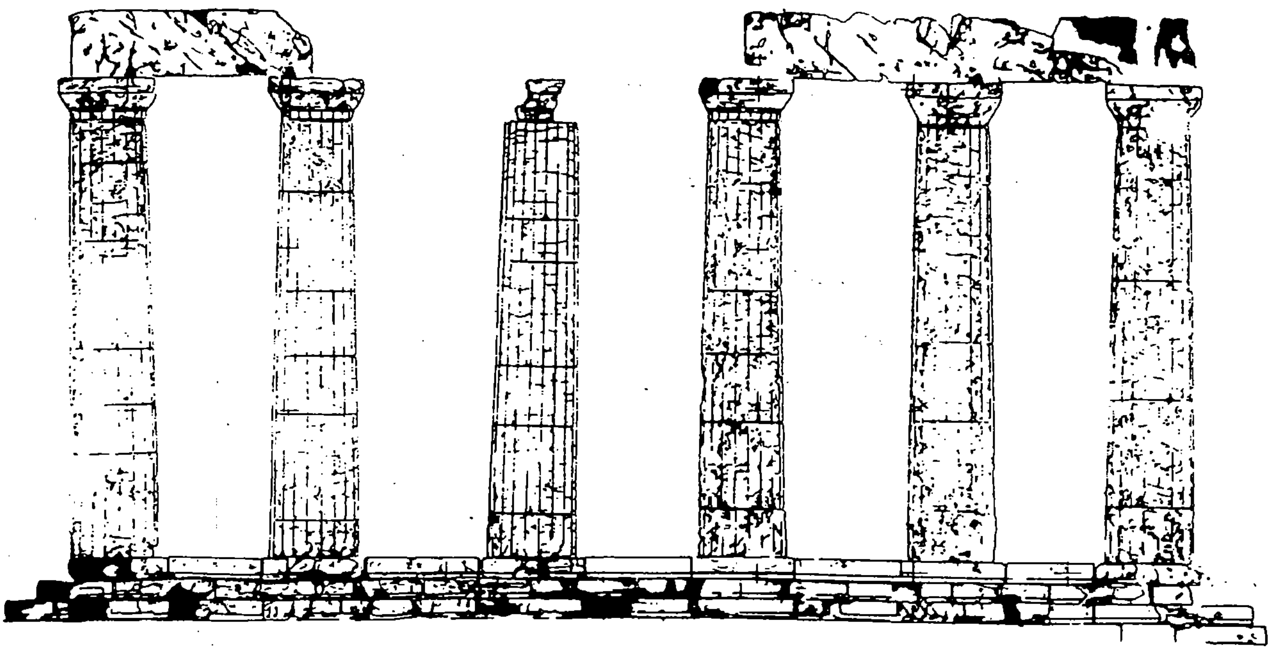
XIV CIPA INTERNATIONAL SYMPOSIUM

2-5 OCTOBER 1991 DELPHI, GREECE



TECHNICAL CHAMBER OF GREECE

INTERNATIONAL COMMITTEE FOR
ARCHITECTURAL PHOTOGRAMMETRY (CIPA)

CIPA
XIV INTERNATIONAL SYMPOSIUM

2-5 October 1991 - Delphi, Greece

ARCHITECTURAL PHOTOGRAMMETRY & INFORMATION SYSTEMS

Edites by: Prof. J. BADEKAS
Dr. A. Georgopoulos
LABORATORY OF PHOTOGRAMMETRY N.T.U.A.

TECHNICAL CHAMBER OF GREECE

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FROM THE EDITOR

Between 3-5 of October 1991 the XIV International Symposium of CIPA took place in Delphi.

The symposium was organized by the Laboratory of Photogrammetry of the National Technical University of Athens under the auspices of the Hellenic Society of Photogrammetry and Remote Sensing, the Hellenic National Committee of ICOMOS, and the Technical Chamber of Greece.

The theme of the Symposium was "Architectural Photogrammetry and Information Systems", which was very well accepted from the participants.

Already in all three previous symposia of CIPA, that is in Granada, Sofia and especially in Krakow the need of integration of Architectural Photogrammetric techniques and activities with special information systems was obvious. This seems to be the only way for efficient management of data collected by architectural Photogrammetry.

The reports of the participants have covered as customary a much broader field giving emphasis to the applications and also to the formation of simple, cheep-photogrammetric systems. Architectural Photogrammetry will survive and serve better the society if its processes become more efficient, faster and cheeper.

The symposium has been attended by 101 participants out of whom 61 were foreigners and 40 were greeks.

Although there was a big effort to attract evenly the participants from all interested disciplines this symposium could not avoid the pattern of all previous CIPA meetings where the magority of participants were photogrammetrists.

In connection with the XIV symposium of CIPA a two day meeting of the CIPA committee members was organized in Athens with one additional meeting in Delphie.

During the meeting some very important discussions took place with the most important decision the approval of the final version of the new status of CIPA being under examination for about three years.

During the meeting of the CIPA committee in Athens a special international seminar on Architectural Photogrammetry was organized at the Technical University of Athens. The seminar was greatly benefited from the presence of the CIPA Committe members in Athens since they had assummed most of the teaching for the Seminar. There are some thoughts for this seminar to become a permament event in Athens.

There are many institutions and persons who have contributed for the success of the symposium. First the CIPA committee members who supported in many ways the Symposium. Next Prof. Armin Gruen President of Commission V of ISPRS has contributed considerably to the CIPA committee meeting, the seminar, and to the symposium. Also the rector of National Technical University Prof. N. Markatos has supported the meeting and between his important duties he found the time to make the oppening of the simposium in Delphi.

Many thanks belong to the National ICOMOS committee, the Greek Society of Photogrammetry and Remote Sensing and to the Technical Chamber of Greece, who have actively participated in the Symposium and the later also for supporting the edition of these proceedings.

Last but not least special thank belongs to my collegues and the students of the Photogrammetric Laboratory, who have taken all the burden of the Symposium.

These proceedings give the activities of the symposium from one point of view. It is really impossible to give the excitement of the lovely discussions and the many opportunities to exchange ideas on architectural Photogrammetry which we have txperienced in Delphi. We hope however that photogrammetrists, architects, archaelogists, conserventionists and managers will benefit from the Delphi Symposium and that they will promote the development of architectural Photogrammetry.

Athens, October 1991

John Badekas

Opening Session

Wednesday, October 2nd, 1991, 11:00 - 13:00

WELCOMING ADDRESS by

Prof. J. Badekas, NTU Athens

President of ISPRS Commission VI

Mr. Rector of the NTU of Athens,
Mr. President of CIPA,
Mr. President of Commission V of the ISPRS,
Mr. Representative of the Technical Chamber of Greece,
Mrs. President of the Hellenic Society for Photogrammetry and Remote Sensing
Mr. President of the Hellenic Association of the Rural and Surveying Engineers,

At this point I regret to say that the Secretary General of the Academy of Sciences Prof. P. Theocharis, the President of the National Committee for ICOMOS Mr. N. Agriantonis, and the representative of the Archaeological Society were unable to come to this Opening Session,

Dear colleagues,
Ladies and Gentlemen,

On behalf of the organizing committee I have the privilege and the honour to welcome you all to the opening session of the XIV International Symposium of CIPA, The International Committee of Architectural Photogrammetry. I said colleagues but it would be most appropriate if I said friends since most of you are friends for many years. The Symposium in "Architectural Photogrammetry and Information Systems" is expected to touch all recent developments in this fascinating field and also to be a forum for discussions on present international practical activities and applications. I can hardly ,imagine any other place in the world which could be more suitable for our meeting. Delphi is full of excellent monuments, archaeological and artistic masterpieces and a cultural heritage which goes beyond Greece and goes to Europe and to Humanity. There is also an extremely high spiritual heritage here since we can interpret the meaning of the oracle which was operating here that proper confrontation of very complex problems goes beyond science and rationalism and requires also an amount of devination. This can have a big effect not only to our science and profession, but also to the facing of the complex problems that make humanity suffer today like environment, economy, international relations or deteriorating cities.

Let us hope that our stay here will provide the devination that everyone of us needs for making his life more meaningful and relaxing.

I would ask you to forgive me for the emotion with which I welcomee you today, but 17 years ago in the spring of 1974 again as chairman of the organizing committee I was welcoming the participants of the 3rd International Symposium of CIPA held in Athens. Things have changed considerably since then. From the photogrammetric surveys we have moved to the complete documentation of monuments and to the integration of our data in special Geographic Information Systems. We have the proceedings of the 1974 symposium and very soon we will have the proceedings of this one too. It would be very interesting to make a careful and systematic comparison.

Our meeting seems to proceed well. We are expecting about one hundred participants from 20 countries and 35 reports are going to be presented, followed by a round table discussion. Most aspects are favourable and allow us to foresee a successful symposium. The enthusiastic presence of you is the most promising factor.

I hope that together with a successful symposium you will have a pleasant stay and the opportunity to get some idea of the Greek culture, of our nature and the Greek people. To prepare this meeting the organizing committee and the staff of the Photogrammetric Laboratory have worked very hard. I feel deeply obliged to them and I would like to thank them from this place.

I also would like to thank all our contributors with the help of whom this symposium has been organized.

I wish you a successful symposium and a good stay in Greece.

Thank you very much.

WELCOMING ADDRESS by

Mr. A. Velissarios, General Secretary
of the Hellenic Association of Rural & Surveying Eng.

Dear Sirs,

- Our Association - the Hellenic Association of Rural and Surveying Engineers, is aware of the fact that the National Archaeological Heritage is in desperate need of the contribution of modern Photogrammetry and Remote Sensing.

- The technological advances in computer software, photogrammetric equipment, information systems and CAD, enable the realisation of programmes which Government officials describe as imperative, but too costly for the National Budget.

- Many colleagues, most of which are in this room, have made proposals for programmes, which were well designed, but unfortunately remained as proosals.

We remind you a few :

- Integrated solutions for the preservation and registration of national monuments.
- National Integrated Land Register System for monument and Archaeologicl Sites.
- Archaeological and Cultural Land Registry.
- Programme for the Photogrammmetric reduction of Archaeological Sites.
- Remote Sensing for the preservation of monuments.
- Creation of a Monument Data Base.

Therefore, all of us, independently of our position in Science or Production, must insist in this: The Government agents (Ministry of Culture, Ministry of Environment, Association of Local Authorities, etc.) and scientific groups must support, the transfer of knowledge and capabilities of Architectural Photogrammetry.

Our Association has overlooked, this responsibility. Therefore this initiative presents a challenge for all of us.

We wish success to the course of the Symposium. The location, the subjects and the contributors guarantee it.

WELCOMING ADDRESS by

Mrs. M. Tsaoussi, President of

Hellenic Society for Photogrammetry and Remote Sensing

I would like to welcome all of you to this symposium.

I should point out that it is honourable for Greece to organize the XIV Symposium of the International Committee of Architectural Photogrammetry in this Historical Place.

For Greece Delphi has a distinguished meaning.

Here is the place where Hellenic consciense was first stimulated.

From all ancient Hellenic cities, Delphi was the one that happenings had a cultural meaning.

We all know that Greece among other countries has an innumerable amount of ancient monuments therefore the use of modern techniques of the Architectural Photogrammetry has a great interest for us.

