



The actual situation of photogrammetry and surveying of monuments

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Abstract

On the basis of the rapid development of computer and software, economical and intelligent technologies for documentation and surveying of historical buildings were developed. The experience from projects such as the Frauenkirche Dresden, the cathedrale of Siena, the palace of Güstrow ore the castle of Tirol shows that different methods should be used for a high quality and economy of the results. Because of the expensive investments often involved today, surveying is in most cases handled by specialists. Of great importance is a good cooperation between architects, historians and other experts.

1 The conservation of monuments requires a reliable knowledge of these monuments!

For all people who feel bound to the protection and preservation of the cultural heritage and to the conservation of historical buildings, this introducing sentence is a matter of course. Immense public and private funds are made available for the rehabilitation of monuments. In view of the general pressure of costs, it is however very tempting to save money in the surveying of the buildings and the preparatory investigations. However, in the final analysis this decision often turns out to be the more expensive way. The heading of this contribution should be actually supplemented by a nearly identical one:

Efficient building requires a reliable knowledge of the existing substance of the building structure!

This experience is not new. The investments made in a good survey of the buildings are ultimately cost-saving. Replanning work, stoppage of the construction work due to unforeseen situations or even necessary modifications in the construction may cause costs which considerably exceed those of a proper element survey. Here, of course, the questions are raised how a correct building



admeasure is made and what the most efficient method is. In this contribution I would like to give some instructions and to report about the experience we have gained.

How can a result of a high quality and efficiency in compliance with the requirements be obtained?

The result will first of all depend on the experience and the expert knowledge of the executing person who is able *to understand* the monument, to model completely, correctly and geometrically reliably the details and to mediate them with a high clearness. For such a task, knowledge of the building history and design, architecture symbolism and the specific problems of the object are necessary.

Secondly, the choice and command of the appropriate method used for the building admeasure will be decisive. The knowledge of the possibilities as well as the advantages and disadvantages of each method is not only beneficial to one's own practical work but also to decision makers who assess the quality of any existing as-built drawings or offers for surveying of buildings by service companies.

2 Manual measuring-up work

As instrumental methods are being increasingly used, the traditional manual measuring-up work has lost some of its significance. One of the advantages of the instrumental methods is, on the one hand, the simplicity of the technical tools by which measurements can be carried out with sufficient accuracy even in the immediate vicinity but, on the other hand, a higher expenditure of time or technical equipment will be necessary to ensure an encroaching accuracy over great distances. Because all measuring points must be handled in the true sense of the word, the limits of manual measuring-up work are set by the reachability. In addition, expenditures for scaffoldings and other tools are necessary. The position and the level are always measured separately, one after another. The much estimated advantage of on-site mapping and drawing can also be made use of today when surveying by means of tachymeters. Manual measuring-up work will be advantageous in case of simple structures and wherever expensive reference systems can be dispensed with, i.e. mainly for small objects and as a supplement to other methods.

Instead of measuring tape and sketch block, laser range finders and note books are used today, such as the DIGIPLAN-AddPlan, a specific AutoCAD application. When using this equipment, the user draws the plan view directly on the screen and enters the measured dimension for each distance. During the subsequent calculation of the plan view geometry on a triangular basis, additional observations such as right angularities, alignments or parallelisms are taken into account, besides the distances measured. Any erroneous or forgotten dimensions are immediately detected and can still be corrected on site.

3 Geodetic methods - Tachymetry

For measuring up the interior dimensions of buildings, geodetic instruments are predominantly used today. In former times, theodolites were mainly needed for the preparation of traverses or rectangular reference systems. Using the tachymeters, horizontal angles, vertical angles and the distance to the measuring point can be simultaneously determined. As to the distance measurement, laser range finders are today usually applied as set-up instruments or integrated measuring systems. The light of the laser beam serves the marking of the measuring point which only needs to be indicated by the laser point, without the necessity to view the same through the theodolite telescope. At the same time, the laser beam is sent back to the instrument by reflection on the object's surface so that the distance can be determined. Thanks to the automatic registration of the measuring values, any reading and transmission errors are excluded. Based on the spatial angle and the distance measured, the coordinates are calculated and stored and thus the overall view, the section or the plan view can be generated point by point. Hence, the surface to be measured is three-dimensionally scanned as with a pointer.

In the past, the point coordinates determined in such a manner were converted to a drawing at the office by using the computer and any gaps had to be filled in a second step of operation. Today the new TachyCAD software can be used for this job. By directly transmitting the data to the AutoCAD system, the mapping work is done on site and the drawing is generated with the object in view.



