a new oval painting and wings paintings. The altars where repainted six times during the last centuries and today have a dark brown unattractive surface. To improve the visual appearance, the three altars need to be repainted according the original grain version from the second half of the 19th century, when the woodcarvings where applied. Due to this, the historic surfaces of the altars can be preserved and costs can be kept lower. The Corinthian capitals, curved decoration and panel strips need to become an ochre polychromy, because gold was not used in capuchin churches due to the capuchin vow of poverty. In 2016, when the restoration of the church will be finished, the adaptation and conservation oft he monastery buildings is planed to start.

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Figure 1: Historical photograph 1 showing the desired altar ensemble as it was before World War II

2. AVAILABLE DATA

Despite a thorough search by the Federal Office for Public Monuments, only two historical photos were available. The first photograph (fig. 1) shows the altar area with the side altars and the architectural elements of the interior of the church. Unfortunately, the picture resolution is somewhat low and only the outer limits of the details needed such as the moldings or the decorative elements are well identifiable. This illustration, on the other hand, is well suited for a reconstruction of the internal and external orientation of the photo.

The situation is different with the second photograph (fig. 2) available. Despite some items being covered by garlands that were part of the Christmas decorations displayed on the altar at the time of the photograph, various details are clearly identifiable. However, since this photo shows hardly anything of the interior of the church, there are no common points that permit the determination of the parameters necessary for photogrammetric reconstruction. Other approaches to a solution using secondary geometric conditions such as parallel or orthogonal edges to calculate the orientation of the camera proved to be too complex. A large number of different combinations of secondary conditions would have had to be tested in order to obtain a reasonable result. Nor is it advisable to rectify the image on various levels, since on the one hand the altar is very detailed and of a fine structure, and on the other hand there is no information about the spatial depth of the object.

Figure 2: Historical photograph 2 with Christmas decoration

3. RECONSTRUCTION APPROACH

Given that none of the existing illustrations satisfied all the preconditions for reconstruction, we decided in favor of a combination of the two photographs. In a first stage, the internal and external orientation was determined for photo 1 showing also the interior of the church. It was then possible to reconstruct the identifiable outline of the altar three-dimensionally with additional geometric conditions. These assumptions were tested by means of a back projection. In the second stage of the analysis, this outline helped to determine the necessary parameters for the second photo, in which all the details are better visible. Thus many details such as moldings, decorative elements and ornamentation could be added to the now available framework of the altar. Again, a visual check was by means of a back projection of the three-dimensional model into both images.

3.1 Back projection

An important verification tool for this work is the back projection of the 3D data of the altar into the existing photographs. The representation of the edges of the model in the image level permits a visual check of the various interim stages of the reconstruction. Since this work is developed in a number of stages and the results of each stage form the basis for the next step, a permanent check of the intermediate results is of great importance. A precondition for this is of course a sufficiently accurate photogrammetric determination of the internal and external orientation of both photos.

3.2 Monoplotting

Monoplotting denotes the process of intersection of a spatial image ray with a given surface, e.g. a digital terrain or surface model (DSM). The use of an existing CAD model also allows the inclusion of geometric conditions. If an image is absolutely oriented with respect to the 2,5D or 3D surface, each measured image point defines a direction vector pointing onto the surface. This method made a three-dimensional reconstruction of some parts of the altar at all possible.