Architectural Photogrammetry should be considered an efficient and useful tool for Surveying Monuments, Historical and other buildings.

Authorities and others responsible for maintaining building and monument heritage should give a great consideration for the Photogrammetric methods.

Especially now that the development of computer techniques and the implementation of CAD Systems makes Photogrammetry economic and rapid and therefore attractive method to use.

I would like to thank all the organizers that helped financially.

Thanks to all sponsors and congratulation to the organizing committee.

Hoping that the works of the symposium end up with positive results and messages for Architectural Photogrammetry, I wish you a pleasant stay in Delphi.

Maria Tsaoussi
President of
HELLENIC SOCIETY FOR PHOTOGRAMMETRY
AND REMOTE SENSING

WELCOMING ADDRESS by

Prof. A. Gruen, ETH Zurich

President of ISPRS Commission V

Honorable Guests, Dear Friends and Colleagues, Ladies and Gentlemen,

This is the fourteenth CIPA International Symposium of Architectural Photogrammetry. The history of these symposia is a true story of success. They have established themselves over the years as key conferences for all those who are interested in architectural photogrammety from a scientific and practical point of view. It has always been the particular flavour of these meetings that scientists, developers and practitioners from this discipline could meet people from adjacent professional fields in a relaxing atmosphere, created by professionalism, creativity, mutual understanding and friendship.

ISPRS is one of the supporting organizations of this conference. In particular ISPRS Commission V ("Close-range photogrammetry and machine vision") has a vivid interest in the operations of CIPA and serves as the intermediate partner, in terms of cooperation both on the scientific as well as on the organisational level.

As a matter of fact, through close cooperation between representatives from CIPA, ICOMOS and ISPRS we are able to finalize the draft version of new CIPA statutes during these days. These statutes will serve as a framework for the future operation of CIPA. If the statutes will be finally accepted by ICOMOS and ISPRS we will see some changes, as for instance a new election procedure for Committee Members, a change in the structure and composition of the Committee, a stronger involvement of non-European National Societies and experts and a few other items of minor impact. It is the desire and expectation of all of us, that CIPA - dressed in new organizational and administrative clothes - will prosper and grow in the years to come as it did in the past. There is no organization throughout the world that would support and promote the cause of architectural photogrammetry as well and as competently as it is done by CIPA.

The topic of our Symposium is "Architectural Photogrammmetry and Information Systems". It is evident for quite a few years now and it is well understood by all of us, that photogrammetry as a whole and architectural photogrammetry as a part of it must face an increasingly "digital" environment. New sensors (e.g. CCD cameras) and scanners, computer platforms (workstations), image analysis and computer vision algorithms, CAD - systems and the like are providing surroundings, in which photogrammetry has to find its role, if it ever seeks a chance to survive.

We are living in the information age. Nowadays we are confronted with information systems virtually everywhere. Spatial information systems play as GIS already an important role in our profession. Architectural photogrammetry, as an information generating process, has to adopt this new technology, or furthermore, it has to integrate itself into the framework of information systems.

Information systems (IS) may be used together with architectural photogrammetry in a fivefold way :

(a) For the recording of data : An IS, or a CAAD, which could be considered a part of an IS, could serve as the platform for the initial description of the object to be recorded.

(b) For the processing and editing of data : An IS could serve as the platform for (digital) processing of image data in vector or in raster form (or both).

(c) For the analysis of data : Queries concering type, geometry, history, preservation status and much more information about an object could be addressed to the database of an IS.

(d) For the documentation and conservation of data : The administration an storage of an IS could serve to maintain architectural and related information (geometry and attributes) in large databases.

(e) For the presentation of data : The visualization capabilities of a modern computer workstation could be utilized to display the object as a whole or in parts in various attractive ways.

In the terms of reference of the ISPRS Working Group V/5 on "Photogrammetry in Architecture and Archaeology" the "Study of appropriate applications of CAD/CAM and LIS/GIS" was already in 1988 identified as an important subject, which deserves deeper studies in the future.

It is my pleasure to see this problem being fully acknowledged now by CIPA and it is my hope that appropriate solutions will find their way into the professional practice in not too distant a future.

With the selection of the Symposium site of Delphi, the CIPA Committee has shown its great appreciation for both the host country and the Director of this meeting, Prof. Badekas, together with the organizing group from the Laboratory of Photogrammetry, National Technical University of Athens.

It is in particularly this country - Greece - more than any other, where we can find an abundance of highly ranked

WELCOMING ADDRESS by

Prof. M. Fondelli, University of Florence

President of CIPA

President, Ladies and Gentlemen, Colleagues,

The International Committee for Architectural Photogrammetry is in Greece for the second time. The first CIPA meeting in this historic country was seventeen years ago. During the past time, the CIPA situation was very developed and today it is characterized by a considerable expansion of the centres producing photogrammetric surveys of architecture, a technical evolution in favour of this field of application, but also an efficient specialised training.

The CIPA must promote the information available to heritage conservation experts concerning the real possibilities offered to them by photogrammetry, remote sensing, spatial information systems, computer graphics etc, for the knowledge measurement, representation and conservation of monuments and sites.

CIPA objectives for the coming years are to extend the international audience for the integration of the technological development of photogrammetry and the techniques associated with it into the applications to the architectural, urban, archaeological and natural (sites, historic garden) heritage.

The task of CIPA is to be a forum for discussion between photogrammetrists and architects, historians, archaeologists and conservationists for the exchange of ideas, problems, knowledge, methodologies, experiences and results.

CIPA is not a duplicate of the ISPRS or of the ICOMOS, but an intermediary integration system in order to combine the up-to-date problems for heritage safeguard with photogrammetric and remote sensing applied procedures.

From this Symposium, CIPA can verify the development and increase of scientific knowledge and make a general balance.

Thank you for the impulse that your welcome will offer to orientation of CIPA. I must particularly thank on behalf of the CIPA Committee Prof. Badekas and his collaborators for the kind and warm reception in Greece.

monuments, architectural and achaeological objects and sites and items of art. As a consequence, the World Heritage List includes as many as eight outstanding sites in Greece. Only three of them have so far been surveyed photogrammetrically. With a little surprise I have realized that Delphi still belongs to the unsurveyed sites. May this Symposium help to open the eyes of the responsible persons, may it help in demonstrating them what an excellent tool modern architectural photogrammetry constitutes for the world's heritage.

As we commemorate this year 2500 years of democracy, we realize how special it is to go back to the roots of our European culture. At this point we should remember that the Delphi oracle dates back almost another thousand years more to the Mycenean period.

I am convinced that this Symposium, in a environment of unsurpassed beauty and historical spirit, will generate another highlight in the history of Architectural photogrammetry.

My thanks and respect go to the CIPA Committee Members who made the wise decision to support a Symposium in Delphi.

My particular appreciation is for John Bakekas, our dynamic and restless symposium director and for his team of excellent young photogrammetrists, who together have prepared this conference.

On behalf of the ISPRS and its Commission V, I wish the organizers a smooth and successful conference, the active participants most interesting technical sessions, the accompanying persons good spirits for their excursions, and all of you a most enjoyable time in this famous place, which used to be the centre of the universe, and serves now for a few days as the centre of the world's Architectural Photogrammetry.

Integration of computers and CAD to Architectural Photogrammetry

Wednesday, October 2nd, 1991, 15:00 - 16:30

Chair: M. Fondelli

AN INTEGRATED PHOTOGRAMMETRY AND CAD SYSTEM APPLIED TO THE RESORATION OF A SEVENTEENTH CENTURY HOUSE

Fred Aldsworth BA,FSA,MIFA, Archaeologist
The Conservation Practice, U.K.

ABSTRACT
Restoration of the important late seventeenth century mansion at Uppark, England, badly damaged by fire in August 1989, is being greatly assisted in an accurate, cost-effective, and efficient manner by the application of analytical photogrammetry, to capture in digital form the standing remains, and AutoCAD, to replicate the original design from salvaged fragments.

BACKGROUND

Photogrammetry has been used in connection with historic buildings for over fifty years. David Stevens* has recently re-emphasized the role of this technique for recording purposes and, with William McKay & Daryl Fowler**, he has introduced the idea of linking photogrammetry with CAD to help reconstruct buildings that have been damaged by fire.

The ability of photogrammetry to capture raw data in a digitised form at full scale, i.e.life size, provides the accuracy required by the architect and engineer dealing with major restoration projects as well as producing basic information required by the archaeologist and architectural historian to distinguish periods of construction and alteration. CAD allows the operator to handle and edit that information to the same degree of accuracy and the combination of the two techniques permits accurate, life-size reconstructions to be prepared in a digital form for use in a variety of ways. The integration of the two methods provides an ideal medium for the reconstruction of historic buildings for which information survives as a mixture of *in situ* remains, which can be captured by photogrammetry, and salvaged fragments which can be digitised, held in store on the computer, and slotted into place on drawings using CAD.

* Stevens,D.,1989. Photogrammetry for the Record. Transactions of the Association for Studies in the Conservation of Historic Buildings, 14:17-21.

** Stevens,D.,McKay,W.M.,&Fowler,D., The combined use of photogrammetry and CAD in the reconstruction of fire damaged buildings. International Archives of Photogrammetry (Zurich 1990) :77-84.

The system is being used throughout the U.K. by The Conservation Practice, a multi-disciplinary team of architects & specialist consultants dealing with the restoration of major historic buildings. This paper outlines how the system is being operated on one of these buildings.

THE PROJECT

Uppark House, West Sussex, England, is a late seventeenth century country mansion, extended and refurbished with a fine collection of furnishings acquired on Grand Tours undertaken by successive owners in 1749-51 & 1775-76. As a result of an unusual series of events the house was relatively unaltered from about 1815 until acquired by the National Trust and placed on show to the public in 1960.

The entire building was badly damaged by fire in August 1989. Whilst the former service rooms in the basement were relatively unscathed by the fire, though affected by water, and most of the ground level floor survived intact, above this there was a virtual total loss of roof, upper floors, wall finishes, and five highly decorated & extremely important ceilings. A salvage operation conducted during the fire led to the saving of most of the art treasures from the ground floor showrooms.

The decision to restore the house to its former glory, wherever possible preserving *in situ* fragments and re-using salvaged material, has led to a restoration project of major proportions and on an unprecedented scale in the United Kingdom. The brief and philosophy for the repairs is such that an exceptionally high level of salvage and recording was necessary, not only to enable fire-damaged areas to be accurately reinstated but also to understand the evolution of the house and provide a basis for the future management of the property.

Archaeological techniques were employed for the salvage operation during which every item was individually recorded and a massive sieving operation has been conducted through the ash which had been placed in more than 4,000 refuse bins. As a result, over 15,000 items, ranging from floorboards, pieces of wallpaper & panelling to metal fittings & plaster fragments, are available for re-use or use as models for replacements.

METHOD

The complete absence of any plans, elevation drawings, or detailed drawings of the house before the fire and the limited access available to the structure for long periods immediately highlighted the need for a comprehensive study of the standing remains. The decision was taken at a very early stage to initiate a comprehensive programme of photogrammetry which had to be carefully programmed to allow maximum photographic coverage before areas of the building were covered in scaffolding.