Figure 1

Work at the TachyCAD measuring station with electronic theodolite and laser range finder. The objects to be measured are three-dimensionally scanned as with a pointer and on-line mapped at the „drawing table“ note book.



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The high accuracy and reliability of the method, the contactless measurement and thus the possibility to apply it in complicated situations, the operation by a single person, the extraordinarily rapid collection of the measured data, the possible great density of points as well as the capability of preparing the drawing on site are clear advantages that have a perceptible impact on quality and efficiency. A limiting factor to the application of this technology is the necessity of a stable standing place for the instrument during the measurements. For this reason, any parts of the building which cannot be directly viewed must be surveyed by photogrammetrical methods.

4 Laser scanner

For some time, new instruments are being tested on which demanding requirements are placed for the future work. Using the laser scanner, the surrounding space is automatically scanned through a 360° circular disk and 180° vertical angle so that a three-dimensional stereoscopic image is obtained. At present, there are still a few technical problems that need to be solved, for example the high power consumption and low angular resolution which, however, will certainly be tackled before long. In spite of the availability of specific evaluation software, the disadvantage of this method - in comparison with the tachymetry - is that an additional vectorization is necessary. As this operation, including the valuation and generalization involved, is carried out later at the office, an additional operation on site will probably be unavoidable, and if it's only to fill any gaps in hidden areas.

5 Photogrammetry

In photogrammetry the specific geometrical properties of the photographic image are used to survey the objects imaged. Generally, this method is used for the production of maps by means of aerial photographs, but also for many other special applications. A wide-spread - in fact, the original - application includes architectural surveying and surveying of building. This method was developed by Albrecht Meydenbauer in 1858 and was applied in practice at the Königlich-Preußische Meßbildanstalt in Berlin as from 1885. Making use of the central perspective of the photographic image, the position, shape and size of the objects to be measured are determined from at least two photos.

This photogrammetrical method is based on two measuring chambers which combine the properties of a camera with those of a precise goniometric instrument. By taking a survey photograph, the spatial directions of all points to be surveyed are registered at the moment of exposure. Thus the object's geometry is objectively stored in the survey photograph. At any time later, using photo, a specialized evaluating engineer does the surveying work proper on the basis of a generalized representation and abstraction and in consideration of all details. This surveying work can be supplemented or repeated at any time.

While a stable standing place is necessary for angle measurement with the theodolite, survey photographs with a sufficient film sensitivity and thus short shutter speeds can also be taken from lifting appliances or even helicopters. Using this method, photos of structural elements can be taken which, otherwise, are only accessible via expensive scaffoldings or not at all. Taking the survey photographs seems to be a „roundabout way“ to the final as-built drawing but, almost in passing, a valuable photographic documentation is obtained.

One of the very essential advantages of the photogrammetrical method, i.e. the splitting of the measuring process into two operations (taking the survey photographs and evaluation), was used by Albrecht Meydenbauer for the systematic documentation of monuments 100 years ago. Whereas any other measuring method makes sense only after the complete drawing has been prepared, the object's geometry can here be stored, for the time being, in survey photographs. The evaluation and actual surveying work can then be carried out at a time later, even if the building no longer exists. It would be desirable to have recourse again to such a simple approach of the preservation of monuments.

5.1. Shooting technique



Figure 2

Dome of Siena, taken with a 13 x 18 UMK at a scale of 1 : 2. Only 150 photos were needed for the interior space.



The visibility of details and accuracy of the photogrammetrical evaluation depend mainly on the photographic resolution of the photo. Consequently, the shooting conditions are primarily governed - apart from local conditions - by the photographic scale. For example, a photographic scale of approx. 1 : 250 is necessary for an evaluation at a scale of 1 : 50. The number of photos to be taken necessarily increases as the image size decreases. In order to cover a certain area, the number of photos to be taken with a 6 x 6 camera is eight times the number of photos to be shot with a 13 x 18 camera. It goes without saying that 35 mm cameras are completely unsuitable for this purpose.

For the 34 as-built drawings of the cathedral of Siena, which were mainly made by photogrammetry, about 4,000 survey photographs sized 6 cm by 6 cm were available. As the use of these photos for triangulation and stereoplotting required too much effort, essential parts of the dome were retaken with a large-format measuring chamber within a few days.

For several years digital shooting systems have been used which, however, have replaced the photographic measuring chambers only in specific fields of application. The resolution of the images is still too low so that a much greater number of photos would be necessary. The decisive advantage of the digital shooting systems is that the measuring process can be automated and thus the measuring results can be determined in real time. But this is possible only for points signalled in advance which can be definitely identified and evaluated by the computer. All tasks in which the operator has to identify, to evaluate, to differentiate and to generalize the contents to be surveyed will be performed, also in future, by means of the traditional photogrammetrical methods. Seen under this aspect, an automation of architectural surveying still seems to be very questionable.

