XIII Congress of the
International Society for Photogrammetry
Helsinki, 1976

Commission V
Invited Paper

MAURICE CARBONNELL
Institut Géographique National
Paris, France

Technical Progress in Architectural Photogrammetry

Technical progress in architectural photogrammetry during the last several years includes the general trend towards improvement and better adaptation of equipment, the use of all photogrammetric methods, and the expansion of fields of application in the sphere of architecture and protection of sites.

EQUIPMENT

THERE ARE MANY working conditions to be considered in architectural photogrammetry and, because there is no univeral solution, one must accept that a range of equipment is necessary. It is with this range of equipment that photogrammetric instruments have been involved. We consider below the different technical criteria to be satisfied and the different solutions adopted for each of them.

VARIOUS PRINCIPAL DISTANCES

In addition to phototheodolites, which have long focal lengths and narrow fields of view, many cameras have been produced with short principal distances and wide fields of view. In this category are the largest number of instruments now being produced, e.g., all the stereometric cameras (except the Officine Galileo Veroplast) and some small format individual cameras.

More recently the necessity for cameras with much longer focal lengths (problems of accuracy and of distance from the object being photographed) has encouraged manufacturers to build new devices with focal lengths intermediate between those of the small cameras and those of the phototheodolites, the most useful ones still retaining a large field of view. During recent years one has been able to purchase

Officine Galileo Verostat : f = 100 mm,
9 by 12 cm format
Carl Zeiss TMK-12 : f = 120 mm,
9 by 12 cm format
Zeiss Jena UMK : f = 100 mm,
13 by 18 cm format
Hasselblad MK-70 Planar: f = 100 mm,
6 by 6 cm format
Wild P-31 : f = 100 mm,
4 by 5 in. format
(principal point off center)

Various Japanese Sokkisha cameras also have been produced.

VARIABLE PRINCIPAL DISTANCES

It is possible to slightly modify the principal distance of some cameras in order to focus at different distances. This facility, which is being reexamined by the manufacturers following recent optical and mechanical advances, is based on four different technical solutions: (1) displacement of the objective lens by a spiral movement (Officine Galileo, Hasselblad), (2) displacement by a translatory movement (Zeiss Jena), (3) introduction of rings of different thicknesses between the camera chassis and the lens (Wild), and (4) introduction of additional lenses in front of the objective (Carl Zeiss).

LARGE INCLINATIONS

Some of the older plotting instruments are able to process photographs taken at steep inclinations. However, these instruments are hardly compatible with modern terrestrial cameras, particularly small format cameras. An idea of Dr. H. Foramitti consists in giving the camera a large, well-determined tilt angle, and also in adding a simple device to the plotting instrument in order to process the photographs taken under these conditions, so long as the photographs are taken in the normal case (i.e., parallel axes).

This solution, first adopted by Carl Zeiss, is now being used by other manufacturers (Wild, Zeiss Jena, Officine Galileo, Nikon) for single or stereometric cameras, in which the required inclination is obtained ether by use of an offset level or the use of a circular quadrant with identations. The additional device for the plotting instrument is an "inclination calculator" which is introduced between the plotter itself and the drawing table.

ABSTRACT: *The development of architectural photogrammetry is very important. However, we do not deal here with everything accomplished in the various sectors of this field of application of photogrammetry and with the surveys in which procedures are now more-or-less standardized. We confine this short paper to the technical progress, that is to say the increase and the better adaptation of equipment, the use of other photogrammetric methods such as graphical stereoplotting and rectification (orthophotography, aerotriangulation, numerical and analytical methods, use of analytical plotters, inverse photogrammetry) and the expansion of fields of application (structural problems in monuments, precise determination of their geometrical characteristics, measurement of the surface effects of disease in stone, surveys and protection of historic centres)..*

RÉSUMÉ: *Le développement de la photogrammétrie architecturale dans le monde est très important. Nous ne voulons toutefois pas présenter ici un tableau complet de tout ce qui se fait dans les différents secteurs de ce domaine d'application de la photogrammétrie. L'objet de ce court rapport est limité aux progrès techniques, c'est-à-dire à l'accroissement et à la meilleure adaptation des matériels, à l'emploi de méthodes photogrammétriques autres que la stéréorestitution graphique et le redressement (orthophotographie, aérotriangulation, méthodes numériques et analytiques, utilisation des restituteurs analytiques, photogrammétrie inverse) et à l'élargissement des domaines d'application (problèmes de structure des monuments, détermination précise de leurs caractéristiques géométriques, mesure des altérations de surface dues à la maladie de la pierre, relevés et protection des centres historiques).*