The photographs and survey control now provide not only a source for three-dimensional photogrammetric plotting but also a permanent record of the structure immediately after the fire. Photogrammetry, undertaken by Atkins AMC of Pewsey, commenced on the exterior and this was repeated some six months later after a temporary scaffolding roof had been torn off during gale force winds in January 1990. The two sets of external records are available for detailed three-dimensional comparison which may be required as evidence for insurance claims. In the interior the photogrammetry had an extended role for not only does the information provide basic data for the architect and engineer but it is also providing the detailed information which allows the project archaeologists to spend their time analyzing the structure rather than recording details by manual methods.

The total loss of both the first and second floors in all rooms and even the ground floor in two of the rooms made access difficult, and over half the photography was taken from four and eight metre towers, as well as from the top of the external scaffold looking inward. The site grid was extended into the eleven surviving internal spaces and in order to complete the internal survey a total of six hundred photographs (each 13cms.x 8cms.) were used to provide four hundred stereoscopic pairs. Approximately eight hundred hours were involved in plotting and editing detail on CAD.

The *external elevation drawings* were produced on CAD to a 1:50 compatible specification, i.e. if two lines merged at this scale then only one would be plotted, but the digitised information is used at scales of up to 1:5 for details of openings & mouldings. The specification was extended to record in greater detail areas where severe external damage had been caused by the collapse of a chimney stack and this included the plotting of individual brick courses & cracks, and a series of vertical profiles were prepared in order to measure the amount of distortion in the masonry fabric. The information provided in digital form on AutoCAD was layered according to the requirements of the architect and this provides a permanent record of the exterior of the building immediately after the fire. The drawings have subsequently been extended manually to include a few areas inaccessible to the camera and to complete the elevations as they would have looked before the fire on a separate set of layers. Additions are made using the best available information - measurements taken from the structure are fed directly into the system and salvaged items which are repeated around the building are stored as W-block files for insertion on any drawing in the system (Figs.1 & 2).

Plans of the building have been prepared from horizontal sections created from photogrammetric information and the project has been greatly helped by the ability of the system to produce this information at a time when access for manual measurement was not possible. The drawings can be used at a variety of scales, for the whole house or for a single room, and for a variety of purposes, to record the positions of salvaged floorboards or to plan services & emergency fire exits.

The *internal elevation drawings* were produced on CAD to a 1:20 compatible specification but these are also capable of being produced to a much larger scale and this, again, has been beneficial in the handling of small details, such as plaster mouldings, which though destroyed can be mirrored or copied in from identical *in situ* fragments. Since all the floors and ceilings above ground floor level have been destroyed, elevation drawings include walls of at least three levels - ground, first & second or attic floor, and the information can be stored and used in this form to facilitate the recording of features which flow from one level to another. Where appropriate, adjoining rooms are stored alongside one another thus allowing complete elevations and sections through the building to be produced. The digitised information has been layered according to the type of building material, brick, stone, plaster etc., or by the form of detail, room corner, true edge of plaster or broken edge of plaster etc., and this allows for the information to be edited and presented in a variety of ways.

These photogrammetric plots, which often record only the masonry fabric of the walls on which the finished surfaces of plaster, wallpaper, or panelling will be mounted, have subsequently been upgraded using the best available information - plaster edges, scars, and marking-out lines, can be measured & fed onto CAD for storage at full scale. Details, such as cornices, dado rails, panel mouldings, architraves, and skirtings, are identified, classified, drawn, and stored full-size as W-blocks. Pre-fire photographs have been used for general layout & identification but difficulties have been encountered in using this material for photogrammetry because many have been taken with a plate camera and tilt-back lens which has eliminated the normal vertical distortion found in other cameras.

Over one hundred very detailed reconstruction drawings have already been produced in this way and others are being prepared. They are used at a range of scales and forms to facilitate the needs of the structural engineer, mechanical & electrical engineer, architect, & the historian (Figs.3-6).

TECHNICAL SUMMARY

A site grid was established to maintain a continuous three dimensional relationship for all the survey, architectural, & archaeological work undertaken. The photography was taken using a Zeiss UMK 1318 camera using Ilford FP4 film processed in Agfa Refinal. Photo-flood lighting was used to reduce shutter speeds due to the non-rigid nature of the scaffold towers. Control was installed using a combination of techniques and equipment, including intersection by theodolite and bearings & distance, mainly to targeted points but sometimes, due to lack of access, to photo-identified points.

All data was captured, by Atkins AMC, using two Galileo-Siscan Digicant 40 analytical instruments, with post-digital editing being carried out on AutoCAD Release 10.

CONCLUSION

The integrated system of photogrammetry with CAD, as used at Uppark and on other projects undertaken by The Conservation Practice in the UK, provides an ideal medium for the recording of historic buildings and the production of reconstruction drawings in an accurate, cost-effective and efficient manner.

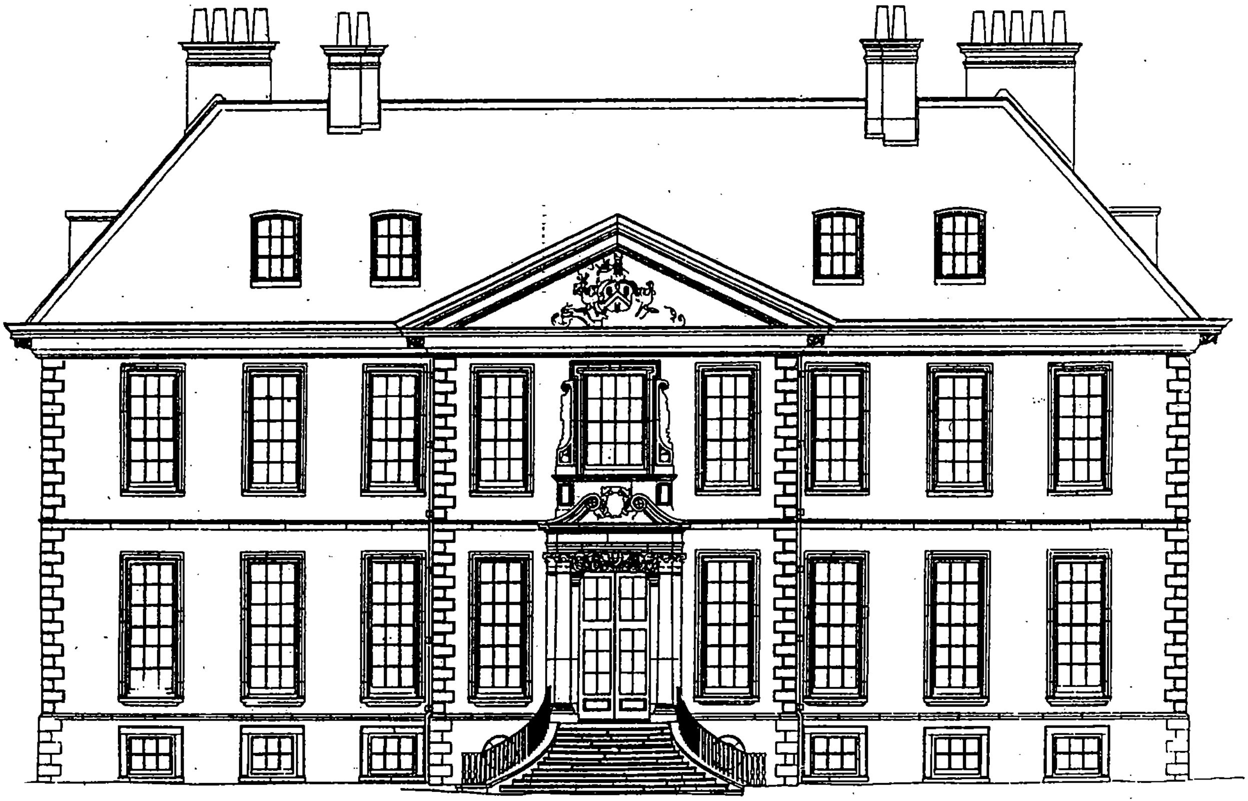

Fig.1 The south elevation of Uppark House, very much reduced from a digitised CAD drawing.

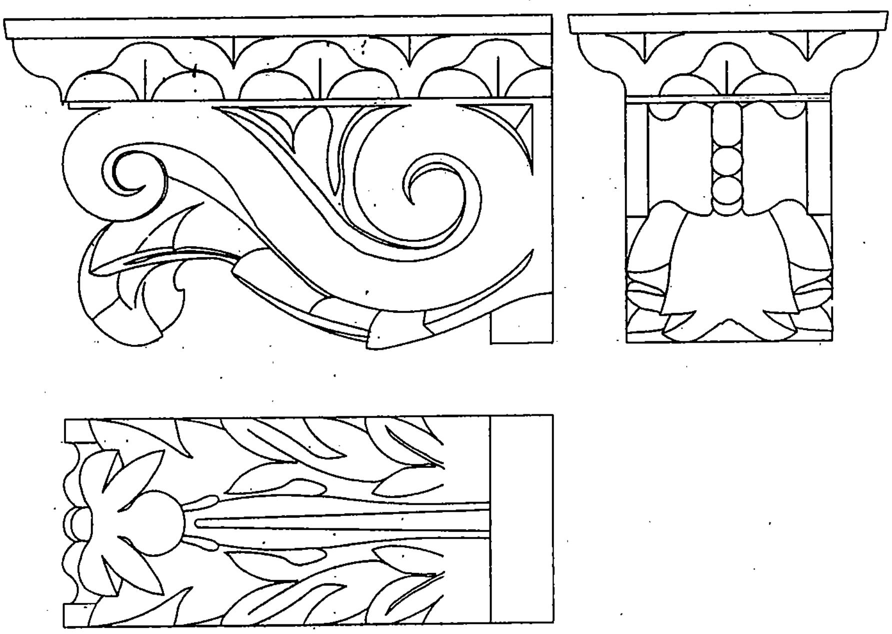

Fig.2 Three views of a modillion eaves bracket, stored at full size as a W-block on CAD. Over one hundred of these have been carved to replace those lost in the fire. The drawing, prepared from surviving fragments, is used at full scale for issue to the carpenter and in a reduced form many times on elevation drawings.