5. 2. Stereophotogrammetry

Only stereophotogrammetry makes it possible to survey any surfaces true to line and with spatial accuracy. By taking two survey photographs with parallel photographic axes and a stereoscopic viewing of the images, the viewer obtains a virtual model of the surface. Its geometry can be exactly determined by tracing this spatial model with a measuring mark in a three-dimensional manner. The measuring process is extraordinarily quick. By tracing the lines, the points are registered practically on-online and with a density and speed unreachable with other methods.

The photogram is usually represented as an orthogonal projection in the plan view, as a map of the territory, or in the front view of a facade, for example. The information about height and depth, i.e. the third dimension, can be traditionally represented as a contour line or isometric line according to topographic maps and, mainly on facades, as horizontal or vertical profiles for plan views and sections. The determination of profiles and views of a complex facade decoration is hardly conceivable without stereophotogrammetry. Using this method,

architectural structures can be imaged with all deformations, curvatures, sculptures, decorations etc. truly recorded. In view of the high measuring speed, in particular where a great information density and high degree of difficulty is encountered, the extra expenditure for taking such survey photographs is acceptable. In many cases, other alternatives are precluded anyway for the said reasons.

Thanks to the modern analytical stereoplotting instruments that can perform the calculations required to derive the drawing from the image, the efficiency is considerably increased and the fields of application are decisively extended by higher degrees of freedom in the shooting conditions and by the consideration of distortion factors and other deviations from the image taken in the central perspective.



Figure 3

Work with stereoplotting instruments. In the photogrammetrical measurement, the survey photograph takes the place of the object to be surveyed.

A particularly impressive proof of the potential and capabilities of stereoplotting is furnished by the photogrammetrical reconstruction of the altar of the Frauenkirche in Dresden. Images of such details and accurate shapes would not be possible by using other methods. Based on the stereoplotting of the altar ruin and by referring to historical photos, the original state of the altar and the organ was reconstructed in all detail by order of the Frauenkirche Foundation. Thanks to the favourable conditions under which the old photos were taken, the latter could ideally be used for stereoplotting.

