TACTILE SURVEYING METHODS OF SURVEYING BUILDING DETAIL – AN ESSENTIAL COMPONENT OF COMPUTER-AIDED BUILDING SURVEYING

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ABSTRACT:

Computer-aided tacheometry and photogrammetry are used increasingly for surveying building geometry. The use of manual methods such as tape, measuring-stick or laser-distance meter are equally widespread for buildings as long as the building geometry is reasonably simple.
However the surveying of building elements with complex geometries (such as a column capital or gothic window) is difficult to integrate in computer-aided surveying systems.
This paper proposes a building surveying approach for this neglected area that employs tactile object surveying in combination with classical methods of tacheometry and photogrammetry and so makes the most of both methods.

1. INTRODUCTION

In most cases the term building surveying is usually understood as the geometric measurement of the building in plan, section and elevation. For planning or research purposes a whole series of supplementary information is required and typically the amount of information required increases and becomes more specific as planning or research progresses (Petzold, 2001).

A geometric survey is undertaken using geodetic or photogrammetric measurement systems which have been tailored to the needs of building surveying. In general these necessitate a degree of technical knowledge and not least financial resources. The integration of new technologies such as photogrammetry and tacheometry in an integrated surveying approach together with manual measurement techniques compensates for the main weaknesses in traditional surveying. However two fundamental problems still remain:

- A large proportion of measurements do not occur in direct contact with the building which means that some information will not be noticed, and
- the integration of new technology through an intelligent software system does not simplify the use of the measuring equipment itself.

In addition a further element is not considered in the traditional up-front survey: the need for increased and more detailed specific information during the course of research or planning process.

This paper looks at the use and systematic integration of tactile surveying methods for geometric surveying in direct contact with the building. The essential characteristics and deficits of traditional measurement approaches will be investigated as a basis for developing a simple concept for surveying building detail. Finally, possible means of implementing such a concept using existing tactile measurement systems will be examined and assessed.

2. TRADITIONAL MEASURING TECHNIQUES

Traditional building surveying using conventional measuring techniques is oriented around producing analogue documentation in the form of plan, section and elevation. Conventional methods include manual surveying by hand, reflector-less tacheometry and photogrammetry. These methods have been further developed to suit the IT demands of current planning and renovation practice (Donath et al, 2002).

2.1 Computer-aided manual surveying

Computer-aided manual surveying using an electronic distance meter is the simplest way of quickly and cheaply measuring spatial geometry. The following characteristics can be identified:

- The measurement occurs in direct contact with the building.
- The measurements are taken between two surfaces (length of a wall, room height, door width etc.) which the distance meter is held up against.
- There is a minimum distance measurable, depending upon the distance meter.
- Measurements can only be taken between two points in direct visual contact with one another.
- Simple spatial constellations (primarily with even surfaces) can be measured reasonably effectively and efficiently.

2.2 Reflector-less tacheometry

Besides computer-aided manual surveying a common method is the use of reflector-less tacheometry. Despite its adaptation to the requirements of planning there are still a number of disadvantages associated with reflector-less tacheometry:
- The direct contact with the building is lost.
- There must be a direct visual connection between the equipment and the point to be measured.

- Tacheometry necessitates special skills and therefore specialist building surveyors.
- The building survey therefore has to be delegated to experts. These experts know their craft but may not have sufficient knowledge concerning planning requirements or be able to identify specific problem areas.
- The survey is seldom extended with specific more detailed information during the planning and renovation process. Once the specialist surveyors are finished the survey is seen as completed. In addition, planners and researchers do not have the necessary skills to extend the existing survey in the same way.

2.3 Laser-Scanning

Laser-scanning is a special technique associated with reflector-less tacheometry in which an object or part of a building is scanned resulting in a high-resolution 'cloud' of points. The disadvantages of the system are similar to those of reflector-less tacheometry with some notable additions: Laser-scanning results in a high-resolution description of a surface geometry from which building-relevant parameters have to be deciphered in a second-step. This post-modelling is still in the developmental stage so that laser-scanning is not practical for building surveying at present. In a later section we will come back to a special application for laser-scanning in the surveying of building detail.

