

## EXAMPLE OF DATA FUSION AND 3D PRESENTATION OF A VERY COMPLEX IRREGULAR BUILDING

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**ABSTRACT:** As one method of surveying seldom meets all needs for recording complex shapes and surfaces of a historic building, a combination of methods (tacheometry, photogrammetry and manual measurements) has often to be used. Each of the methods has its advantages, either in easy recording of global structures or in contributing a high level of details so a combination of them is often a must.

Beside the problems of fusion of data from very different origin, the presented example (Crypt Colonia Güell in Barcelona, Spain) shows the limits of 2D-representation of complex shapes in plans and orthophotos and develops alternatives for a flexible and comprehensive visualization of the final model.

### 1 INTRODUCTION

The church of the workers housing estate Colonia Güell near Barcelona – one of Gaudí's best designs – is left unfinished. When the works stopped in 1914 only the crypt was completed since then giving an impression of the beauty of the intended construction. Unfortunately in the time after Gaudí's plans and with it his design was lost. To reconstruct it, a team of building-researchers under the leadership of Prof. Graefe, University of Innsbruck, needed a detailed presentation of the existing parts of the church. The most complex part, the torso of a tower [Figure 1], is subject of this paper.



Figure 1: Inside and outside view of the tower of Crypt Güell

### 2 DATA FUSION

#### 2.1 DIGITAL TACHEOMETRY

Tacheometry combines the measurement devices theodolite and electronic distance meter. The first one measures angles in horizontal and vertical planes, the latter the spatial distance to the object point. The distance meters used in building surveying are reflectorless, which means that you do not need to put a reflector on the target point. Reflectorless distance meters use a powerful visible red LASER beam causing a red spot on the object. That makes targeting much easier avoiding to use the telescope and the crosshair.

Thus the three spatial polar measurement-elements bearing, vertical angle and spatial distance from the instruments position to the object-point are recorded. These data in combination with the point-number and a point-classifying code are automatically stored on a chip card.

Having finished the measuring-work, data are transferred to a PC running a surveying software. All evaluations are done referring to a pre-defined co-ordinate-framework, which is also used calculating the photogrammetric points. The result is anyway a set of evaluated 3D points.

Point by point recording requires a preceding reduction of the continuous object's surface to a set of representative discrete points. This selection should be done in a way, that the points can be identified and related mutually during restitution. This will need a sketch with the position of points to be measured and their topology. After measurement the points must be transferred to a CAD - software and correlated into lines and faces.

Alternatively to the chronological separation of measuring and restitution, this two steps can be done simultaneously. Data are transferred directly to a laptop where the co-ordinates of the points are calculated and lines and surfaces between directly drawn in a CAD-software.

## **2.2 DIGITAL PHOTOGRAMMETRY**

Photogrammetry is an indirect measurement method to extract geometrical information of spatial objects from a number of photos. So the measurements are not taken directly on the object itself. For data acquisition increasingly digital cameras are used.

As a discipline, architectural photogrammetry is currently undergoing profound changes. New technologies and techniques for data acquisition (CCD cameras, Photo-CD, photo-scanners), data processing (computer vision), structuring and representation (CAD; simulation, animation, visualization) and archiving, retrieval and analysis (spatial information systems) are leading to novel systems, processing methods and results (e.g. Hanke [1]).

Working with digital images needs special computer equipment (hard- and software). Recently, systems are under development which combine the functionality of former analytical plotters (stereoscopic restitution) with the accuracy of bundle adjustment and the advantages of digital imaging systems. This "digital photogrammetric plotters" are relatively new for architectural applications, but will replace all "classic" systems in the near future. They can automate the measurement process to a high extend.

Results of photogrammetric restitution are 3D co-ordinates of all points, that show up at least on 2 photographs. Also lines and faces between them are part of the topological model output. Including coordinative known control points to the restitution process will lead to a framework of points, lines and faces, which can easily be exported to any CAD environment.

Further results of digital photogrammetry, beside facade plans and orthoimages, are 3D-models of the monuments. These virtual models can be completed with original image texture on their surface to give photorealistic presentation.

Thus created "photomodels" can be used to visualize e.g. damages on sensible cultural heritage to serve as a tool for the best decision of the responsible authorities (e.g. Hanke [2]).

## **2.3 COMPARISON AND COMBINATION OF MEASUREMENT TECHNIQUES**

Tacheometry results mainly in 3D-coordinates of discrete points whereas photogrammetry yields - besides the geometry - to additional quality information of the surface (e.g. color etc.). The photogrammetric restitution is not restricted to discrete points, but can also produce continuous lines and faces. Photogrammetric images are also a proper storage-media for future work, i.e. if the density of the evaluated points has to be increased. As a sectional method, photogrammetry needs at least two images from different camera positions (or one photo with additional information about the object's geometry). The polar reflectorless tacheometry on the other hand needs only one set up of the instrument and is therefore suited for hardly visible and narrow parts of an object where its would be impossible to get two images have a good intersection of corresponding rays.