ZUSAMMENFASSUNG: *Die Entwicklung der Architektur photogrammetrie in der Welt ist sehr-bedeutend. Wir wollen jedoch hier nicht eine vollständige Darstellung von allen Leistungen in diesem Bereich der Photogrammetrie vorzustellen. Dieser Bericht beschränkt sich auf den technischen Fortschritt : das heisst, die Zunahme und die bessere Anpassung der Materiales, die Anwendung anderen photogrammetrischen Methoden als die zeichnerische Stereoauswertung und die Entzerrung (Orthophotographie, Aerotriangulation, nummerischen und analytischen Methoden, Verwendung analytischen Auswertungsgeräte, Darstellung eines Projektes im Messbild), und auf die Erweiterung des Anwendungsbereiches (Strukturprobleme der Denkmäler, genaue Bestimmung ihrer geometrische Charakteristik, Ausmessung der Veränderungen der Oberfläsche infolge der Krankheit des Steines, Ausmessung und Beschützung der historichen Lagen).*

In order to be able to rectify photographs obtained under such conditions (e.g., camera inclinations of 30° and 60° or 30 and 70 grades), special devices must be constructed for a particular inclination angle and a particular focal length. Only Carl Zeiss actually markets such a device (KEG-30).

ADAPTATION OF PLOTTING INSTRUMENTS TO A WIDE RANGE OF PRINCIPAL DISTANCES

The wide range of principal distances and the resulting need to adapt the plotting instruments are not problems peculiar to terrestrial photogrammetry. Modern plotters generally have greater versatility regarding focal lengths (from 85 to 310 mm). However, in architectural photogrammetry, the widespread use of small metric cameras necessitates a further extension of plotting capabilities towards shorter focal lengths i.e., in the 50 or 60 mm range. Three solutions have been devised:

- *the construction of special equipment solely for photography taken in the normal case (this solution is not recent);*
- *the selection of a fairly wide range of focal lengths but tending towards the shorter ones, e.g., Zeiss Jena Technocart (focal lengths from 50 to 215 mm); or*
- *the manufacture of additional devices for the plotting of small camera photographs, e.g., Carl Zeiss devices for the Planimat D.2.*

DEPTH OF FIELD OF A SUBJECT: Z-RANGE OF PLOTTING INSTRUMENTS

With respect to the depth of field of a subject, the simplified instruments constructed for short principal distances and the normal case have generally good properties; but, unfortunately, the capabilities of the new, more or less universal, instruments are smaller. They are generally limited to a z-range on the order of 300 mm; this range is usually sufficient but may not be so always, and in any case it usually imposes restrictions on the scale of the model formed in the instrument. The use and development of analytic plotters should lead to real progress in this domain and in the domain of steep slopes.

METHODS

Plotting and rectification are the two principal methods employed in architectural photogrammetry, but other photogrammetric methods are now used for the survey of monuments and sites.

New experiments in the field of orthophotography have demonstrated its acceptability for architectural surveys, provided that the subject does not present sudden breaks in continuity. Based on the work of the Officine Galileo (W. Ferri) on the inside of the dome of Santa Maria del Fiore in Florence, good orthophotographic surveys have been done in Poland, by J. Jachimski and Z. Sitek (ruins of a medieval castle, the walls of which are both complex and irregular in fabric), and in Western Germany, by M. Döhler (Roman wall) and E. Seeger (Baroque decorative features in stucco). The surveys so obtained were used in combination with plotted line-drawings of the parts of the monument which presented too high a relief.

We should remark on the increase in the number of cases where aerotriangulation was used. C. Sena, in Italy, and H. Mohl and E. Mohr, in Western Germany, have performed experiments in the adaptation of this technique to suit architectural surveying, and have produced encouraging results; this should simplify the task of measuring control points.