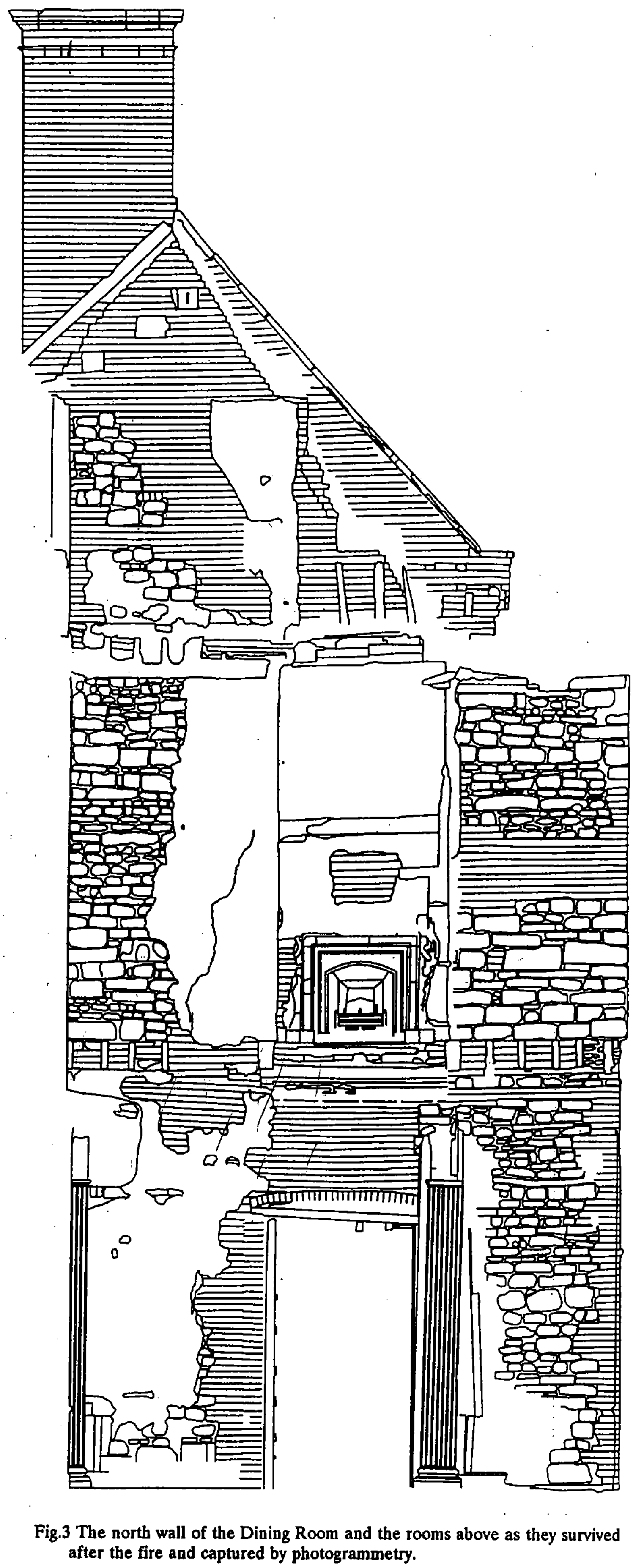

Fig.3 The north wall of the Dining Room and the rooms above as they survived after the fire and captured by photogrammetry.

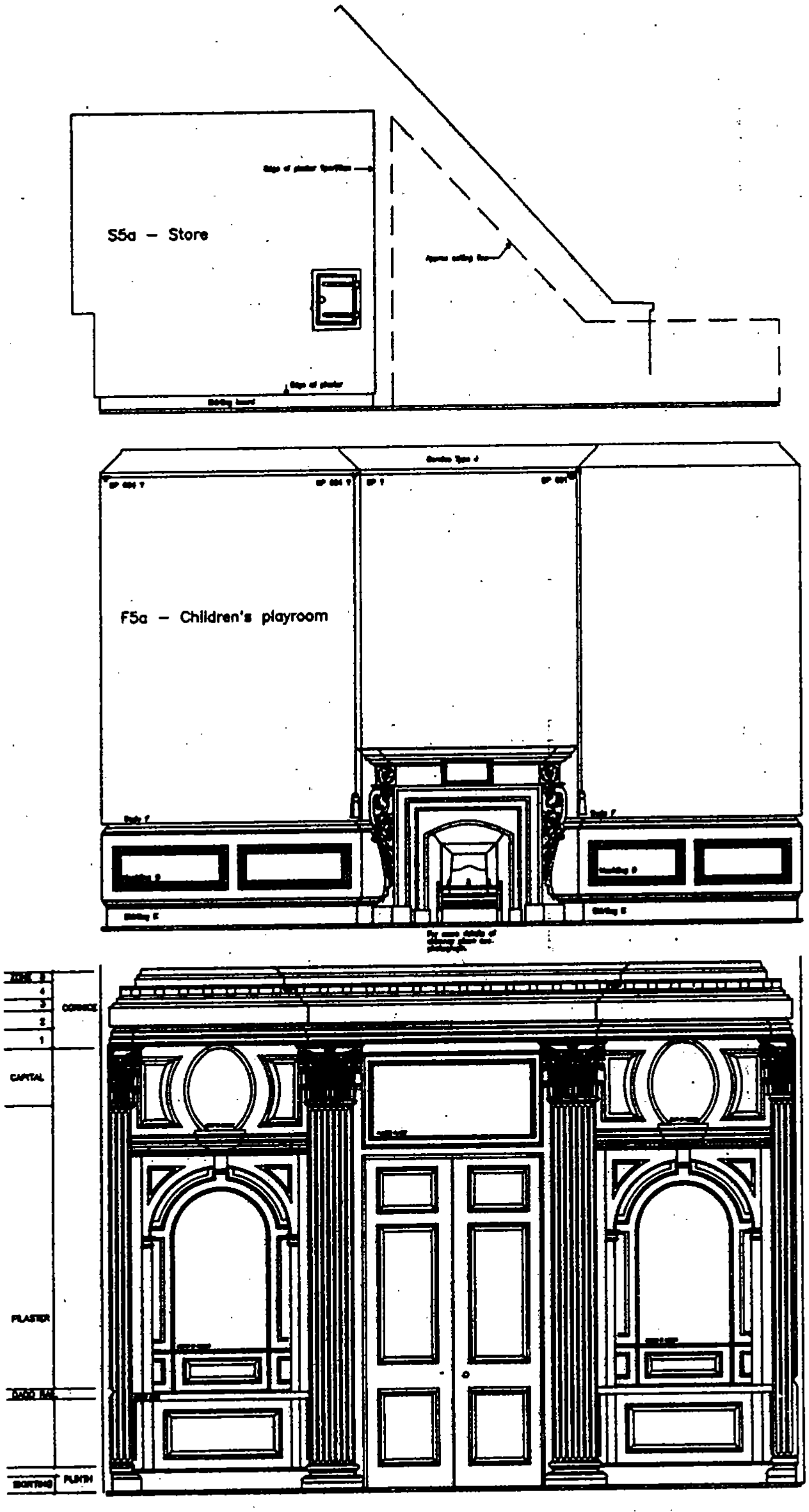

Fig.4 The north wall of the Dining Room and the rooms above as reconstructed on CAD using full scale information wherever possible.

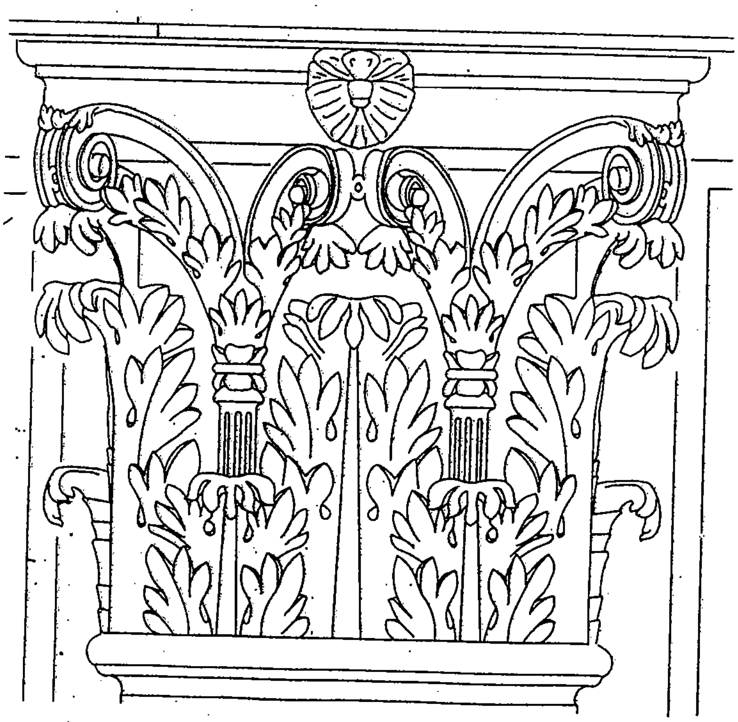

Fig.5 A drawing of a Corinthian capital from surviving fragments, held as a W-block on CAD for inclusion in elevation drawings of the Dining Room.

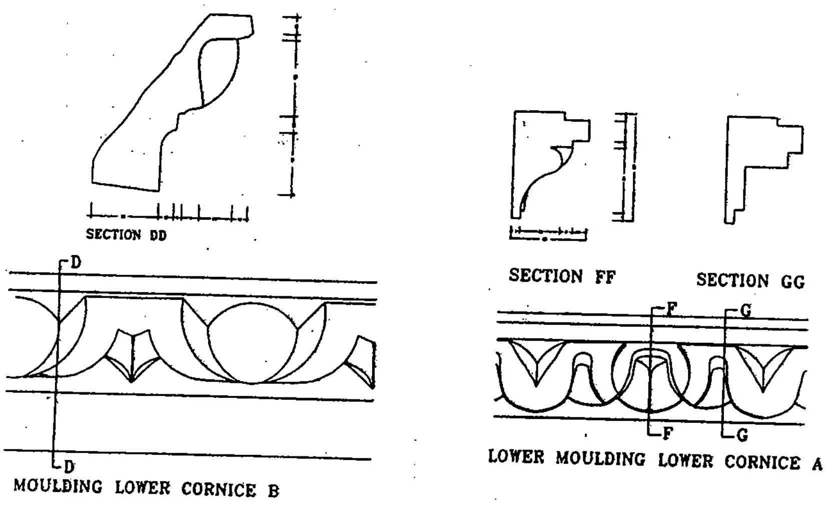

Fig.6 Drawings of carved details prepared from surviving fragments, held as W-blocks on CAD for inclusion in elevation drawings.

ANALYTICAL PHOTOGRAMMETRY AND COMPUTER GRAPHIC REPRESENTATION: COMPARATIVE ANALYSIS BETWEEN DIFFERENT SYSTEMS ON THE CITY WALLS OF CITTADELLA (Padova) ITALY

Laura Baratin, Clemente di Thiene
Centro Interdipartimentale di Cartografia e Fotogrammetria - Istituto Universitario di Architettura - Venezia

The University of Architecture in Venice is involved in a research program on the walled city of Cittadella. A specific field of experiment has been tested to determine how to combine "classical" expertise with the "new" approach of computer vision, 3D models and cost-benefit analysis. The aim of this project is to establish a precise set of specifications for the technical approach to historical analysis and restoration. Here, photogrammetry must provide the cartographical support and constitute the basic reference for all future interventions. At issue is the graphic model which has to provide geometric information and architectural details at various scales while at the same time being compatible with personal computers and accessible to the research programs of many different disciplines. We will test instruments and procedures, comparing the results of photogrammetrical restituion of walls and towers.

Summarizing briefly, our attention will be dedicated to:

1 - analytical restitution at different scales with autocad editing,

2 - different restitution systems related to photograph-based bidimensional and tridimensional digitization programs (PHOX system, Elcovision, MR2 Rolleimetric system...)

Great attention will be dedicated to the search for graphic quality which is both precise and affordable.

The various experiments we have conducted in Cittadella have given conclusive results. Within the scope of this project we have responded to the needs of various disciplines involved in the analysis of the city walls by considering those procedures,costs and instruments relative to each field of experiment.