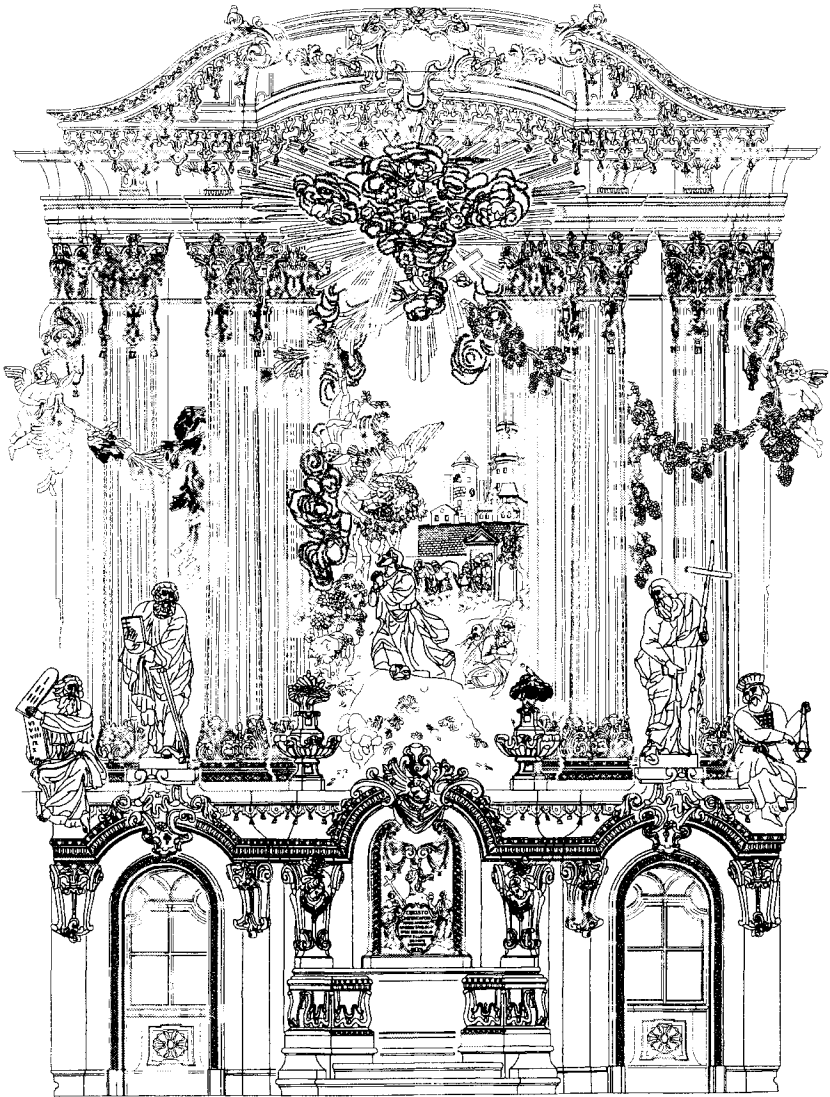


Figure 4
Photogrammetrical reconstruction of the altar of the Frauenkirche in Dresden.
Original scale 1 : 10.

5.3. Simple photogrammetrical methods

Using the relevant software, which is available in various versions and places only moderate requirements on the hardware and measuring technique (e.g. digitizing panel for measuring the image points), the coordinates of the object point are determined one after another from the image points measured in at least two photos according to the intersection method. In this way, the drawing can be generated point by point. An important prerequisite for obtaining a reliable result is to precisely identify - from two different perspectives - the point to be measured. In most cases, this requirement is fulfilled in surveying simple structural elements. However, it is not possible to reliably cover e.g. the form of an arch. In this case and also when it comes to determining profiles or contour lines, deformations or deflections, i.e. in cases where it is not possible to survey well-defined points, stereophotogrammetry is the only way out.

5.4. Rectification and digital image processing

Plane wall surfaces can be reproduced, of course, by two-dimensional images taken at a uniform scale even if converging lines occur due to tilt or avertence. In this case, it is necessary to rectify the image. Using a specific enlarger, a rectified survey photograph is optomechanically produced which constitutes a true-to-scale image with the properties of a high-quality photo. The expenditure is significantly lower than that for admeasure and drawing all architectural details and aspects. Some limitations must be accepted for components which are in front of or behind the reference plane. For example, the eaves ledge at the upper image edge is distinctly shown as an underside and thus it is too high and not true to scale.

As the capabilities of the personal computers increase, the rectification and further processing of scanned images gains more and more in importance. Digital image processing is advantageous if it is necessary to combine several rectifications to mosaics but it is also possible to rectify the image so as to get other mathematical forms (cylinder development, dome segments). For building research at the Tirol castle, rectifications and digital mosaics are mainly used for wall developments and a true-to-stone representation. The exact stereoplotting of the main architectural lines is supported by rectified images and thus supplemented by the details. The digital images can be reproduced with a good photographic quality.

6 Application of CAD systems

Today the application of CAD systems is a matter of course and provides for an additional increase in efficiency when preparing maps and as-built drawings by the utilization of various software functions. Specific effects can be obtained, in particular, when the drawings are further processed by the computer in the subsequent planning process. Modern plotters guarantee a high graphic quality



which contributes to the improved clearness and readability of the drawings, thanks to the differentiation of line types and area signatures.

While, at the beginning, CAD was considered a „digital drawing board“, the computer-aided design has developed into a comprehensive tool of all experts involved in construction activities. Admeasure and element survey do not remain unaffected by this progress. Based on modern measuring-up technologies, a structured component-related data base is generated directly during on-site measuring work or the photogrammetrical evaluation. From the architectural model produced in this way, area- and space-related data can be directly derived and used in tender programs and facility management systems. In this connection, the different measuring-up systems are meant to be specific data collection systems which run under one and the same software.

Applications in the form of graphic data banks are being prepared also for restoration activities. For example, in the documentation of damage and planning suitable measures for high-quality faHades, a lot of information is gathered; an efficient management of this information, which also has to be entered in as-built drawings, is only possible in data banks. Updating and optical preparation of the data stock are done in CAD drawings which are coupled to data banks. This allows the information to be geometrically assigned and presented as well as evaluated and analyzed at a large scale.

7 Summary

There will be hardly a situation in which any specific task can be efficiently solved at a high quality level with only one of the methods outlined here. In order to deal efficiently with such a task and to guarantee a high quality level, the application of several methods will be necessary which supplement each other. Of course, in order to be able to choose the methods best suited, it is necessary to know the advantages and limits of each method. The major investments required for the equipment (tachymeter, measuring chambers, laboratory apparatuses, stereoplotters, high-capacity computers and software) as well as for qualification and training are worth the while only if this equipment can be used over extended periods. Consequently, some specialization and work sharing will be unavoidable for the engineers. An exact definition of the task, discussions about the specific requirements and the organization of the cooperation between all persons involved, i.e. the architect, curator of monuments, restorer, surveyor/photogrammeter and also the building owner - will gain more and more in significance.