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COMPUTERS IN ARCHITECTURAL RECORDING: THE TACHEOMETRIC METHOD

ABSTRACT

Architectural recording is the production of a full architectural representation of all available architectural data of a building in a specific time. The record can be retrieved for the uses of the preparation of conservation projects, archival backup and monitoring. This paper is the first among a series of papers directed towards exploring the applications of computers and the latest technologies in architectural recording. The main objective of this series of studies is to develop a comprehensive list of computer aided recording techniques suitable for architectural recording and documentation, aiming to improve the choice of technology thus improving the process of architectural recording and documentation. The study starts by introducing a theoretical background on the basic concepts and definitions related to architectural documentation and recording, then moves to identify the available technological alternatives and methods appropriate for architectural recording and documentation. Three methods are identified as computer ready, namely: tacheometeric methods, close range photogrammetry and close-range 3D laser scanners.

The study then focuses on the tacheometric method as an example of available computer aided recording methods. A case in which this technique was used is then analysed.
The study concludes by determining the potentialities and limitations of the tacheometeric method and identifies best practices for its application.
KEYWORDS: Architectural recording, Architectural documentation, Computers, Tacheometric method, Practice, Egypt.

Documentation:

The goal of documentation is to provide architects, engineers, and scholars with comprehensive information about buildings, sites, structures and objects of special significance. As mentioned in the guide lines for architectural and engineering documentation, made by the historic American building survey society:

> *"Documentation is used to provide the basis for enforcing preservation easement. In addition is often the last means of a preservation of a property, when a property is to be demolished, its documentation provides researchers access to valuable information that otherwise would be lost."* (HABS, 2003)

Documentation can be defined as a process which produces written, printed or other kind of material, furnished data and information for which knowledge might be derived, which, constitutes the knowledge base for a conservation process. (Laugerquist B., 1999)

The ideal documentation of an object would allow the user to gain the same complete information as the investigator who examined the original on site. Obviously, such documentation, including a description of the materials and geometry of even the smallest object part as well as the surrounding topography and environmental conditions is possible. (Boehler, W., et-al, 1999)

To sum up on this issue documentation was defined in the guidelines for the recording of heritage building in a statement of principles for recording and documentation historic building, which took place during the course of workshops conducted by the recording and documentation committee of ICOMOS 1988:

> *"Consists of compiling all available past and present records (written, graphic photographic, and the like) about an historic resource"* (Blumenson J., et-al, 1988)

Architectural documentation is the act of preparing plans, sections, and elevations for each building, showing spaces in relation to each other, levels, cracks, and damage to internal and external facades, In addition to recording all architectural and decorative details. (Historic Cairo, 2002)

Architectural recording identifies three main steps: (Laugerquist, 1999)

- Recording as a backup of historic structures and buildings, in case if they should be damage or destroyed, or to be used through a valorisation process in a societal context,
- Recording in order to prepare conservation project documents,
- Recording as a monitoring device in order to detect changes which occur with the passage of time or because of external forces.

Technological Alternatives Suitable For Architectural Documentation

Recording tools cover many applications, tools and techniques of distance measurement vary from the simplest tools to the most sophisticated technologies that science and engineering have reached, with a wide range of applications. Here in this part, the study shall concentrate on one application only, which is the studying of measurement methods suitable for measuring the geometry of the architectural objects and buildings (not the topography), followed by the transcription of this data into usable architectural presentation. Even within this segment of technologies and techniques, it will be hard to list and describe all the technological alternatives that have been devised; the study shall concentrate on the most familiar techniques.

There are eight different technological alternatives for surveying methods that can be considered in acquiring measurements of an architectural object, and the following is a description of each:

Traditional measurement methods

- This system is the most usual method. Points are located in this system by direct distance measurement, this method is used very effectively if the site is accessible, not too large and easy to overlook, moreover development of handheld electronic distance-meter and software supporting automatic measurement control had made it much easier.

