HYBRIDE PHOTOGRAMMETRIC AND GEODETIC SURVEILLANCE OF HISTORICAL BUILDINGS FOR AN URBAN TUNNEL CONSTRUCTION

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ABSTRACT
The paper reports on photogrammetric and geodetic surveying for control measurements of historical buildings that are located in the neighbourhood of a large tunnel construction in the city of Bremen, Germany. The tunnel is about 800m long and 30m wide, and it is currently built by slotted wall method. Due to the ditch depth of about 20m it is likely that adjacent buildings might get significant deformations or damages which then have to be compensated financially. In this situation a three-dimensional object survey has to be performed that includes image documentation of damages. A total of 10 buildings had to be observed. The required object accuracy of ±1mm has been successfully achieved.

1 INTRODUCTION

In the 1980ies plans have been initiated for a large inner-urban street tunnel in the city of Bremen, Germany. The designed "Hemelingen Tunnel" was mainly planned as a connection between the freeway and the car factory of Mercedes-Benz, and to ease the traffic load within parts of the city. The location route mainly passes older residential areas in need for redevelopment, and some industrial zones as well (total length of location route approx. 2.3km). The tunnel is currently built in an open ditch, i.e. without underground work. However, some adjacent building have to be pulled down in order to dig the ditch. After finishing of the tunnel construction work the area above ground will be rebuilt as redeveloped residential and recreation areas.

Figure 1: Construction site "Hemelingen Tunnel"

Figure 2: Construction work in open ditch

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The pure tunnel is about 800m long and 30m wide. In the neighbourhood of the construction site a number of older buildings exist, mainly built between 1900 and 1930. One of the buildings is the silver tool factory of Bremen listed for preservation, another one is a church. In some cases the distance between buildings and sheet pile wall is less than 1m. The condition of the buildings is very different, it varies from houses to be refurbished to recently renovated houses.

An approximately 20m deep ditch has been dig for the construction of the tunnel (Figure 1, Figure 2). Due to possible ground movements and changes of the ground water table in the near surrounding of the tunnel, subsequent movements of the buildings can be expected that could lead to significant damages. During the initial project stage a financial volume of several million DM has been projected for possible renovation costs.

In order to avoid claims for damages without good reasons, the project leader has placed orders for extensive evidence control measurements. These should document the existing damages on buildings before any construction work has been started. This includes all visible damages on interior and exterior parts of the buildings, e.g. setting breaks or damages bricks of the walls. Each damage is then measured by special gauges or tools, and documented by photographs (example in Figure 3). This work has been carried out by legally authorised experts.