In addition to our conclusions, outlined in this paper, we have proposed a new set of experiments which will be conducted in the near future.

In brief, we can simply state that the photogrammetrical survey of city gates and towers has to be carried out in a different way from a survey of the city walls. The reasons for this variation are both technical and economical as different types of information are required for each type of survey.

Towers and gates will be investigated using "classic" photogrammetric methods, that is, using large size film and interchangeable lenses, because of their large dimension (from 14 to 20 meters in height), their number (36), and their several relevant architectural details. In addition, special attention has to be given to the area of connection between these elements and the walls since towers and gates are the statical support of the walls, and because the greatest number of disconnections, cracks, and deflections are concentrated here.

The photogrammetrical survey of these elements is aimed at producing analytical restitution at a large scale (1:50). Consequently, the format of the film has to be broad in order to both reduce the number of topographical points required and to create bigger models which can be explored stereoscopically. These large models are a marked advantage in a study of such elements because of the great amount of information which they provide.

For the walls, on the other hand, it is more convenient to use pseudometric cameras with interchangeable lenses that have restitution systems adequate to accept the use of monoscopical photographs. Because of the great extension of the walls (35 sections of approximately 40 meters each), the scale of the drawings will be 1:200. This scale is sufficient to create a comprehensive "general map" of the walls, but is inadequate for any detailed analysis, either architectural or archeological. Our goal is to simplify and to accelerate the procedures we rely on (outlined in the following pages) and to identify the photographical "treatment" most capable of providing all the information, such as cracks, stratification of the different layers of masonry, control of erosion, and placement of the guard walk, necessary for restoration interventions.

From the technical point of view, in order to reduce the number of photos necessary for this program we anticiapte the use of a lift truck. Not only will this decrease the number of shots needed, but it will also result in photos of the structure with the least possible degree of distortion.

One requirement of the targets is that their form and dimension be such that they are easily centered when the digitizer is used for the restitution process using printed photographs. Therefore they will have the shape of a square of approximately 20 cm. The usual information required for their correct classification (number, code, date, etc.) will also be transferred.

As far as restitution is concerned we have planned to use stero-analytical instruments in order to achieve a higher degree of efficiency and better results.

Every model will have to respect codified specifications in order to guarantee uniform and accessible data. All data will be recorded in an ASCII file and all the specifications of file format will be stored on disk to enable the most general use for CAD programs, particularly AUTOCAD.

Since the ultimate goal of this process is to produce a tridimensional "wire frame" model of the walls, the restituted form has then to be tri-dimensional. This means that every point has to have three coordinates related to the general system of reference set up by the principal topographical net. The lines connecting the various points of the model, or of any other graphical entity representing an object in the space, will then be lines in a three dimensional space.

In the general scope of this specific work we intend to process all the elements that are considered significant by the various disciplines (archeology, construction theory, chemistry, physics, etc.) into a three dimensional model which will constitute the "space archive" of the walls. Accordingly, all bidimensional drawings produced will be recorded in an Autocad (DWG) record. Particular attention will be dedicated to photographical rectification as it is necessary to have a continuous image of the entire measured object.

This restitution is problematic, however, because the walls are not aligned rectilinearly from tower to tower and the crenellation is not on the same plane as the main body of the walls. The first problem can be solved by taking a photo for every single element of the broken line. For the second we are trying to find an interesting solution thanks to new instruments provided by the Galileo firm which we will discuss shortly.

The phase of restitution is divided into two parts:
1) Three dimensional restitution carried out at different scales of representation: one for the wall's gate and towers, and one for the masonry panels.
2) Photographic restitution (rectification) of all the boundary walls - the aim of this experiment.

Three Dimensional Restitution

The restitution of the photograms for the gate and the towers is carried out with a stereoscopic analytic instrument (Kern DSR1) at a scale of 1:50. This graphic representation is expressed as an orthoganal projection viewed on a vertical plane and obtained through the analytic interpolation of targets. Within this geometric representation of the observable solid the average parallel plane to the front view of the optical model contains all the numerical information belonging to the survey (targets, elevations, contour lines, etc.).

The residual error on this plane of representation is maintained at +\-0.3 mm at the scale of design. Diverse analytical systems were tested for restitution of the masonry panels starting with a photograph taken with a semi-metric camera rather than a stereoscopic one.

In addition to the summary described above, the general characteristics of these systems should be as follows:
a.) the capability of using simultaneously a number of photographs from 2 to 8;
b.) the use of a digitizer as an instrument able to measure the two plate coordinates;
c.) the use of a personal computer as a tool of calculation;
d.) the possiblity of interfacing with Cad programs, preferably AutoCad;
e.) the restitution of three dimensional points.

The representation has been established at a scale of 1:200 and the graphic information is stored both in the system of general reference and as an orthogonal projection on the vertical plane parallel to the single segments of the fragmented line.

In the case of Cittadella, in order to guarantee a great degree of control and precision in the restitution of these points, a minimum of three photographs is necessary in order to formulate the model. In general, this model consists of a number of "n" photographs covering the same segment of wall or part of that same segment. This representation includes the crenellation contours, all holes, targets, and the most evident bands of stratification in the wall's diverse layers of masonry. At a scale of 1:200, the graphic error of this representation is always maintained below 4 cm.

A comparative analysis of the diverse systems available on the market (Rollei System MR2, Phox, Elcovision 10 is part of a series of tests we are developing with the Insitute of Topography of the University of Bologna, on several buildings and under different conditions), the characteristics of which will be described later, has been performed on a very limited area on the internal "masonry panels" using six targets with a (RMSE) root mean square error of 3 mm in absolute value.

One aspect of this process still under consideration regards the stereoscopic photos. These are always taken with a semi-metric camera which permits a "classic" analytic restitution. This "classic" restitution then acts as a control against which are compared those results obtained with other systems.

Within this experiment, not only has the restitution of targets and of the values of orientation parameters been evaluated, but these targets and parameters have also been singled out as a series of characteristic geometric points related to the structure of the object from which we have extrapolated three dimensional coordinates. In particular, for the Phox system, photographs are taken with a Pentax camera format 24 x 36 mm and focal length of 50 mm. The average scale of these photograms fails between 1:500 to 1:750 with an average scale of enlargement about five times greater than that of the negatives.

For the restitution, if three prints are used possessing targets lying on different planes which have been partially surveyed topographically, the number of photos required by the program, between 10 to 15 when using a non-metric camera and from 7 to 10 when using a metric camera, can be derived photogrammetrically from the stereoscopic photos of the same section of wall. These photos contain significant points identified as coordinates which are used for the analytic restitution.

The phase of orientation is executed in two stages: in the first phase the calculation of orientation parameters is conducted ignoring the resulting distortions, as all images are distorted to a certain extent; in the second phase all parameter distortions are accounted for and corrected. The value of the "sigma 0" indicates the orientation's degree of precision and the residuals of observation expressed in digitizer units. In general, the lower this value, the more reliable the orientation.

After creating the orientation without taking distortions into account, the second phase of calculation proceeds in a manner similar to the first one, but in an interactive mode with a ratio of convergency that tends towards 0. To continue, one proceeds by establishing the constitutent elements of the subject through a coincidence of corresponding significant points. Related to these restored points are the three dimensional coordinates X,Y,Z. In correspondence with the coordinate digitizer, these points are assigned specific values pertaining to the residuals of observation and the value of "sigma 0" relative to these same residuals.

If the Elcovision system is used for restitution, a semi-metric Leica R5 camera with a format of 24x36 mm and a focal length of 24 mm can be used. The average scale of photograms, as found in the stage of the "masonry panel" experiments, exists here at a scale of 1:500 and 1:750 with an average scale of enlargement from about 5 to 7 times greater than that of the negatives. The dimensioning and positioning of the models is established by means of targets as pointed out previously in the phase of the topographical survey (6 points in total).

The preliminary phase of orientation allows one to control the data's reliability, first providing the residuals of the sights on the grid (Dx and Dy), then the points of orientation relative to parallax Py and absolute (Dx, Dy, Dz), and finally the (RMSE) root mean square error of the calculated parameters. It is also possible to identify the three dimensional coordinates of the retained, significant targets of the object and to compare them with the stereoscopic restitution by means of a graphic editing program developed within this system. According to the scheme of photos necessary for restitution, those three taken using the Rollei MR2 system are executed with a semi-metric Rollei 6006 camera with a focal length of 40 mm. Here, two convergent takes are aimed towards a central point containing the six targets identified previously using the analogic photographic points in the three takes. Although this increases the number of points necessary for the solution of the photogrammetric problem, a maximum of eight different points, between which all distances must be known, and a maximum of twenty observations must always be maintained. The average scale of the photograms remains equal to that used in the preceding case although the restitution is performed at an enlarged scale three times greater than that of the negatives.

The phase of orientation occurs in different stages: initially the model develops from two photograms to which are then linked all the others following a pre-established sequence until finally this set of models is processed and placed on an average position on the targets. The final orientation of this synthesis of models is calculated photogram by photogram according to the parameters of the shots, the orientation, and the residuals of observation.

The Rollei apparatus uses the same number of points derived from images for the acquisition and treatment of data as those used in the preceding experiment. The control of the design is obtained, also in this case, by identifying and combining points. Control of the outcome of the layout, however, is entrusted to the sigma of the coordinates of single points (minimum three photos) and is automatically processed. This qualitative evaluation of the diverse systems with which we've experimented, which are differentiated primarily in the final stage of the photogrammetric process, is based on the use of simplified systems and efficient software, but surely suitable for objects of ordinary morphology.

The quantitative analysis which appears in the enclosed table confirms the evaluation made previously on the described aspects of the system keeping in mind that one must compare separately the planimetric aspect X, Y from the altimetric Z., However planimetric values match those values intrinsic to the graphic tolerance of the scale of representation and change considerably when depth is also introduced. If, on one hand, the metric data is obtained with sufficient approximation, the semantic aspect is often quite deceiving, although we must consider that we have compared two diverse methodologies, the first being very experienced and the second completely new.

Photographic Restitution

The masonry curtain under consideration, as was mentioned previously, remains the object of this test of photographic restitution at a scale of 1:100 then reduced to a scale of 1:200 with the proceeding photo mechanics. The shots necessary to obtain photographic rectification of the masonry panels presented problems as they are not rectilinear. In fact, a shifting of pararellism with the plane of reference creates errors in the coordinates on the printing plane which affects the corrected orthogonal projection. For this reason we have photographed separately every fragment of the segmented line in such a way that the optical axis of the lens was perpendicular to the wall.

The operation of rectification is carried out with an analogic technique reproducing the original image under particular optical and geometric conditions on an appropriately inclined plane using the same targets of the restituion. The plane of projection always corresponds to a vertical plane parallel to the segment ignoring the plane of crenellation. Fortunately we have today the possibility to transfer information from photographic prints into a numerical form which can be stored in and manipulated on a personal computer. Furthermore we have also the capability to test a numerical system of rectification through digitial information. In fact, the Orthomap system, produced by Galileo Siscam and tested by us, permits the rectification and orthogonalization of numerical images.