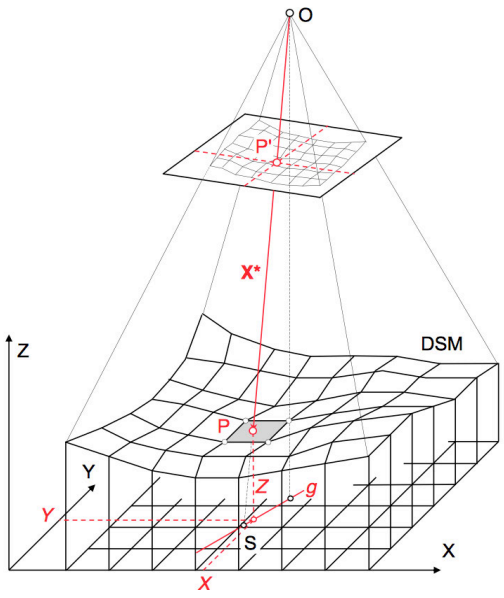

Figure 3: Principle of Monoplotting method (Hastedt and Luhmann, 2012)

3.3 Geometrical conditions

The CAD software was used not only for the three-dimensional modeling but also for the photogrammetric reconstruction of the altar. As a result, the many geometric conditions necessary could be implemented faster and more easily. A fundamental condition for this work was the orthogonality of the elements to each other. The assumption that the section planes of connected edges of the altar were at a right angle to the back wall, made the three-dimensional reconstruction at all possible. The necessary height of the section plane in each case was determined using the monoplotting method. The additional assumption that all edges in one plane formed right angles in pairs also allowed many of the areas covered for instance by the Christmas decoration to be bridged.

A further important geometrical assumption was that of a common axis of the various column elements. Once the direction of the axis had been determined, the already known building elements were repositioned and the missing elements reconstructed. The section planes necessary for the monoplotting were positioned at right angles on the axis.

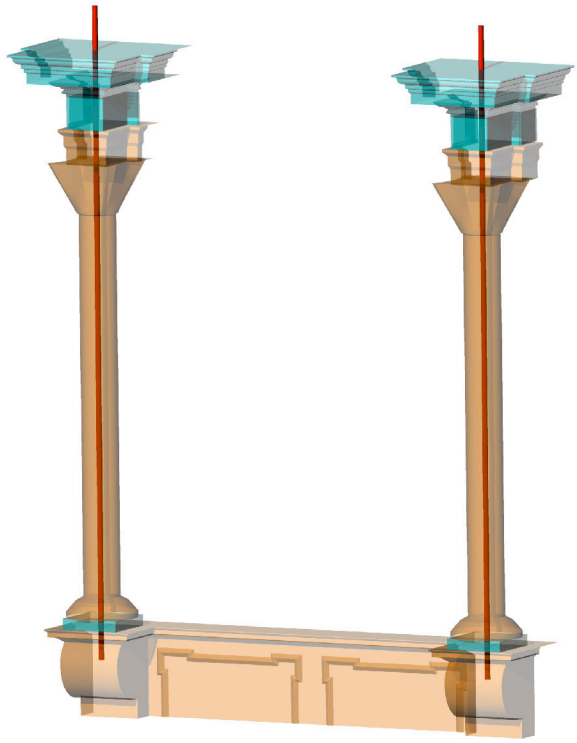

Figure 4: Column axes used as geometrical conditions

A further fundamental aspect was the justified assumption that when the altar was built, decorative elements and their shapes were repeated. The making of moldings in practice requires specific molding carpenter's plough and a separate plough iron must be manufactured for each of these tools. To prevent this effort getting out of hand, the carpenter would for sure try to use them several times. In addition, the use of dimensional relationships (proportions) of the construction element groups to each other was common at the time. The use of CAD software enabled these proportions of the altar and their assumptions to be implemented more easily and adapted wherever necessary in the reconstruction process.

4. WORKFLOW

Figure 5: The present situation of the altar ensemble

4.1 Photogrammetric reconstruction

In order to achieve a detailed survey on site, the present altar space was subject to detailed geometrical measurement with a terrestrial laser scanner. This available dataset made it possible subsequently to investigate the recorded geometry of the church interior for common features in the historical images. In this way, a large number of reliable control points for the photogrammetric determination of the interior and exterior orientation of the first historical photograph (Fig. 1) could be achieved.