2.4 Photogrammetry

Photogrammetry using stereo-image or multi-image photogrammetry is rarely used for most building surveying projects, primarily due to its high cost, the need for specialists and the post-processing requirements for its assessment. In principle stereo-image photogrammetry is suited for measuring the geometry of irregularly structured building details.
The rectification of single-image photogrammetric results is suited for surveying building surfaces. It is a quick means of measuring a large amount of geometric correct information at high-resolution. Rectification does, however, have limitations when measuring irregularly structured surfaces. Developments in conjunction with laser-scanning approaches are still in the early prototypical stage.
All photogrammetric approaches require a direct visual contact between the camera and the area to be measured. Areas which are covered up or surfaces which fold back on themselves cannot be measured.
As with tacheometry, the direct tactile contact to the building is lost. Where cameras with insufficient resolution are used, object information within the image may not be recognisable.

We can conclude that geodesic or photogrammetric approaches are well-suited for establishing an initial survey. These can be used to develop an overall geometric model and to provide an geometrically-corrected basis for basic charting requirements. Its most important contribution to the building survey is the provision of a high-level geometric reference system to which all further geometric measurements can be related.

3. DEFICITS

The examination of the characteristics of traditional and conventional measuring approaches show that they have no or only limited suitability for the supplementary measurement of small-scale details. A whole area of surveying remains unaddressed, which at present is covered by supplementary sketches, direct modelling (profile measure, plasticine etc.) or more complex measurement using string, plumb-line and measuring stick. These traditional manual techniques also have particular disadvantages:

- Sketches only provide geometric information where the drawing has been annotated with geometric measurements.
- Supplementary sketches cannot be integrated as geometric data in the digital building model. They can be used as a descriptive attribute attached to a particular building element.
- The exact spatial location of the measured information cannot be determined.

These disadvantages are most noticeable in the surveying of details such as profiles, capitals and other complex and non-standard building elements (windows, doors etc.). A reliable on-site survey of each individual situation is fundamentally important for the assessment of building renovation works, for instance for the repair, extension or reproduction of building elements and details. Ornate building elements, often made of multiple elements are particularly common in the renovation and conservation of historic buildings and are difficult to survey using traditional approaches.

4. NEW TECHNIQUES FOR BUILDING SURVEYING

This gap in the coverage of geometric building surveying can be addressed by tactile surveying methods adapted to the requirements of existing buildings (Fig. 1).

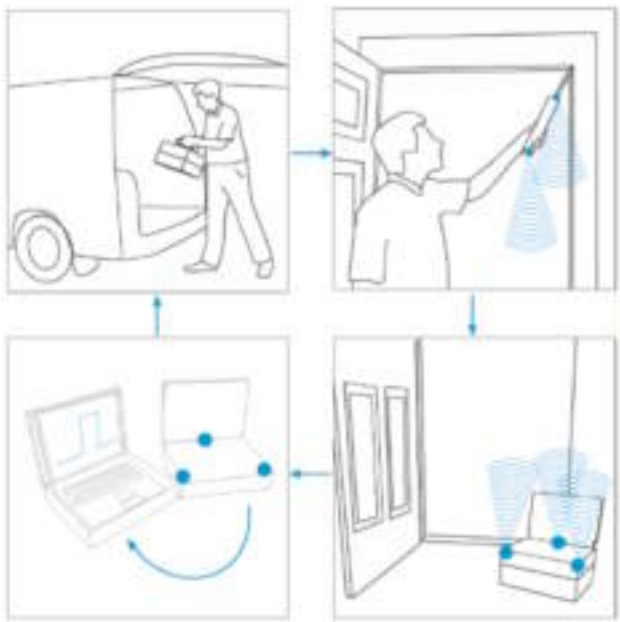

Figure 1: Tactile building surveying

Manual building surveying methods can play a significant role in conjunction with modern tactile surveying tools.

4.1 The integration of tactile approaches in a system for building surveying

Before individual approaches can be examined in detail, tactile surveying methods need to be integrated into the overall surveying approach. The integration of tactile approaches into

the system is important as all tactile tools have the following common characteristics:
- high precision,
- low reach,
- often realised under laboratory conditions.

All tactile approaches when used in isolation are unable to measure overall high-level geometric information, and are therefore unable to position building elements with the necessary precision within the overall geometric survey. Instead they refer to their own system of reference provided by transmitters and receivers located close to the object to be surveyed.