Various types of tests have been carried out:

- the creation of a digital photoplane of the same segment of wall tested in the preceding case;
- the creation of a digital photoplane including diverse shots in order to test the patchwork of photogrammetry;
- the creation of a digital photoplane of a particular shot with a semimetric camera with a focal length of 150 mm and successive vectorialization of each segment of the wall texture at a scale of 1:25;
- the creation of a digital ortophoto always of the experimental segment.

The digital photo plane has been created from a digital image of a shot from the knowledge of the coordinates of the object and the corresponding coordinates of a certain number of points of the image plane.

The procedure does away with the errors due to the inclination of the camera but does not eliminate the deformations due to the different inclination of the photographed object. For this reason we have decided to have two different planes, one for the crenellation and one for the wall panel, both integrated with the coordinates given by the targets surveyed photogrammetrically.

The quality of the photomap is determined by the control of the residual error resulting from the calculation of the parameters of the homography. If the object is similar to a plane and the coordinates of both the object and the photo map are correct, the residual error is close to zero.

The experiment for the digital orthophotography has been treated on the digital image taken with the corresponding targets and a DTM created on a regular grid of 20 cm. This procedure eliminates the various errors of inclination, both of the object and the camera integrating the DTM with a file of restitution where the lines of the elements with different depth (such as holes, embrasures, etc.) are clearly delineated. The measures on the orthophotography being correct we have been able to confront these results with the previous ones.

Drawing a conclusion at the present stage we can state taht we do not have great differences between the various instruments and softwares: all of them as far as the problem of Cittadella is concerned present tolerable errors for the scale of restitution.

The use of Rollei 6006 and MR2 system has the advantage of a larger size of film therefore reducing the number of photos and topographical targets. Given the extension of the walls this is a device that will cut down the cost drastically.

We will develop in the near future the experiment with Galileo Siscam in order to set up correct specifications for the use of Orthomap system: it looks in fact the best solution, the quickest, the most agile and definetly adequate to the demand of the sciemtific committee governing the conservation of Cittadella.

CITTADELLA	QUADRANT
SECTION 4	SOUTH-WEST

VERTEX	TOPOGRAPH. TARGETS			RESTITUTION KERN DSR1			ORTHOMAP PHOTOPLANE		ORTHOMAP ORTOPHOTO	
	X	Y	Z	X	Y	Z	X	Z	X	Z
2	124,9212	121,9879	16,9872	124,9181	121,9966	16,9899	124,9200	16,9900	124,9100	16,9800
3	117,5905	120,7668	16,6198	117,5905	120,7664	16,6160	117,5400	16,5500	117,6100	16,6000
4	111,1214	119,4932	17,0205	111,1227	119,4988	17,0248	111,1200	16,9700	111,1300	16,9900
15	125,2616	120,7467	4,7362	125,2700	120,7500	4,7279	125,2500	4,6900	125,2800	4,7000
16	117,6119	119,426	4,7127	117,6126	119,4267	4,7106	117,6100	4,6700	117,5900	4,6800
17	111,6196	118,2052	4,4077	111,6200	118,2019	4,4036	111,6100	4,3600	111,6000	4,3900

PRECISION CONFRONTED WITH TOPOGRAPHICAL TARGETS

VERTEX				Dx	Dy	Dz	Dx	Dz	Dx	Dz
2				0,0031	-0,0087	-0,0027	0,0012	-0,0028	0,0081	0,0072
3				0,0000	0,0004	0,0038	0,0505	0,0698	-0,0195	0,0198
4				-0,0013	-0,0056	-0,0043	0,0014	0,0505	-0,0086	0,0305
15				-0,0084	-0,0033	0,0083	0,0116	0,0462	-0,0100	0,0362
16				-0,0007	-0,0007	0,0021	0,0019	0,0427	0,0219	0,0327
17				-0,0004	0,0033	0,0041	0,0096	0,0477	0,0196	0,0177
		medium		-0,0013	-0,0024	0,0019	0,0127	0,0423	0,0019	0,0240
		rmse		0,0038	0,0043	0,0047	0,0191	0,0241	0,0171	0,0110

PRECISION CONFRONTED WITH KERN DSR1

VERTEX							Dx	Dz	Dx	Dz
2							-0,0019	-0,0001	0,0081	0,0099
3							0,0505	0,0660	-0,0195	0,0160
4							0,0027	0,0548	-0,0073	0,0348
15							0,0200	0,0379	-0,0100	0,0279
16							0,0026	0,0406	0,0226	0,0306
17							0,0100	0,0436	0,0200	0,0136
					medium		0,0148	0,0398	-0,0012	0,0238
					rmse		0,0217	0,0250	0,0166	0,0105

CITTADELLA	QUADRANT
SECTION 4	SOUTH-WEST

	TOPOGRAPH. TARGETS			RESTITUTION KERN DSR1			RESTITUTION SYSTEM PHOX			RESTITUTION SYSTEM ROLLEI MR2			RESTITUTION SYSTEM ELCOVISION		
VERTEX	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
2	124,9212	121,9879	16,9872	124,9181	121,9966	16,9899	124,9012	121,8898	17,0026	124,9250	121,9830	16,9870	124,9120	121,8930	16,9770
3	117,5905	120,7668	16,6198	117,5905	120,7664	16,6160	117,5875	120,7559	16,5869	117.6030	120.7460	16,5960	117,5970	120,5910	16,5440
4	111,1214	119,4932	17,0205	111,1227	119,4988	17,0248	111,0999	119,4759	17,0005	111,1210	119,4990	17,0260	111,1530	119,3960	16,9580
15	125,2616	120,7467	4,7362	125,2700	120,7500	4,7279	125,2589	120,7159	4,7525				125,2170	120,7340	4,7200
16	117,6119	119,426	4,7127	117,6126	119,4267	4,7106	117,5896	119,3985	4,6989	117,6020	119,4240	4,7130	117,5470	119,3700	4,7080
17	111,6196	118,2052	4,4077	111,6200	118,2019	4,4036	111,5876	118,1189	4,3987	111.6100	118.2120	4,4080	111,6100	118,2040	4,4120

PRECISION CONFRONTED WITH TOPOGRAPHICAL TARGETS

VERTEX				Dx	Dy	Dz	Dx	Dy	Dz	Dx	Dy	Dz	Dx	Dy	Dz
2				0,0031	-0,0087	-0,0027	0,0200	0,0981	-0,0154	-0,0038	0,0049	0,0002	0,0092	0,0949	0,0102
3				0,0000	0,0004	0,0038	0,0030	0,0109	0,0329	-0,0125	0,0208	0,0238	-0,0065	0,1758	0,0758
4				-0,0013	-0,0056	-0,0043	0,0215	0,0173	0,0200	0,0004	-0,0058	-0,0055	-0,0316	0,0972	0,0625
15				-0,0084	-0,0033	0,0083	0,0027	0,0308	-0,0163				0,0446	0,0127	0,0182
16				-0,0007	-0,0007	0,0021	0,0223	0,0275	0,0138	0,0099	0,0020	-0,0003	0,0648	0,0560	0,0047
17				-0,0004	0,0033	0,0041	0,0320	0,0863	0,0090	0,0096	-0,0068	-0,0003	0,0096	0,0012	-0,0043
		medium		-0,0013	-0,0024	0,0019	0,0169	0,0452	0,0073	0,0007	0,0030	0,0036	0,0150	0,0730	0,0275
		rmse		0,0038	0,0043	0,0047	0,0117	0,0373	0,0197	0,0095	0,0111	0,0115	0,0348	0,0644	0,0332

PRECISION CONFRONTED WITH KERN DSR1

VERTEX							Dx	Dy	Dz	Dx	Dy	Dz	Dx	Dy	Dz
2							0,0169	0,1068	-0,0127	-0,0069	0,0136	0,0029	0,0061	0,1036	0,0129
3							0,0030	0,0105	0,0291	-0,0125	0,0204	0,0200	-0,0065	0,1754	0,0720
4							0,0228	0,0229	0,0243	0,0017	-0,0002	-0,0012	-0,0303	0,1028	0,0668
15							0,0111	0,0341	-0,0246				0,0530	0,0160	0,0079
16							0,0230	0,0282	0,0117	0,0106	0,0027	-0,0024	0,0656	0,0567	0,0026
17							0,0324	0,0830	0,0049	0,0100	-0,0101	-0,0044	0,0100	-0,0021	-0,0084
					medium		0,0154	0,0405	0,0056	-0,0018	0,0091	0,0048	0,0176	0,0909	0,0324
					rmse		0,0085	0,0381	0,0234	0,0101	0,0096	0,0104	0,0405	0,0596	0,0340

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RECTIFIED IMAGE MEASURING SYSTEM BY ANALYSIS OF PERSPECTIVE FOR OLD CENTERS RESTORATIONS

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RECTIFIED IMAGE MEASURING SYSTEM BY ANALYSIS OF PERSPECTIVE

1.THE AIM OF RESEARCH

This research belongs to the studies which have been developing by Prof.R.Di Stefano, School of Specialisation on Restoration of monuments, University of Naples, in order to investigate the knowledges and the methodologies for historical cities restorations.

Studies have to provide with a complete documentation oriented to the knowledge and preservation of the historical city, and,therefore, to the consequent activities of city restoring, planning, exploitation and managing.

All data provided with the present documentation will have to be, afterwards, collected in order to to be continuously integrated and made available with accuracy and quickness, making reference to every point of the city, on which it is necessary to develop interventions designing. Hence it follows the great matter to pick out an efficient and suitable informative system. To this purpose, our university pool found very useful the cooperation with Galileo Siscam, and with this latter is setting up a data base alike Gart, which permits to collect data both alphanumerical, graphical and photographic.

It is well known that, in order to have a complete documentation, it is necessary to have town planning, architectural and archaeological surveying, which, obviously, consist not only of whole cartography on the plane.

It is necessary to consider also the third dimension in order to know "site volume", which regards both the natural terrain on which is built and the buildings which form it.

So it is clear that, for documentation and basic knowledges purposes, it is very important to make surveying about ancient iconographical elements collection and "new surveying", which may give a right representation of the exact current shape of every element of the architectural patrimony.

To these "new surveying" belong developments of facades ("courtains") the roads and the squares and, more generally, the representation of all that defines "the architectural style of a city".

Graphic representations accuracy for restorations purposes, depending from the kind of job to be performed, for the town planning restoration studies and for the singles interventions depending on the methodological part we have to carry out.

It is clear that, for example, at executive level of the project, the surveying of the "courtains" must be very accurate, both in the geometric data and in the representation of every architectural elements.

In the preliminary analysis and general level of the planning can be admissible a low accuracy.

Accuracy limits depending also on artistic and historical values of the zone and on the consequent kind of intervention which is intended to be performed.

To this purpose, in the historical centers, the "protection degrees" were located: GP1, that is buildings of a remarkable monumental value, monumental plants and factories of a remarkable historical-artistic value; GP2, that is buildings of a considerable architectural value which, as a whole, represent very interesting architectural expression forms and which have conserved, inside themselves, very important elements that build up architectural features; GP3, that is buildings belonging to minor Architecture, of acceptable environing, town planning or volumetrically value; GP4, that is building which do not require a particular protection.

To these "protection degrees" correspond the following interventions: to GP1 and GP2, the most rigourous "architectural restoration"; to GP3, "the conservative restoration"; to GP4, "the building reconstruction" or, in some cases, "the building replacement".