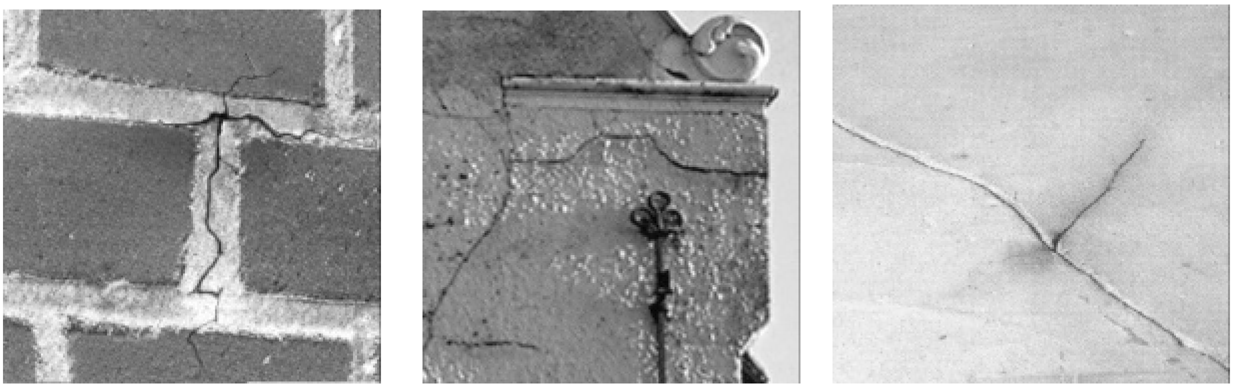

Figure 3: Documentation of existing damages

One part of the evidence documentation dealt with the three-dimensional measurement of building geometries. In contrast to usual setting measurements performed by precise leveling only, one has also expected movements of the buildings that might occur not only in vertical direction. Investigations of the soil mechanics let assume that, in principle, the buildings might set non-regularly, thus leading to non-linear deformations. For this reason photogrammetric measurements have been carried out in addition to geodetic measurements, that will also be used as pictorial documents of the as-built status. In the past few years the IAPG has gathered experiences in the photogrammetric recording of large objects (Luhmann & Tecklenburg, 1997).

The special technical problem of this project can be addressed by the location and inaccessibility of the buildings, and the definition of stable reference points used as a certain reference for future measuring epochs. In order to find a solution a combination of photogrammetric and geodetic measurements has been carried out, that will be discussed in the following paragraphs.

2 ON-SITE MEASUREMENT

2.1 Specifications

The total project consists of 10 buildings in a distance of about 50m besides the tunnel construction site. For each building those parts of the façades have to be measured that face the tunnel, i.e. more or less all front sides of the buildings. The total area of façades amounts to ca. 9800m².

The façades have been prepared by signalised targets (Figure 4), that had to ensure a high reproducability in their position for future measurements. According to civil engineer experts the point density has been defined to ca. 4m, thus a total number of 250 reference points had to be measured for all buildings (overview in Table 1). The object point accuracy has been specified to 1mm in all co-ordinate axes.

number of buildings	10
total area of façades	ca. 9800m²
number of signalised points	900
number of reference points	250
average point distance	4m
number of photos	720

Table 1: Project data

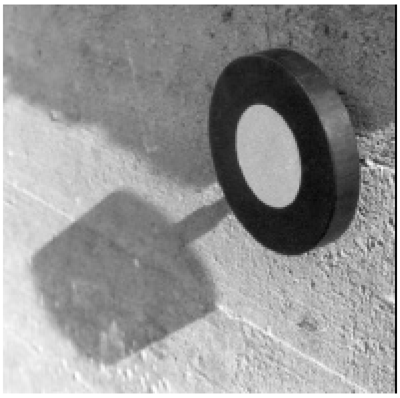

Figure 4: Point targeting

2.2 Image acquisition

Two digital cameras Kodak DCS 460 with 14mm lenses have been used for photogrammetric image acquisition. The achievable accuracy in object space has been estimated by

$$s_{XYZ} = q \cdot m_b \cdot s_{x'y'}$$

A mean image measuring accuracy of $s_{x'y'}$=0.2 pixel resp. 1.8µm has been expected for the used point targets. Although much higher measuring accuracies are possible for this type of camera, a lack of accuracy has been taken into account due to uncertain exterior conditions. Especially uncontrollable light conditions might lead to a worse image quality. Assuming a mean image scale of m_b=500 and a design factor of q=1.2, the above specified object accuracy of s_{XYZ}=1.0mm can be achieved.

Data storage of images is performed directly on PCMCIA disk drives built in the DCS 460 cameras. On site the images have been stored on a laptop computer additionally in order to ensure a direct analysis of the image quality.

The target points have been manufactured as special adapters that could be mounted into caburized screw dowels. The reproducability of the adapters inside the holes has been investigated beforehand, and has been proven to better that 0.1mm. For the actual target centre retro-reflective material has been used (Figure 4). In addition to the reference points a large number of temporary tie points has been added.

Due to the limited space for the selection of image stations and due to the height of the buildings, numerous images have been taken from a stroke riser (Figure 5).