Following this ideas we decided to do the interior part of recording (mainly inside a narrow staircase) using tacheometry and the exterior walls with digital photogrammetry. The data fusion of both techniques was possible using a common global coordinate system for both the setup points of the theodolite and the control points for photogrammetric orientation. For this task a traverse links the interior and exterior part of the crypt.

## **3 PRESENTATION OF THE TOWER OF CRYPT GÜELL**

The aim of presentation of any recorded data is to give the viewer a clear idea of the object and to make the correct geometry throughout the building available.

There are two basically different approaches to do the presentation of historical buildings. To show a part of an object by its intersection with horizontal or vertical planes, yielding to two-dimensional sections and profiles. Interesting parts, lying outside the defined plane, are projected into the scene by given mathematic rules. Also the concept of recording often depends on the intended way of presentation. For example, the so called one-meter-draft is measured in this special height above the floor. Vice versa the presentation is determined by the measurements, a later change is generally not possible.

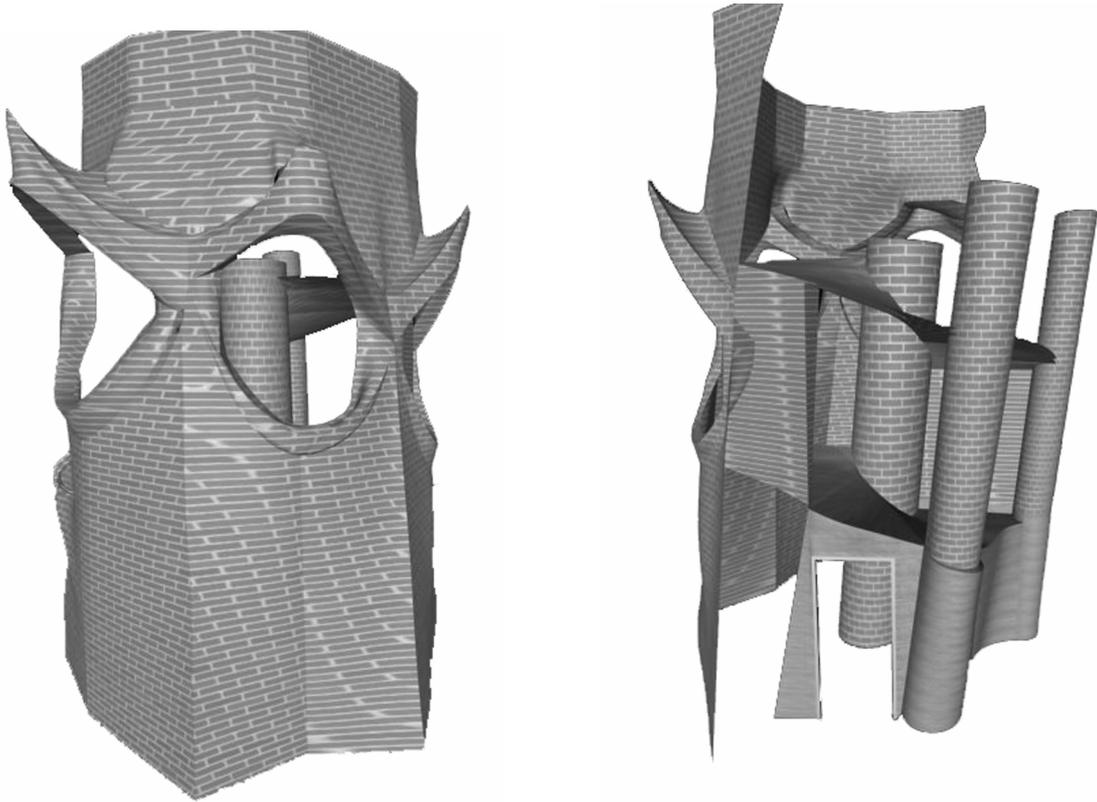


Figure 2: perspective inside and outside view of a part of the 3D – model

The second approach recognizes the building as a three-dimensional geometry. The goal is to create a 3D model consisting of a number of points represented by its  $X,Y,Z$  – coordinates, lines and surfaces. All these geometrical elements are mathematically defined. Projecting photos onto the geometrical correct model even leads to photorealistic surfaces, so-called photomodels [Hanke, Ebrahim,1999].

The first approach is useful only in cases of regular, geometrically simple shapes. The more complex the structure the more problems arise in selecting single representative intersections. In case of a irregular, organic designed shape like Gaudi's architecture [Figure 2] it is no longer applicable at all.

This 3D model can also be regarded as a data storage concept. Further results can be derived from this model, e.g. by parallel or perspective mapping to an arbitrary viewing plane [Figure 3 + 4]. Even animations (fly-over and walk-around) can be created easily from this concept.