A certain approximation, on the dimensional surveying, is admitted but homogeneous in every part of the represented "courtain" and is admitted also a certain difference about the details of the formal drawing of the buildings depending on their protection degree. The surveying of fronts development carried out by means of traditional methodologies or by means of ordinary photogrammetric techniques, is a very hard work from a financial point of view, consequently it has never been possible to perform the surveying of the "courtains", depriving the whole study of a very important investigation tool.

There are also many cases where the ratio between road size and heights of buildings doesn't permit to perform any traditional photogrammetric investigation.

In order to try to overcome these difficulties, it has been decided to investigate the experiences, already done somewhere else, to make "developments of fronts" by means of taking sloped photographs after rectifying them, assembling on a mosaic and, finally, representing graphically.

This applied research has been carried out, under the guide of Prof.Ing.Fondelli (Engineering Dept., University of Florence), by a pool where technicians of Architectural Photogrammetry Laboratory (Conservation of Architectural and Environmental Values Dept., University of Naples), together with those ones of Galileo Siscam S.p.A. and Alisud S.p.A. Laboratories, have worked together.

This kind of scientific cooperation permitted to test the possibility (both economical and technical) of new methodology for building courtains surveying within accuracy limits indicated for town planning restorations works.

The first time that the present work was shown, was at the National Naples Congress, at Naples University, Conservation of Architectural and Environmental Values Dept., June 27, 1991.

2.STATE OF THE ART FOR "COURTAINS" SURVEYING

Techniques which use the photograph as a tool for traditional surveying methodologies find always new applications in the architectural field. Photography, which defines "lines" and "areas" of the architectural composition, permits to overcome the limit, (existing in the usual surveying methodologies), to locate only "points", among which lines are laid out. It means that the photograph provides with all the data related to architectural elements.

This representation is obtained from a photograph through instruments and processing which use the rules of Perspective Geometry.
The use of photography is to mention again about the photoplanes, obtained assembling on a base net work a set of aerial rectified and scaled photographs.

It is possible to find a similar use of these photoplanes, in case of building courtains in the historical centers: this use it is already been adopted in some Countries of Central Europe.(FIG.1,2)

In general terms the most used techniques are:

1.stereophotogrammetric data collection

2.photographs rectifying

3.assembling on photoplanes

4.drawing, starting from rectified photographs

5.individualization of many pointson building fronts by analytical photogrammetry.

Drawing scales which are most used are: 1:200 for whole building courtains; 1:100 for partial courtains and 1:50 for particulars.

This methodology was designed over twenty years ago by Hans Foramitti, with a clear reference to the historical centers, where, to take photographs, is necessary to slope a lot the camera station axis because of the dimension of the roads.

In order to use these photographs, it is possible to employ stereophotogrammetry and photographic rectification; in this latter case, it is not theoretically necessary to have stereoscopic photographs. From the beginning this methodology of "photographic surveying" showed itself of a great interest for speed execution and for low costs. It was established, also, that the results were not perfect mainly due to perspective deformations but the obtained image was enough representative of the surveyed monument and gave an accurate information of the conservative conditions of the building.

3.GEOMETRIC FUNDAMENTAL

A contribution to this research can be given starting from the courtains geometry, that shows areas and structural elements nearly flat, and that shows vertical and horizontal outlines (edges, windows, doors, roof eaves, rain pipes, etc.). References elements useful for projective and perspective procedures.

Fast developments of electronic technologies can give also some new solutions, especially when it is possible to employ the digital image processing of the photograph and data collection by Personal Computer. The above techniques are useful in order simplify photograph taken and plotting of the acquired image and, in the meantime, we get photographic and graphic products of a great metric documentary value and of a great qualitative value.

A large number of photographs are hard to be managed, by means of classic methodologies, in order to achieve controlled mosaics and metric graphical representations.

Anyway, consequent processing resulted in a very original form, that consisted of having a raster file by scanner devices, from the collected images, their rectification plottings by means of rectification, their consequent "electronic mosaicking" by equalizing the different used images, the final graphic and bidimensional numeric plot on Personal Computer.

The procedure we used for rectifying was Moebius perspective grid, in order to restore horizontal and vertical elements that were changed by the position of the external orientation elements of the monocamera station.

In Fig.1 it is easy to verify as the perspective could modify itself when normality could restore among different vertical and horizontal lines intersecting themselves in the sloped photograph. The rectifying procedure can be integrated with a compensation algorithm for setting up distances and lengths in horizontal, vertical and sloped direction.

It is clear that the mosaicking can be performed always on Personal Computer, using triangulation methodologies, to ensure the best linkage for the whole set rectified images.

When the photographic assembling of the whole considered courtain is finished, images restoration will have to be performed, if necessary, to obtain a final image of the building. This operation comes out as a preliminary in comparison to the vector plotting and should be performed directly on the same Computer.

Results are still on a experimental basis and so they can be improved.

4.ALGORITHMS FOR RECTIFICATION METHODOLOGY

The "Rectification techniques" normally deform the original image so to eliminate non-parallelism effects of focal plane of the camera and of the object to survey.

Operation limits and analytical instruments costs can strongly condition the use of these techniques in Architecture field. These conditionings can be removed by using electronic technology development computer's field.

Having an image, in a raster form, there are some simple algorithms that permit rectifying operation in a effective way and without particular limits.
Among the points which build up an object plane and the points which build up the image of the same object obtained with a camera, there is a relationship that hang together every point of the object to a point of the image and vice-versa.(FIG.4)

By means of this procedure it is possible to rebuild an orthogonal projection starting from whatever camera picture of the object even if very sloped. About the computation of the parameters which defines the transformation, this is done by writing the equations for almost four points of known coordinates on the object and by resolving the equation system that comes from: generally, are known more than the four points strictly necessary: in this case, the minimum least squares adjustment must be applied.

The geometric concept of "point" is replaced by the term "pixel" (picture elements), that is the minimum unit in which the image has been splitted once transformed from analogical to digital. The pixels will be correctly positioned by collineation relationship producing, because of their information content in terms of grey levels, the "orthogonal projection".

The same computer that performs the rectified image provides easily the user with the possibility to perform the graphic plotting and its storing on disc by using a mouse which drives a cursor on the video graphic station. The vectorial information so produced can be obviously used independently from the image or can be associated to it for updating purposes, control or information completeness purposes.

The power and the flexibility of a numeric system on executing rectified image are remarkable, It is very important to determine the parameters that define the transformation of the image in another rectified one, and for this determination we need to know the coordinates of some object's points.

To have this known point we have to carry out some measurements by surveying instruments or by very complex and expensive instruments.

In the present algorithm we do not use any known point, but only the horizontal and vertical line position on the photograph to determinate the parameters for "collineation relationship".

Once established rectifying procedures of the perspective image, it's necessary to have the possibility to join the different photoplanes performed to create a mosaic.

This rectifying procedure produces images with homogeneous scaling, so they can be joined to form a single image in a unique reference system, that it's true only if overlaying are guaranteed among images.

Afterwards, it is possible to perform in the complete image some numeric techniques to improve the image, such as grey levels equalization, filtering and so on.

5.FIELD TEST

In order to verify the real correspondence of the relative accuracy of the obtained drawings compared with tolerance, we did some controls by performing some direct and indirect measurements and by comparing some dimensions on the drawings with those ones corresponding in reality.

Measurements were carried out by using a manual methodology by means of double Invar meter. For the upper zones, by using a theodolite in forward intersections, a series of high points were measured

It was impossible to use Laser distance-meters, as the sloping of the views, necessary in this case, were too excessive.

Coordinates of 25 points distributed in the front under examination were determined and 35 distances among points were measured directly.

The measurements results (direct and indirect) so performed, permitted to find a sufficient amount of distances that were compared with those ones measured directly on the drawings. In general terms, this comparison showed a sufficient correspondence to the precision limits requested and established.

Keep in mind that the current experimental research is addressed to determine a "speedy" work methodology effectively applicable to the environing reality of the historical centers, not claiming to achieve high precision results, as those ones provided by the classic terrestrial photogrammetry methodology and by surveying. It is to point out that the ratio between road size and building height demands an amount of photographs so large to make not proposable photogrammetry plotting data collection.

On the other hand, the rectified methodology we are talking about is not intended to be against the traditional analytical plotting methodologies from a single frame,which without doubts permit more accurate results.

Local operations involve so many troubles that a traditional geometric picture framing, in order to make measurements of the points coordinates, may lead to so high costs to make, practically, impossible the execution. Just in these cases the methodology is useful to satisfy many documentary needs.

The work methodology so improved, makes possible to enlarge fronts surveying to the remarkable amount of building courtains existing in the historical city because it gives great advantages related to costs and to necessary operation times.