Figure 5: Image acquisition out of a stroke riser

Figure 6: Angle measurement

2.3 Image configuration

Each object has been measured according to an individual image configuration. In general, camera station have been selected in a way that every object point has been imaged in at least five photos in order to meet the accuracy specifications.

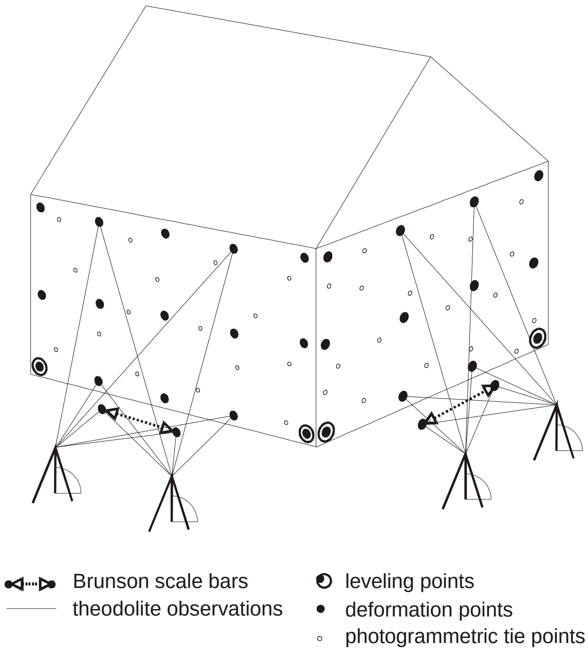

Figure 7: Example of a geodetic network of measured directions

In order to create a long-term stable reference system, the object point which is farest from the ditch has been selected as origin of the local object co-ordinate system. Using the 3-2-1 method known from industrial metrology the co-ordinate axes have been defined without any constraints.

Parallel to the actual measurement of the buildings a signalised test field has been set up on site in order to provide the possibility of re-verification and calibration of the cameras. Figure 8 shows some examples of metric images of different buildings.

Definition of scale and datum of the object co-ordinate system was performed by precise leveling and geodetic angle measurements using an industrial theodolite measuring system based on precision theodolites Leica T2002 (Figure 6). Targeted precision scale bars (Brunson), again taken from an industrial metrology system, have been used to define reference distances in object space. As an example, Figure 7 shows the geodetic network of directions for the measurement of control points, and the configuration of photogrammetric tie points as well.

Figure 8: Examples of metric images

3 RESULTS

3.1 Image processing system

The measurement of image points has been carried out by the program Ax.Ima (AXIOS 3D Services) that consists of sophisticated algorithms for the determination of ellipse-shaped targets even under poor image quality conditions. The accuracy of these algorithm has been shown in previous investigations (Luhmann, 1996).

The bundle adjustment program BINGO (Kruck, 1983) has been used for image orientation and three-dimensional point determination. Here all geodetic observations have been integrated with weights according to their accuracy.

3.2 Achieved accuracy

The average measuring accuracy of the geodetic measurements amounts to 0.1mm for precise leveling and also 0.1mm for 3-D point determinations using the theodolite system. Consequently these observations are available with superior accuracy with respect to the photogrammetric measurements.

After the combined bundle adjustment mean residuals of image co-ordinates of about 0.9µm have been achieved. The standard deviations of object point co-ordinates vary between 0.5mm and 0.8mm in X-, Y- and Z-direction. Compared to independently measured reference distances a mean uncertainty of length measurement of 1mm is resulting.

4 SUMMARY

A combination of photogrammetric and geodetic methods has been applied to a complex and extensive task of evidence documentation. The specified accuracy of 1mm in object space has been achieved. The main technical problem has occurred with the difficult conditions on-site and hard to access buildings. Image processing has been performed by precise image operators. The measured image co-ordinates have been processed in a combined bundle adjustment including all geodetic observations.

For the following measuring epochs the transformation of measured points is mainly based on differences between the epochs, because the reference points have been determined with superior accuracy using precise leveling and a theodolite system.

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