Tactile methods

- This system relies on the registration of the coordinates of the tip of a probe attached to the point required to be recorded. Several developments occurred to this system in the last few years in heritage object recording robot-like systems with automatic target detection. Different technical approaches have been developed in Coordinate Measuring Machines (CMM), in robot-like machines (e.g. Faro system) and in photogrammetric based systems (e.g. Aicon system).

Tacheometeric methods

- Tacheometry is the process of recording three dimensional polar coordinates of an object describing point's position through angle and distances. Intelligent Tacheometry is an automated controlled process with a computer (usually a notebook), in addition to reflector less measuring totalstation. This enables new ways of capturing the geometry in integration with other methods of recording. Further uses and developments are shown like robot-totalstation and video total station.

Close range Photogrammetry

- This system is based on obtaining measurements from images, computer assisted analytical photogrammetry revolutionized the field widely. Digital images whether from CCD cameras or from scanned images have made it possible to produce a digital object model, which is a process more objective and easier than traditional photogrammetry.

Close-rang scanners

- Scanning is a method of obtaining points automatically or manually from the object with out contact thus producing a sort of digital model in a computer. There are different type of scanners most known are laser scanners and structure light scanners.

Global positioning system GPS:

- Can produce decimetre accuracy when used in different modes using carrier phase information and have proved very useful in heritage projects comprising large areas and for control points surveys for photogrammetric or satellite images processing.

Aerial photogrammetry:

- Is a well established method of surveying and standardizes to a large extents. Topographic mapping in intermediate scale is usually best accomplished by this method (if it is not prohibited).

Remote sensing:

- From satellites is a useful method in documentation, comprising large areas. (Imaging and processing techniques are becoming identical to digital photogrammetry).

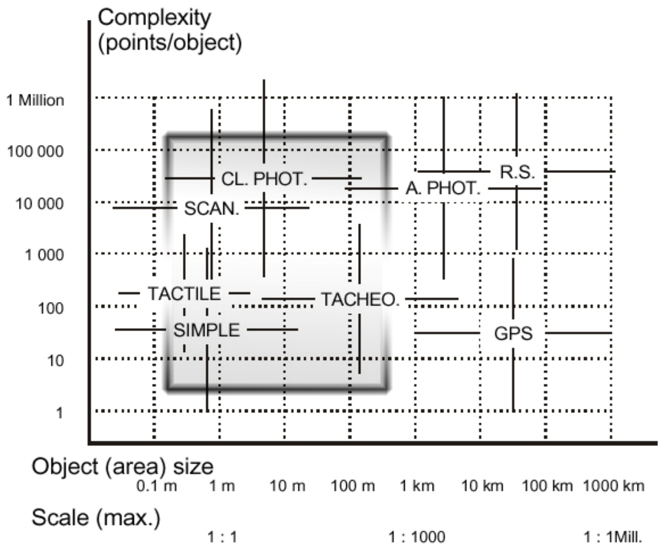

Figure 1: Recording methods considering object's size and object's complexity. Shaded area is the selected scope of the study (selected by the researcher) which represents the tools suitable for architectural recording applications. (Boebler, et-al.; 1999)

A common approach to recording the geometry of an object is through contact measurements, using traditional mechanical devices contacting and referencing positions of various points, like tape measure and folded ruler which are considered as simple measurement devices, or through tactile measurements which is a mechanical contact method based on XYZ recorder or an articulated arm used to touch a specific point on an object with great precision; some CMM can achieve 1 micro meter.

While non contact measurements techniques are divided into active and passive techniques; active techniques like laser scanners and tacheometric reflector-less EDM, or passive techniques like photogrammetric measurements, this issue will be discussed here in later.

A distinction must be made from the studying of the graph in figure 1, by observing the different types of recording methods related to the scale of the object and its complexity. For the purpose of the geometric recording of architectural objects for instance, the main disadvantage of mechanical approaches is that they are restricted to distances and volumes of few meters, and common problem is the danger of scratching the object when the tip of a probe touches the object therefore it will be excluded from the study, in addition, the wide range methods are unsuitable due to their wide range; ranging from one kilometre to thousands of kilometres, and thus, methods of large scale measurements will also be excluded from the study.