We know that analogical numerical stereophotogrammetry can offer a greater degree of accuracy than graphical plotting where it is required to measure certain important features of a building such as lengths, distances between characteristic points, differences in height, etc.

The advantage is considerable if one desires to determine the precise geometrical characteristics of buildings dating from periods of extreme refinement in architecture, such as Archaic and Classical Greece, and the Baroque. Thus it is normal to find the method used in Sicily in the work being done there by the Turin Polytechnic Institute and the German Archaeological Institute at Rome, and for the surveys of the Acropolis buildings at Athens made by the French Institut Géographique National (IGN). However, numerical stereophotogrammetry also is extremely useful for surveys in which the reference planes are not parallel to the Cartesian axes of the plotting machine. Here a numerical survey involving a very large number of points, followed by calculations and by drawing on an automatic tracing table, can offer an excellent solution. The IGN has used this method for the surveying of arches of vaults, for example, and for façades which (as in the case of some of the upper portions of the Farnese Palace) could be photographed only very obliquely.

An excellent example of this process is offered by the photogrammetric survey of the Jameh Mosque at Isfahan made by the Rassad Topographical Company for the Historical Monuments Conservation Department of Iran. It was possible to photograph certain of

the arches, and more particularly the plaster decoration of the vaults and the "iwans," at a very oblique angle in order to preclude gaps, but nevertheless obtain complete and accurate elevations, profiles, and cross-sections.

Analytical plotting methods are also used; the advantages and limitations of these methods are well known. Research is being performed in Sweden and Denmark to simplify their use and to rapidly obtain a point-by-point survey. A drawing is then made by a architect. Stability checks are an important part of the application of analytical methods; an example is offered by the successive surveys made by the IGN on the façade and narthex of the Abbey Church of St. Denis, just outside Paris.

Experiments and works done with analytical plotters are increasing. The Historic Monuments Survey Section of Canada (R. Letellier) uses an AP/C plotter provided by the National Research Council and finds the method extremely worthwhile. At the Turin Polytechnic Institute, the plotter used is the Digital Stereocartograph (DS). C. Sena thinks that this system renders it far easier to form and orient the model in difficult cases (e.g., the amphitheatre at Susa), and the obtaining of drawings or numerical data of different kinds directly from the plotter is a simple matter. The value of such devices in architectural photogrammetry is obvious. While it is true that, owing to their scarcity and cost, they as yet belong to the luxury category of photogrammetry, there can be no doubt that in due course such drawback will disappear and they will come into general use, to the benefit of architectural photogrammetry as a whole.

We mention also further experiments with aerial photographs taken at very low altitude. The IGN and the SFS in France and the Nara Institute in Japan have taken photography from a helicopter with the camera fitted onto a stabilized platform; in Bulgaria a 210 mm camera was used, in an AH-14 plane flying at a height of 120 m and at a speed of 130 kms per hour, to take photography at a scale of 1:600; and the Swedish Historical Monuments Department and Uppsala University have mounted a Hasselblad MK-70 camera in a sports-model plane. The new Japanese stereometric camera NAB-150 has been suspended from a kite-balloon.

Finally, we should mention the increase in the use of inverse photogrammetry for the visual representation of proposed new buildings on photographed perspective views.

Fields of Application

We should concentrate this subject on certain given fields of application whose development is particularly noticeable.

Surveys made for the preservation of monuments in peril or as a prelude to the transfer of monuments to a new site form a very important category of application. The most famous examples are those of the Temple of Borobudur (Indonesia) and of the whole group of monuments at Philae (Egypt), protected under UNESCO international programs and surveyed by the French IGN.

Structural problems in monuments are a sector of photogrammetric applications which is expanding in size and now includes studies of several different kinds. First, there are the stability checks, already mentioned. Next come the studies concerned with equilibrium; an example is the detailed survey of the foundations of the church at Deerhurst (8th and 11th centuries) by the Royal Commission on Historical Monuments (England), conducted in conjunction with archaeological excavations. We will also include the IGN survey of the Pantheon in Paris, which has clearly brought out the distortions produced in the lower portions during construction and compensated for during the building of the upper parts. The survey should also provide a means for calculating the thrust exerted by the immense dome on the four central piers of the building. We would mention, too, the work of the Warsaw Geodesy Institute, which has re-established the structural features and shape of the Wladyslaw Tower and the clock-tower of the king's castle with the aid of old photographs.