Figure 6: Laser scanner point cloud with reconstruction of original photo position using control points

As a check, use was made of a back projection of the edges of the modeled laser scan data into the historical photo.
The camera parameters checked in this way thus made it possible to examine in more detail changes assumed to have been made to the altar ensemble resulting from the restoration measures. A back projection into the three-dimensional point cloud of the laser scan was used to break down the altar into elements that were unchanged, that had been reused in a new position and that no longer existed (fig.7).

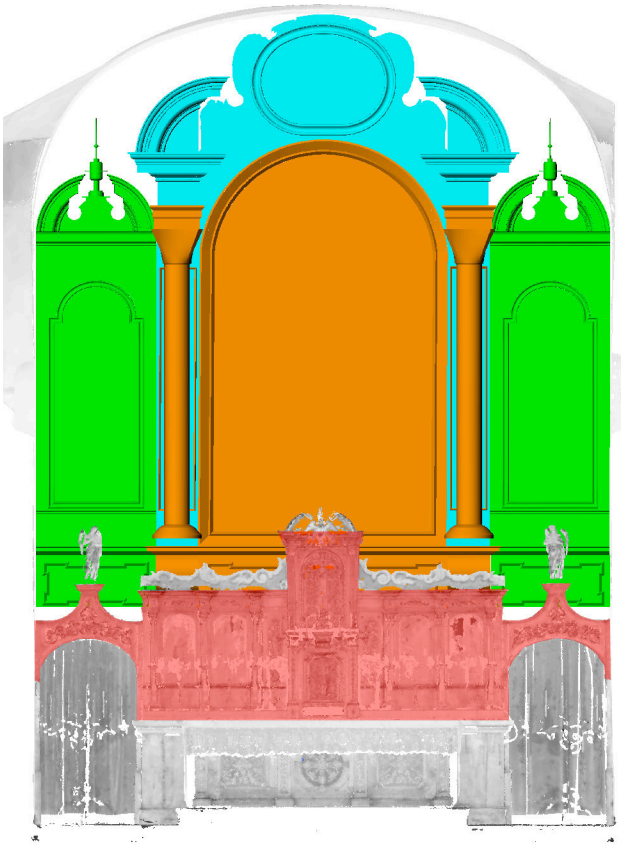

Figure 7: Classification of the elements.
Color scheme: red: unchanged parts,
orange: reused but dislocated parts,
blue: missing but photogrammetrically reconstructed parts,
green: parts reconstructed by geometrical analogy

Locating the unchanged elements and the assumption that the elements were arranged strictly orthogonally to each other also made it possible to determine the position of the back wall of the altar.

In the next stage, the objects that had been reused were repositioned. With the assistance of geometrical conditions such as the common axis of the columns, it was possible to determine their new position. The reconstruction of the frame of the missing elements was the last task in this stage. The starting point for the definition of the external limit was mostly the point of intersection of the line of view with the back wall of the altar. This was once more rechecked using a back projection of the three-dimensional model into the illustration.

4.2 Geometrical construction and back projection

These three-dimensional limit lines of the altar elements were the basis for calculating the internal and external orientation of the second historical photograph. After the camera parameters had been determined, it was possible to add the missing details such as moldings and decorative elements. Once the work in the central area had been completed, the side elements of the main altar were then reconstructed. In both illustrations, it is difficult to get the depth of these objects, or they are in part concealed by the Christmas decoration present at the time of the image taken. For this reason, this missing data, such as that of the moldings, was adopted from the central section of the altar. To begin with, the size was adapted on the basis of the external frame of the objects. Then, the missing information was taken over as additional geometrical condition for the reconstruction. Finally, the results were always verified by a back projection of the three-dimensional model into the two historical images.