Therefore, four methods can be considered for architectural recording: traditional measurements, photogrammetry, tacheometry and 3D scanning. Discussing there characteristics it's obvious that each has strengths and weaknesses, and often they compete up to a certain amount, therefore, a comparativeapproach is undertaken here to detect advantages and disadvantages of each.

Thus, the scope of this approach is limited to the recording methods suitable for the purpose of architectural recording; it's obvious that each method is suited more or less for recording and detecting special quality of an object, in order to understand this issue the study shall discuss the principle, procedures and potentiality of each method.

Tacheometric measurements

Introduction

One of the most useful modern surveying instruments is the Total station. Total stations have become the standards to which other surveying instruments are compared. Using them in the field permits contemporary surveyor to achieve a level of precision that their forebears could not have imagined. Measurements are routinely made and recorded to the tenth or hundredth of a millimetre. Those measurements are then transported into CAD or GIS systems and become part of the data from fieldwork. A given object, wall corner, or survey location is then forever said to be at a point in space defined to an extraordinary level of precision.

Total Station Surveying

The Total station stands for Tachometric Object-oriented Partly Automated Laser survey. The total station is a combination of a theodolite and an EDM (Electronic Distance-measurement Device) the two are attached to a data collector, although the data collector is not technically part of the total station, it is a vital function of the system.

The total station itself consists of three interconnected items: First, there is a sighting device through which one may view target and aim precisely at the target, second, there are sensors; which determine the vertical angle away from the horizontal plane and horizontal angle away from the absolute north for the sighting device, third, there is an electronic distance measurement device (EDM).

The electronic transit displays swing angles (deviation from north) and the angle above or below the horizontal. The EDM sends an infrared beam to a reflector that must be positioned at the point to be surveyed and using timing algorithm to determine the distance to the reflector instrument, some newly developed EDM does not need reflectors (reflector less total station).

The data recorder records the position of the instrument, the swing angle, the elevation angle, and the distance to the target for each measurement. In addition, the data collector (and often the total station itself) can use simple trigonometric formulae to compute the position of a point surveyed from the known position of the total station and the data supplied swing angle, elevation angle, and distance to point.

Most total stations carry a number of useful programs in their memory. For instance, with the free station function, a total station set up at an unknown point can calculate its current position after measurements are made to a couple of known points. Another useful function is called "setting-out" The coordinates of desired points can be input manually or from data registers, and then the instrument will direct the user to the points. The screen will indicate the horizontal and vertical alignments of the point to be found, and then will report how far the prism target must be displaced out or in along the radial line of alignment. In this way the instrument can be used to lay out uniform grid systems on uneven ground. (Rick, J., W.; 2002)

The reflector is normally placed on a simple rod with a point tip; the rod is called the prism pole. Then the elevation offset is entered into the data collector corresponding to the height of the reflector above the bottom of the pole.

The reflector must be positioned in a vertical orientation, so that the distance will be measured to a point directly above the required point. Positioning the reflector is a kind of problem; the prism must be exactly positioned over the point to be measured. That is often impossible, since the prism pole cannot be placed in a vertical plane with its tip on the point exactly.

There are ways to deal with this problem; first, is to remove the prism from the pole and positioning it directly over the point, but not all prism designed for that there are small prism called mini prisms or peanut prism are designed with tip to be place over the point. Second, is to place a reflector tape of bicycle reflector, the later limits the accuracy to centimeters.

Depending upon the procedures used with a total station, accurate measurements may be made to looser or tighter tolerances. The more experienced the surveyor and the better the instrument, the tighter the tolerances possible. Of course, producing measurements to tighter tolerances requires more careful and controlled procedures, not simply more experienced personnel or better equipment.