The determination of geometrical characteristics with as great a precision as possible is an application closely linked to the study of structures. It was assigned particular importance in the work carried out jointly by the Turin Polytechnic Institute (G. Inghilieri and C. Sena) and the University Institute of Archaeology (G. Gullini), whether in the case of the Greek monuments of Sicily (proportions and optical refinements); the Roman buildings, in which by surveying many cross-sections photogrammetry can ascertain the all-important internal spatial distribution; or the ziggurats of Iraq. In this case, photogrammetry provided the means of comprehending the forms of the buildings, checking the unit of measure used by the original builders, and analyzing structural variations between one story and the next.

In this matter, we should mention particularly the study of the true forms of the interiors of large domes. The works of the Officine Galileo (W. Ferri) and the Engineering Faculty of Florence University (M. Fondelli)

on the dome of Santa Maria del Fiore are well known. Their photogrammetric surveys (extended also to other domes of Florence) were continued by a statistical analysis of the difference between the actual form obtained by numerical stereophotogrammetry and the theoretical form expressed by the curve which, for each groin, passes as nearly as possible (i.e., by least-squares) through the points plotted.

Concerning the numerical models of monuments, here again it was in Italy that the idea was most clearly elucidated by a Florentine research team (M. Fondelli, E. Cleur, and F. Greco). Such models, obtained by numerical photogrammetry (either analogical or analytical), offer a means for determining the essential geometrical features of a building, analyzing its profiles and proportions, and observing the changes occurring in these with the passing of time, with the aid of computed figures and subsequently expressible as a line-drawing either on an automatic tracing table or on a screen.

Very short-range photogrammetry can be applied to the measurement of the surface effects of disease on stone. This application is studied in France under the auspices of the Historical Monuments Research Centre and experiments are done on stones or sculptures of various churches.

Overall surveys of historic centers also are on the increase. In various papers we have explained the general principle of the use of aerial photogrammetry for the making of documents which are very useful for the study and the management of historic centers. These documents include not only ground plans but also cross-sections through the center and frontal elevations ("géométraux") of built-up sectors. Some architects responsible for the conservation and development of urban sites have found it useful to adopt the normal plan-section-elevation representation used for individual buildings to express the volume of an historic center.

France presents many applications of this method. In addition to Thiers and Moulins, already discussed, frontal elevations were produced by the IGN for Saint Denis, Rocamadour, Cahors, Beaugency, Strasbourg, Auxerre, Auch, and also for Athens in Greece. In Turkey an excellent survey was made of the Ottoman complex of Suleiman the Magnificent in Istanbul, known as the "Suleimaniyeh" (Prof. G. Tankut and the General Directorate of Cartography). In the United States the Ohio State University School of Architecture (P. Borchers) has carried out an ambitious program of surveys of Indian pueblos in Arizona and New Mexico. For this program aerial photogrammetry was used to obtain flat projections and plan views, but some terrestrial photography also was done, and use was even made of some old photographs taken before 1900, from which plottings were made by hand.

It is equally interesting to prepare photogrammetrically produced perspective views of the historic centers, particularly axonometric views which are perfectly suited because of their conservation of true scale in the three coordinate directions. This experiment, conducted by the IGN for the town of Cahors by using aerial photographs and an analog process, was recently applied to the town of Auxerre.

In this matter automatic processes can be very interesting. At the IGN, Y. Egels has devised a computer program of calculations and automatic drawings which can produce any perspective view, partial or complete, of a historic center from numerical data stored in a data bank.

Inverse photogrammetry is often applied for protecting urban or natural sites in danger of being spoilt by new buildings. But graphical perspectives are also produced on the basis of photogrammetric data.

More generally, as the documents discussed above have accurate geometric properties, it is easy to add the drawings of proposed new buildings and so to study their integration into the historic setting in order to consider the protection of the latter. Similar studies can be undertaken for engineering works and all kinds of proposed roads, new bridges, etc. Consequently, the specialists have excellent documents at their disposal for their study.

Bibliography

A complete bibliography on architectural photogrammetry has been compiled in the reports of the Internationl Committee for Architectural Photogrammetry (CIPA).