A very promising way to visualize 3D data is to create "virtual worlds", not only for computer games but also for "more serious" applications. Using an interactive description format (e.g. VRML), the models can be viewed, turned around or animated in real-time even on a PC. Thus it is suited to create e.g. interactive environments, virtual museums, visualizations and simulation bases on real world data.

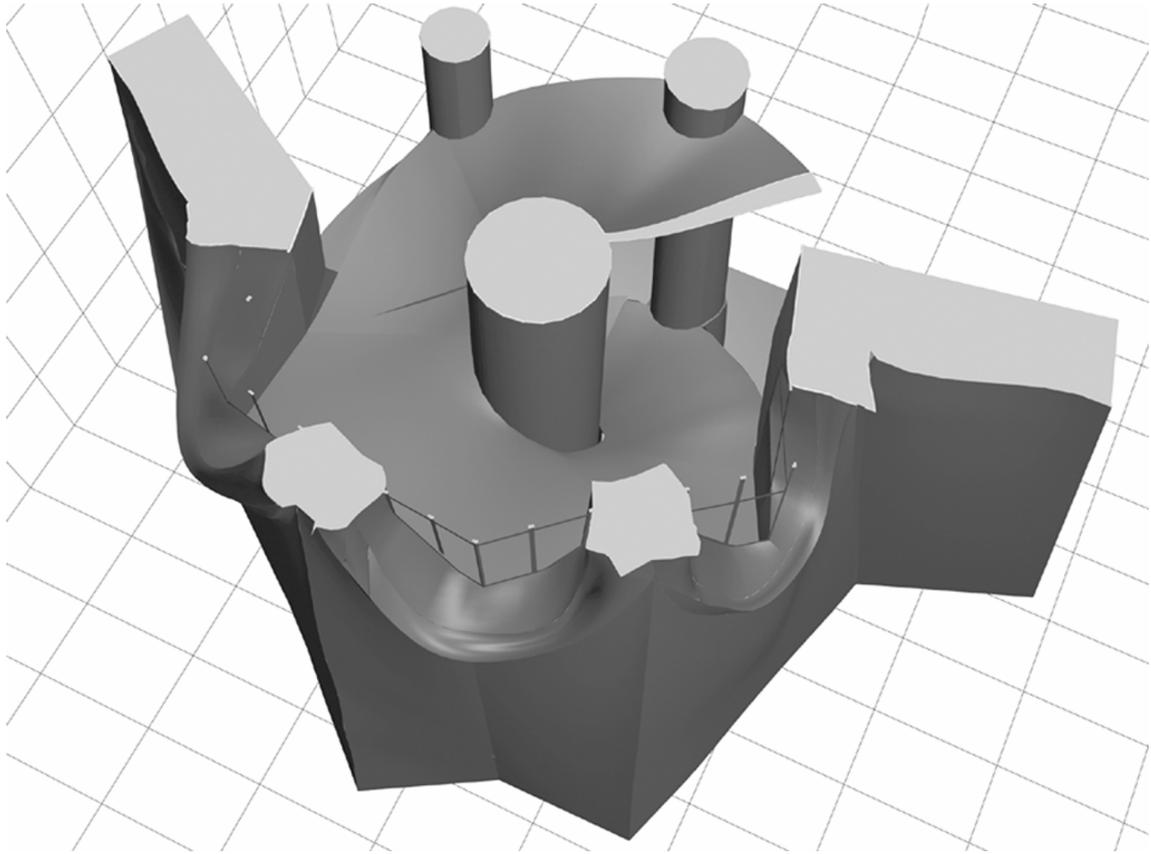


Figure 3: perspective view of a horizontal section

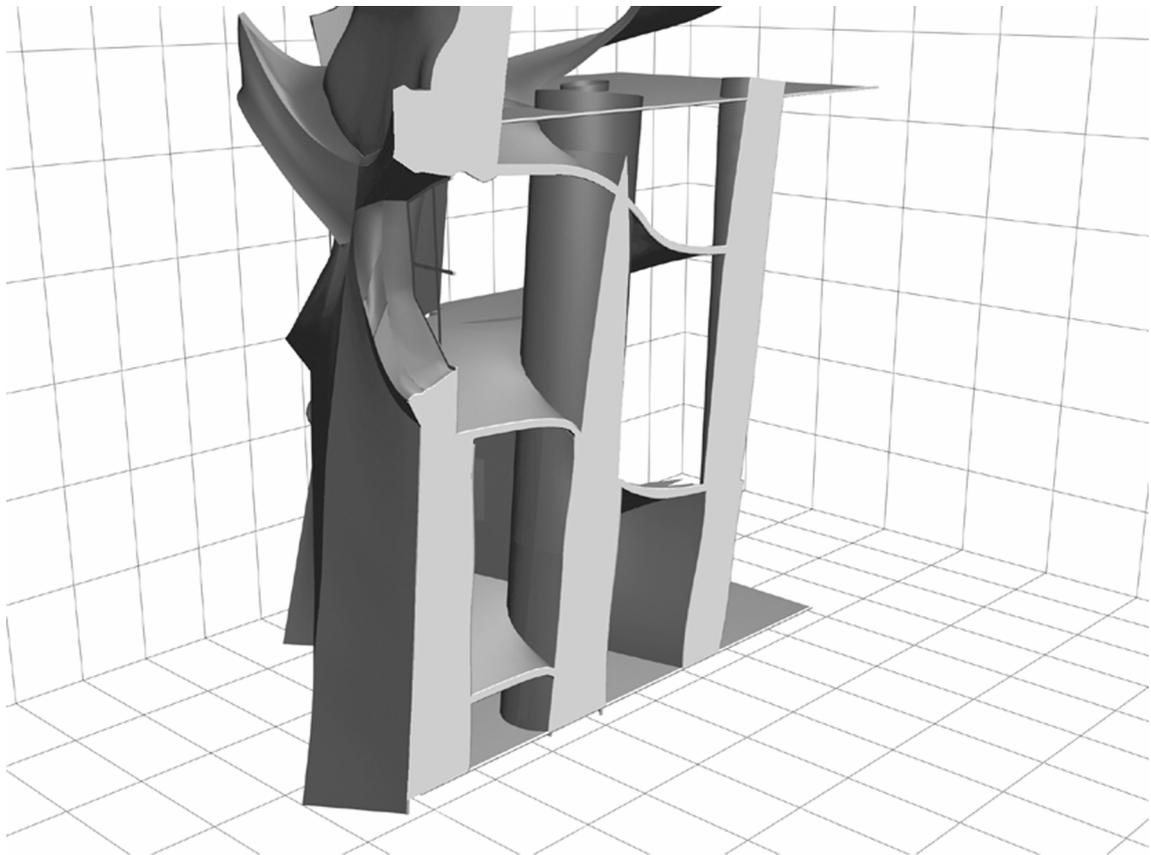


Figure 4: perspective view of a vertical section

#### 4. CONCLUSION

There is a fundamental change with regard to the results of a surveying project. Following this development, the 3D data will be administered in structured information systems that do not prescribe or restrict their further use. Plans and maps, perspective views or profiles and even virtual reality animations are examples of derivative products of a coherent database of the object surveyed. The way of using the derived data is not limited by this database. The kind of presentation will depend on the end user requirements and the specific application at hand.

#### REFERENCES

- Graefe, R., 1999. Eine Installation über Antonio Gaudi's Krypta in der Colonia Güell. *Baukultur* 6/99 pp 28 – 30
- Hanke, K., 1994. The Photo CD - A Source and Digital Memory for Photogrammetric Images. Proc. of ISPRS Commission V Symposium, Melbourne, Australia. In: *International Archives of Photogrammetry and Remote Sensing*, Volume 30, Part 5, pp. 144-149.