Figure 8: Rigorous audit by back projection of the reconstructed outlines into historical photo 2

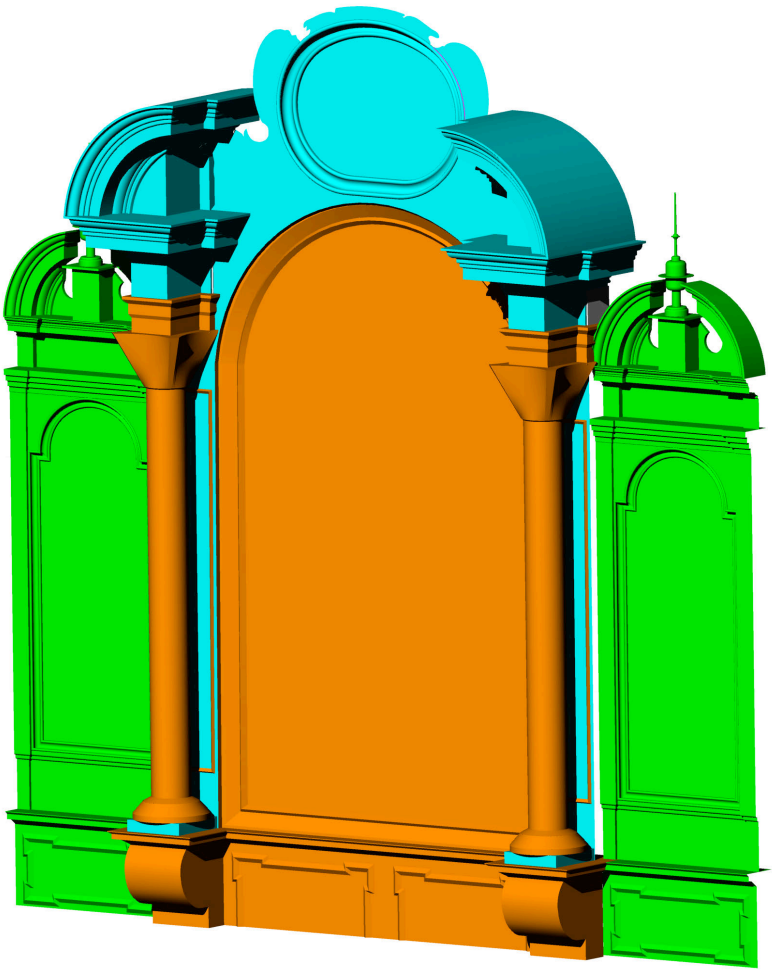

Figure 9: Perspective view of the final 3D model of the reconstructed altar ensemble

5. RESULTS

In order to be able to make available three-dimensional results of the reconstruction to a number of circles of persons in the form of plans, two-dimensional derivatives were produced (fig.10). In addition, two orthophotos in scale of the ornamentation were created. This data forms one of the bases for the intended reconstruction of the altar on site.

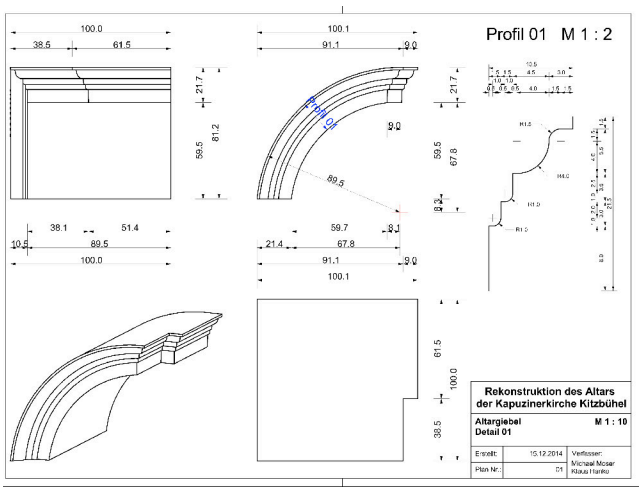

Figure 10: One of the final detail plans for the reconstruction

In the course of 2015 and 2016, on the basis of the above described analyses and reconstructions, the altar area will be completely returned to its condition at the time before World War II.

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