The absolute positioning of measurements from the tactile system in the overall geometric system can be achieved by transforming the local relational co-ordinate system to the overall system as provided by the initial survey. Key points can be measured which already exist in the overall geometric building model. These are typically the corners of rooms, window or door jambs, all points which the tactile measuring systems can also measure. Fig. 2 describes the process of integration within the overall system.

The process corresponds to classic free stationing in geodesic applications. The transformation of the local system to the overall system should be realised so that the high-precision of the detail measurements from the tactile sensors are not distorted by the less accurate positioning of key-coordinates from the overall reference system (corners of rooms). Appropriate algorithms already exist in geodesic practice (see Niemeier, 2002) and can be applied equally to our requirements. With the help of appropriate software, the initialisation process of the measuring equipment in the overall coordinate system is fairly straightforward for the user.

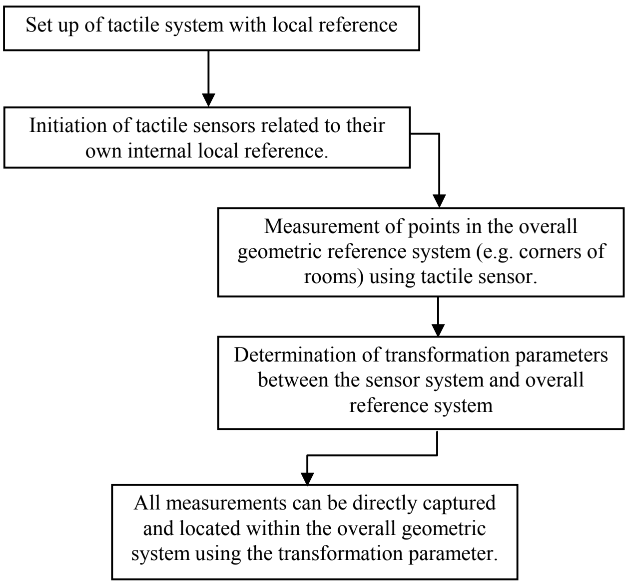

Figure 2: Free positioning of tactile sensors within the overall geometric reference system.

4.2 Tactile Systems

Tactile measurement systems can be adapted primarily from two other independent fields: Geometric controlling in mechanical engineering and positioning systems for VR/AR applications. We shall take a closer look at one system from each application area.

Similar systems are also used to track persons within buildings (Schiele, 1999; IGD, 2003). A variety of different principles are used but all of these are insufficiently accurate to be able to be used for surveying building detail. An independent development using a so-called Indoor GPS system using sound waves has been developed (Ziegler, 1995) but has never achieved practical use.

There are three primary positioning systems which offer potential for surveying building detail:

a) Optical systems
   Optical systems necessitate a direct visual contact between the tactile element and the local reference system. Some systems fulfil very high precision requirements (e.g. laserinterferometric approaches (Leica, 2003)) and all systems are sufficiently precise for surveying building detail. The next section describes two robust systems developed for mechanical engineering purposes (ProCam, 2003) and for positioning VR-applications (HiBall-3100, 2003).
b) Electromagnetic systems
   Electromagnetic systems are often used for VR-applications (e.g. Polhemus, 2003) but are generally not suited for surveying building detail as they can be affected by metal in the building substance.
c) Inertial systems
   Inertial systems (movement sensors) are very flexible as they do not depend upon external reference points. The sensor-drift which can occur means that it has to be used in conjunction with other sensors. Its application for building surveying needs to be examined in more detail. Some existing approaches include (Intersense, 2003).

4.2.1 Optical System: HiBall-3100

The HiBall-3100 tracking system (HiBall-3100, 2003) was developed for AR and VR applications. It has the following characteristics:
- Simple handling and setting up
- Low weight
- High precision achievable through high-frequency positioning

Figure 3: HiBall-3100 optical sensor

Figure 4: HiBall-3100 Stylus

The system consists of an optical sensor with six lenses set up so that a 360° view is possible (Fig. 3). Infrared LEDs serve as reference markers in the working area. The use of a stylus with the HiBall-sensor means the system can be used as a tactile device for locating coordinates (Fig. 4). The HiBall-3100 system has been developed for laboratory conditions and needs to be adapted for use in on-site conditions.