Some total stations measure distance without a reflector, these instruments cannot make a reading from any surface, since any surface to be read must reflect the beam sent to it from the total station, yet a reflector will be occasionally needed according to the reflectance of the building material.

In 1994 the first tacheometer with servomotor measuring reflector less and directed by computer was developed at University of Bochum, in Germany. For the time being this type of instrument was modified, and as to make it more flexible, cameras were integrated into the tube of the telescope, two wide-angled cameras with different focal lengths are in the casing and a third camera is located in the plane of reticule; this is what is so called Ocular camera, and is automatically focused by a gearing in the tube of the telescope.

This new type of instrument robot-tacheometer with integrated cameras is called a “video tachymeter”, maybe in some years; it will be a custom instrument, like the servo-driven reflector less measuring tacheometer, which was developed ten years ago. (Scherer, M., 2004)

Data Processing and Generating the Record

Total station method relies on the registration of the coordinates of the tip of a probe brought in contact with the object point to be recorded or by a use of EDM (Electronic Distance Measure). Total stations produce the same basic spherical measures as optical survey instruments horizontal and vertical angles and a radial distance measurement, yet the Total stations differ, however, by taking additional data and then calculating additional measures. Most importantly, Totalstation is capable of simultaneous trigonometric conversion of spherical survey coordinates into Cartesian orthogonal measures usually east, north, and altitude.

The gathered data is directly transferred to a computer and into CAD system, so the computer can serve simply as a data collector; the input from the total station goes directly into the cad program as if typed from the keyboard. Using the field computer, the speed of recording increases and enables the gathering of three dimensional data. In this way, data relationships can be identified during fieldwork, and point positions can alert the survey team to errors in instrument setup or alignment before significant amounts of flawed data are collected.

The transfer of information from computer to servomotor Totalstation is useful as well. Previously shot points, perhaps from an earlier project, can be very useful reference points in the field. Complex grid system points can also be transferred to the theodolite for the setting-out process. These upload and download transfers can be done directly or through an intermediary storage device.

The software has a number of CAD (Computer Aided Drafting) features, such as surface modelling and 3D visualization; compatible output of CAD files allows direct export to AutoCAD or Microstation programs. The great readability of their menus and the immediate graphic feedback allows crews with little field experience to be productive right away and reduce error rates, while at the same time records are much more detailed information.

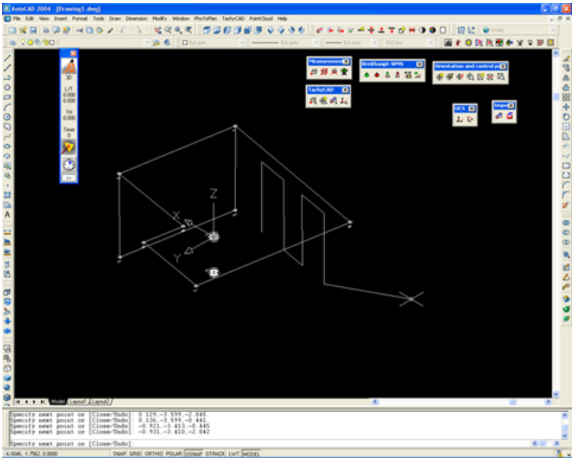

Figure 2 Visualization of surveyed points; gathered points are directly exported to Cad software like AutoCAD, which enables 3D visualization of the surveyed points. (Topotek; 2004)

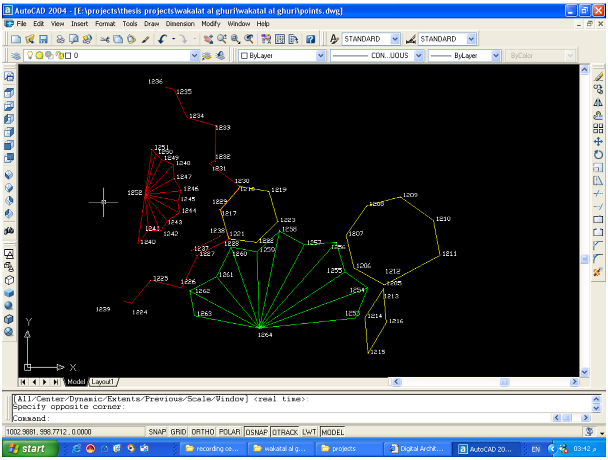

Figure 3 Captured points assigned in AUTOCAD; the theodolite software runs alongside AUTOCAD and provides points and coordinates as if entered via a keyboard. (ECAE, 2005)