- Hanke, K., Weinold, Th., 1995. Using the Photo CD as a Source and Digital Memory for Photogrammetric Images - A Report on its Data Compression Method and the Geometrical Stability of the Transferred Images. Proc. SPIE, Vol. 2646, pp. 42-48.
- Hanke, K., Ebrahim, M. A., 1996. A General Approach for Object Oriented 3D-Mapping in Digital Close Range Restitution. Proc. of 18th ISPRS Congress, Vienna, Austria. In: *International Archives of Photogrammetry and Remote Sensing*, Volume 31, Part B5, pp.
- Hanke, K., Ebrahim, A-B., 1997. A low-cost 3D measurement tool for architectural and archaeological applications. Proc. of CIPA Symposium, Goeteborg, Sweden. In: *International Archives of Photogrammetry and Remote Sensing*, Volume 31, Part 5C1B, pp. 113-120.
- Hanke K, Ebrahim M.A-B. 1999. The „Digital Projector“ – Raytracing as a tool for digital close-range photogrammetry. *ISPRS Journal of Photogrammetry and Remote Sensing*, 1999. Vol. 54 / 1. Elsevier Science B.V., Amsterdam, NL
- Promaska, G., 1998. Automated processing of digital image data in architectural surveying. Proc. of ISPRS Commission V Symposium, Hakodate, Japan. In: *International Archives of Photogrammetry and Remote Sensing*, Volume 32, Part 5, pp. 637-642.
- Streilein, A., 1996. Utilization of CAD models for the object oriented measurement of industrial and architectural objects. Proc. of 18th ISPRS Congress, Vienna, Austria. In: *International Archives of Photogrammetry and Remote Sensing*, Volume 31, Part B5, pp. 548-553.