4.2.2 Optical System: ProCam

The ProCam 3D-measurement sensor (ProCam, 2003) has been developed for use in industrial applications and is based upon photogrammetric principles. The following characteristics are relevant for its use in surveying building detail:

- robust handling
- a variety of pointers are available for measuring hidden points
- high-precision under manual use
- flexible application using so-called target panels

Figure 5: ProCam measurement device with different pointers

Figure 6: ProCam on-site

The measurement sensor contains three integral CCD-cameras that measure a reference field of coded measurement points from which the position of the pointer is measured. So-called target panels, which can be placed freely in the room, can be used to establish an internal reference system for surveying building detail. The interchangeable pointers enable points which are hidden from direct view to be measured. The equipment was developed for industrial use and is correspondingly robust and straightforward in its handling. A CAD-interface already exists. User-dependent interfaces are provided for integration into production processes in industry. The price-performance ratio of the industrial configuration is too low for applications in buildings and building conservation.

4.2.3 Hand-held laser-scanner

So-called hand-held laser-scanners can be used for detail modelling. They are particularly suited to detail measurements because:

- like all laser-scanning approaches they can model surfaces at high-resolution,
- but unlike conventional scanning approaches are only suitable for small areas.

This is exactly where optimum use can be made of the high visualisation-quality of the scanning approach: Critical points and especially complex details can be modelled exactly. For instance, for the modelling of intersections in roof trusses, for measuring capitals, sculptures etc.
The positioning of the HLS laser-scanner head (Fig. 7) itself employs an electromagnetic tracker. This solution is developed for laboratory conditions but could be adapted for use in existing buildings and could eventually lead to a completely new solution for the 1:1 modelling of building details.

Figure 7: Hand-held laser-scanner HLS (HLS, 2003)

The step-up in efficiency in comparison to complex and time-consuming hand sketches would be considerable.

5. FUTURE PROSPECTS: THE POTENTIAL APPLICATION OF SURVEYED DATA OF BUILDING DETAILS

In addition to technical means of realisation, two further factors are decisive for the success and cost-efficiency of surveying building detail according to the techniques described:

1. The integration of surveyed building detail within an overall building survey. The geometric data must be integrated consistently within the overall geometric building model, so that these are usable directly and do not need to be obtained via other systems. In this way the information can be made directly available to all project and planning participants.
2. The building survey data captured must be adapted to fit the requirements of the users and trades. This applies primarily to data format and the form of its representation. This must be provided in a form that the individual participants can use and accept immediately within their own working methods. The surveying of building detail can only become cost-efficient once its value is recognised and its use becomes widespread.

6. BIBLIOGRAPHY

D. Donath, F. Petzold, T. Thurow (2002): Planning relevant survey of buildings -starting point in the revitalization process of existing building - requirements, concepts, prototypes and visions. The CIPA International Archives for Documentation of Culture Heritage, Volume XVIII – 2001, pp. 565-572.

HiBall-3100 (2003): HiBall-3100 Tracker. http/www.3rdtech.com/HiBall.htm.

HLS (2003): http://www.rsi.gmbh.de/hls_d.htm.

IGD (2003): IrDA-Beacon Transmitter. Frauenhofer Institut für Graphische Datenverarbeitung. http://www.rostock.igd.fhg.de/~mmt

Intersense (2003): http://www.isense.com.

Leica (2003): http://www.leica-geosystems.com/ims/product/ltd500.htm

Niemeier, W. (2002): Ausgleichungsrechnung. De Gruyter Lehrbuch, Berlin 2002.

Polhemus. (2003): Polhemus Fast Track. http://www.polhemus.com -

ProCam (2003): ProCam mobiler 3D-Messtaster. http://www.aicon.de (Stand April 2003).

Schiele, G. (1999): Positionierung von Benutzern innerhalb eines Gebäudes. Studienarbeit Nr.: 1739, Fakultät Informatik, Universität Stuttgart (1999).

Ziegler, C. (1995): Entwicklung und Erprobung eines Positionierungssystems für den lokalen Anwendungsbereich. Deutsche Geodätische Kommission bei der Bayerischen Akademie der Wissenschaften, Reihe C, Nr. 446 (1995).