After acquiring the target points of the building directly with a Totalstation, additional measurements may be captured with a hand-held laser meter, a tape or a folding rule at any time. Further more, Hundreds of possibilities are given when combining a CAD system with a surveying tool.

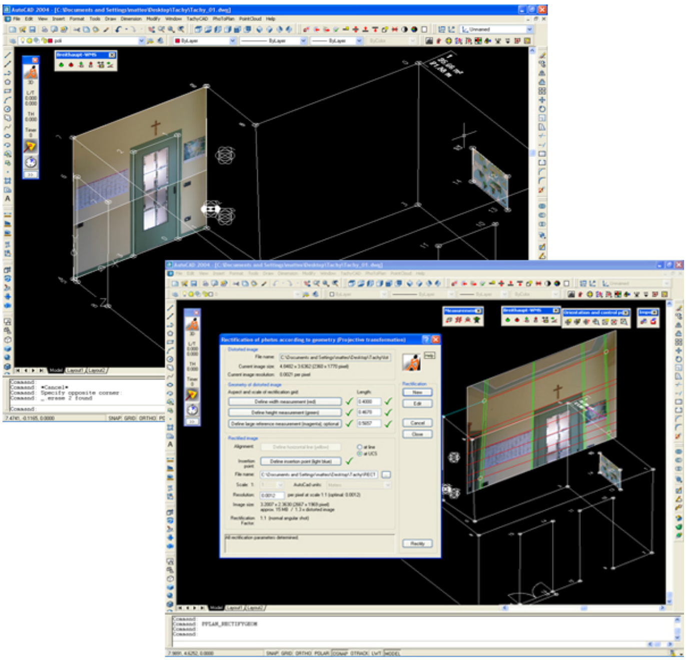

Figure 4 the integration of Tacheometric and photogrammetric techniques; wrapping rectified images into surved points gathered by a Total station, combined in AutoCAD. (Topotek; 2004)

Integration of tacheometric and photogrammetric functions is an advantage in different applications. Rectified images can be used in coordination with a Totalstation, in order to generate 3D model and visualization.

Further more, a reflector less Totalstation with an integrated camera can help in the generation of ortho photos and rectified images with so called process 4 point rectification either through distance measurements or through coordinates. In addition, a new dynamic measurement protocol is introduced through a graphical parametric link between the coordinate system and the image, where points and lines can be detected automatically. (Scherer, 2004)

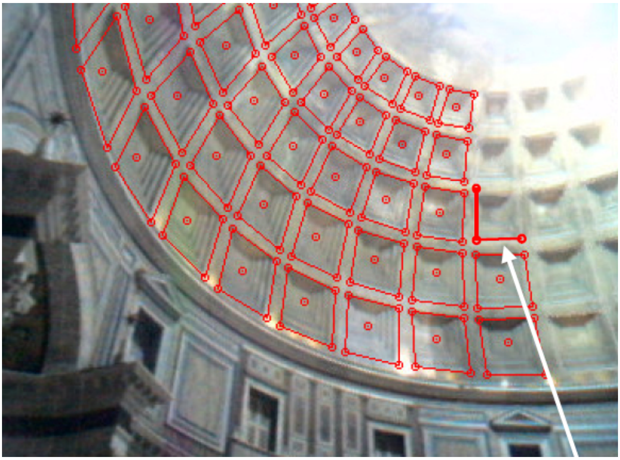

Figure 5 Dynamic visual measurements; newly introduced graphical parametric link between the coordinate system and the image, where points and lines can be detected automatically (Scherer, 2004)

Advantages and Disadvantages of Tacheometric Measurements

Advantages of Total Station

- Data acquisition is faster and more reliable than with hand measurements.
- The working drawing is displayed as it is surveyed, this gives the opportunity to consider where to position the next measure point, make changes, create and reassign layers.

- Multiple view are available; elevation, isometrics, and plans. This gives better understanding of materials and relations.
- Data can be directly used to produce 3D models of structures and architecture.

Disadvantages of total station

- Too slow if intended to gather clouds of points.
- Not suited to capture small objects.

THE HOUSE OF AL-GHURI (909-910 A.H./1504 A.D.) List No. (65, 66, 67) (Case Study no. 1)

This documentation project was performed by the Engineering Centre for Archaeology & Environment (ECAE) within The Egyptian Antiquities Project (EAP) on the House *Sultan al-Ashraf Abu al-Nasr Qunsuwa al-Ghuri al-Garkassi,* monument No. 65, 66& 67. The project was held in the period of 1999-2000.

Documentation project

The objective of this module is analysis of the documentation project; these analyses are performed in four parts. The first part considers the process of data acquisition, the second part reviews the processing of the gathered data, and the third part discuses the object control which represent the tying of the processed information, the last part show the resulted product of the project.

Data acquisition techniques

Two main techniques were used here in this project to gather the required geometric data, first of these techniques is the use of Digital rectification photogrammetry to capture the current state of the building, the second was the total station which was used for tying images and the purpose of registration. The objects were photographed by digital cameras and rectified using the Rolleimetric MSR software.

Data processing

The goal of the captured images was the creation of an exterior model of the building. As mentioned before, two different methodologies were applied here in this project to generate the model; the first is the digital image rectification followed by drafting the façades, after that the resulted façades are tied up to a single co-ordinate system using the total station approach.

Object control

The registration process of the different elevations was performed by a total station; the Totalstation gather points representing the plan profile and then imported into AutoCAD then elevations are tied to the plan profile using CAD tools.

Figure 6 3D reconstructions of the building; drafted elevations are tied to one coordinate system with the help of the plan profile captured by total station. (ECAE, 2005)

Record production

The final output for the project is orthographic drawings of the monument (plans, sections, front elevations, and details). The use of cad motivated more precision and more accuracy in measurements. This method allowed the tying of the elevations and the plans together, this was important in facilitating the documentation achievement.

Conclusions

In case of the total station approach data acquisitions is faster and more reliable than with hand measurements, yet the time required for performing a very detailed survey of a wall, for instance, can be an enormous burden in the field, even if the total station is dedicated to that task alone. The total station is essential for all data registration, controlling processes and tying to the real world coordinates, since it became the normative structure into which detailed Photogrammetry information or hand measurements data are fitted.

Potentialities

Data acquisition is faster and more reliable than with hand measurements. Since the calculations of coordinates are done within the filed, and transferred digitally into the cad system, there is a minimal amount of mistakes.

Using digital photogrammetric rectified images provides great potentialities to create very elaborate drawings and models for areas difficult or impossible to reach. Elevations are placed with respect to a plan profile which facilitates direct comprehension of the building and more understandings and knowledge of the relationships between the building's elements. Missing details are completed manually.

This method probably saves money and time in the long turn due to shorter site visits and the familiarity of the CAD application in the office place.

Limitations

The most significant problem was getting good unobstructed views of the building, where there were several obstacles obstructing many of the building details. Small objects and details increasing the level of details required. The faded images or decayed details in the end of the images also affect the vision of the full details, and thus require an incredible number of images and good photography administration.

The Potential of integration between tacheometry and photogrammetry in a hybrid solution. Tacheometry is not appropriate for small complex architectural objects such as statues. Among the advantages of tacheometry is that it can link directly between the architectural record and the real world directions. Tacheometry can also be used in a reversed mode, for locating (on demand) on site points that represent the once-was-there details of a building.

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