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a


b

Fig. 1

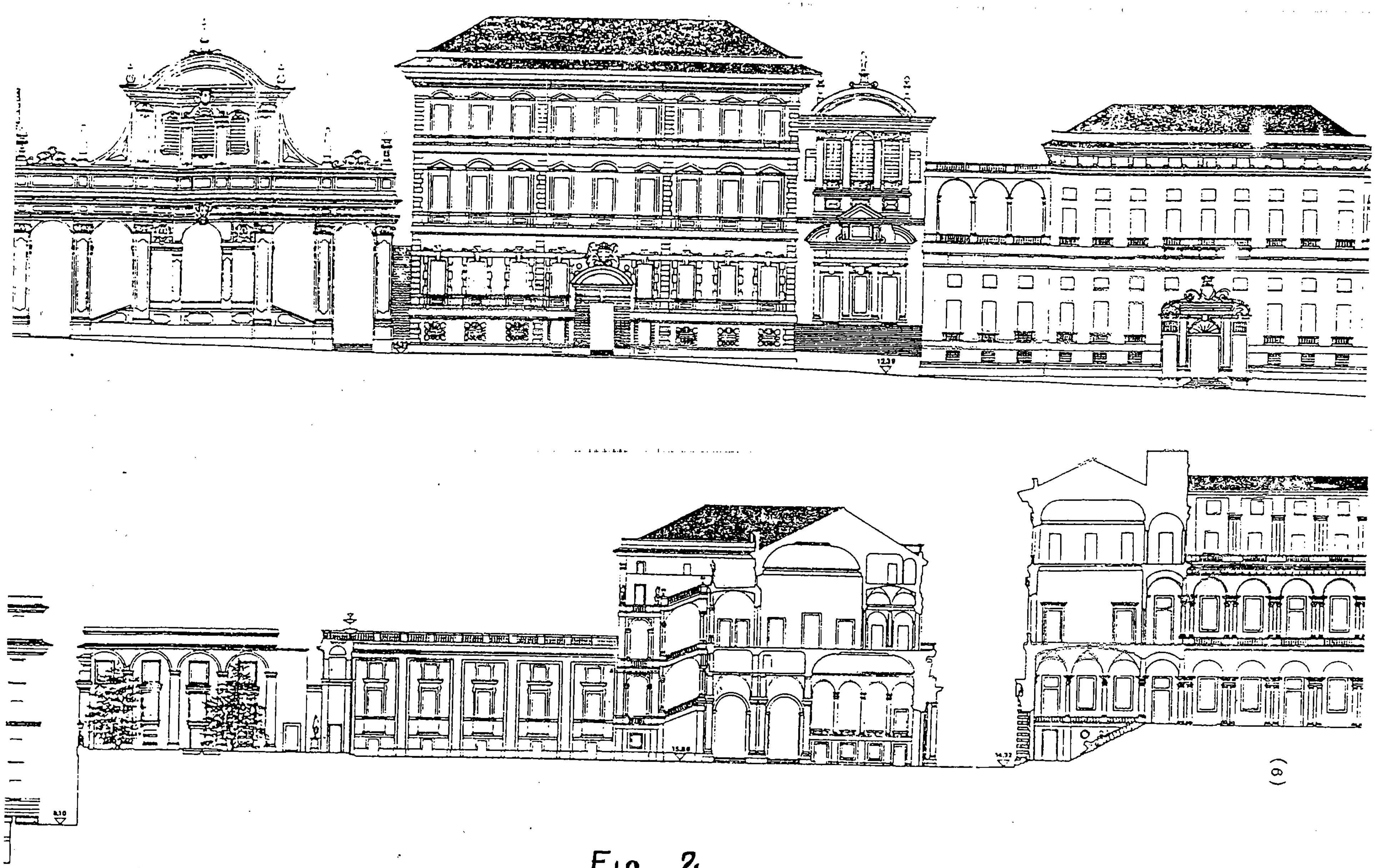

Fig. 2

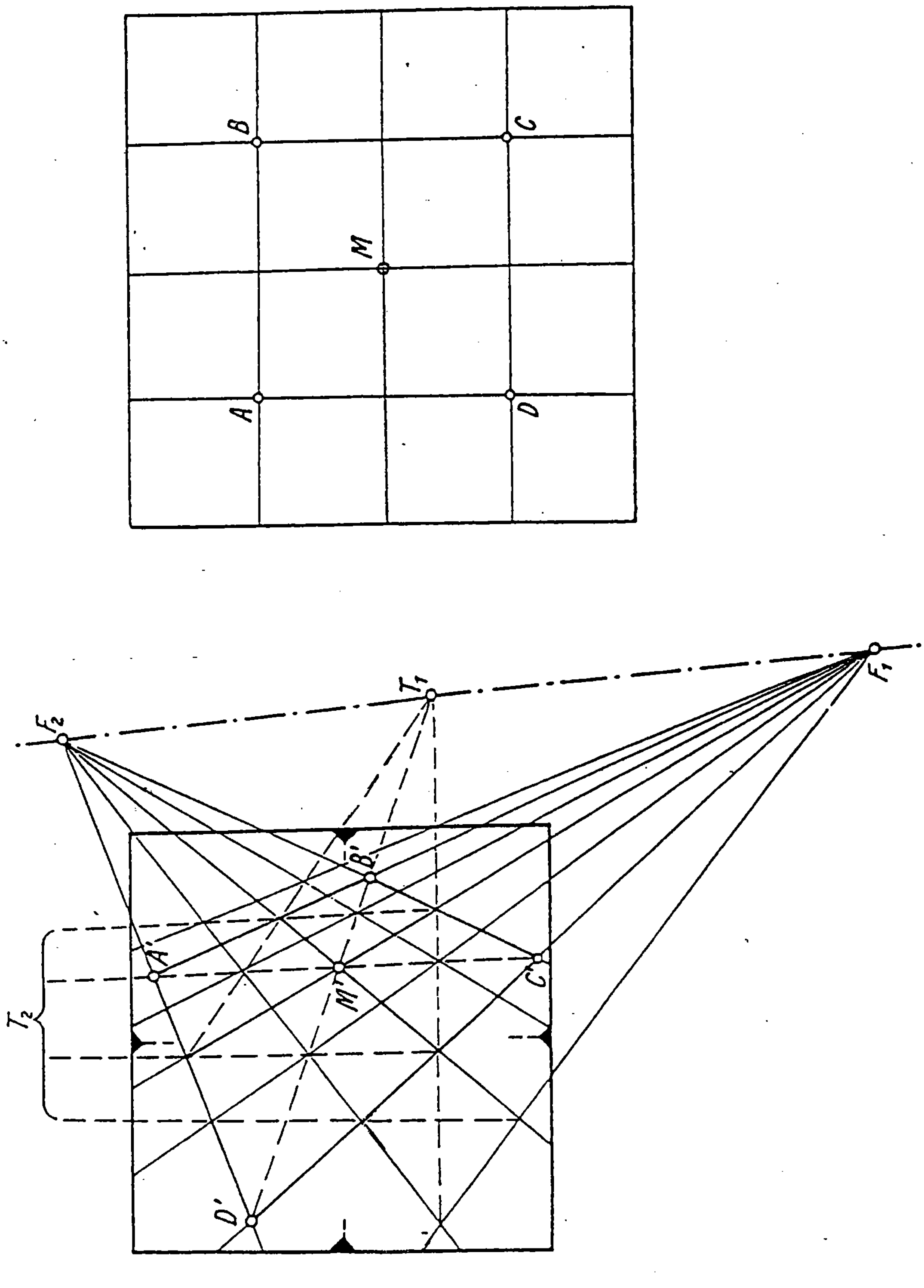

Figura 3

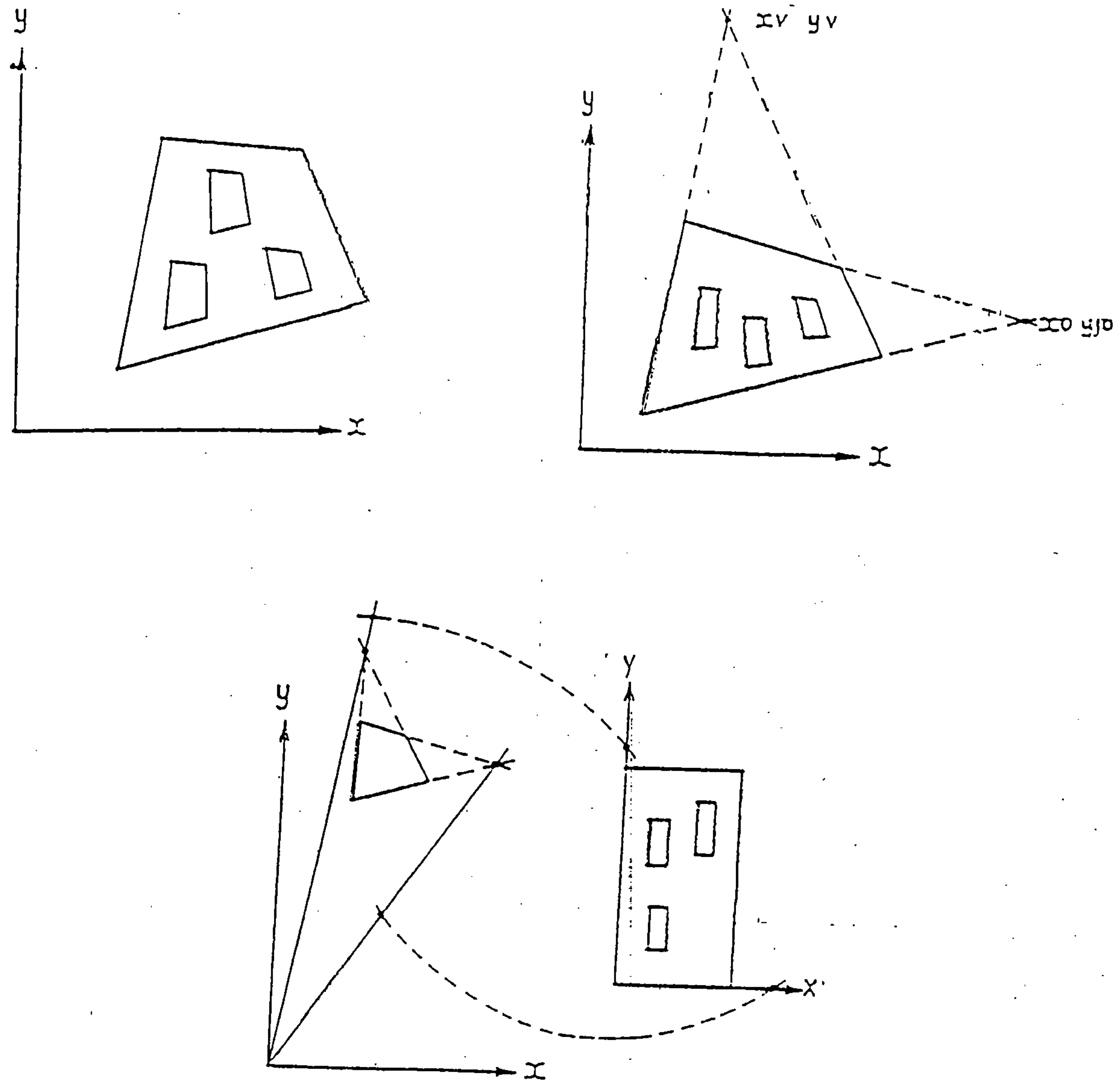

Fig. 4

DEVELOPMENT OF A DIGITAL SYSTEM FOR ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

The availability of powerful workstations and the advent of high resolution digital imaging systems makes the development of a fully digital systems for Architectural Photogrammetry possible. In a joint project between the Institute of Geodesy and Photogrammetry and the Chair of Architecture and CAAD, both at the Swiss Federal Institute of Technology in Zurich, a digital photogrammetric system is under development.

Appropriate digital imaging systems are evaluated and tested. In contrast to existing systems where an operator is measuring all features of interest, a higher level of automation is desirable. Emphasis is placed on novel techniques for semi-automatic measurement of architectural features. Several measurement procedures have been developed, some of which are presented here.

A practical project is used to demonstrate the methods and the efficiency of this system. The steps from image acquisition to the data representation in a CAAD-system are outlined. Issues of sensor resolution and accuracy are addressed. An outlook to developments leading towards semiautomatic and fully automatic recognition and measurement of general architectural features is given.

KEY WORDS: architectural, CAD, CCD camera, digital system, non-metric.

1. INTRODUCTION

Improvements of the processing and storage capabilities of workstations are occurring at a breath taking speed. They provide the platform for processing the large amounts of digital imagery available from a wide range of sensors. With respect to Digital Architectural Photogrammetry the development of high resolution digital imaging systems is of major importance. The technology for systems with a sensor resolution comparable to medium format film cameras is available. A Digital Photogrammetric System for Architectural Photogrammetry must be capable to acquire imagery with sufficient resolution, process the data with a high level of automation, and pass it on to a CAAD-system. The status of such a system being developed in a joint project of the Institute of Geodesy and Photogrammetry in cooperation with the Chair of Architecture and CAAD at the Swiss Federal Institute of Technology in Zurich is outlined.

2. DATA FLOW IN A DIGITAL SYSTEM FOR ARCHITECTURAL PHOTOGRAMMETRY

Images can be acquired with film based cameras as well as with systems and/or cameras using solid-state sensors. Former still provide for a higher resolution, but the film must be developed and digitized before the data can be used in a digital system.

A Digital Photogrammetric Station (DIPS) is used for processing. It must provide for ample storage space for the large amount of digital imagery, a tremendous

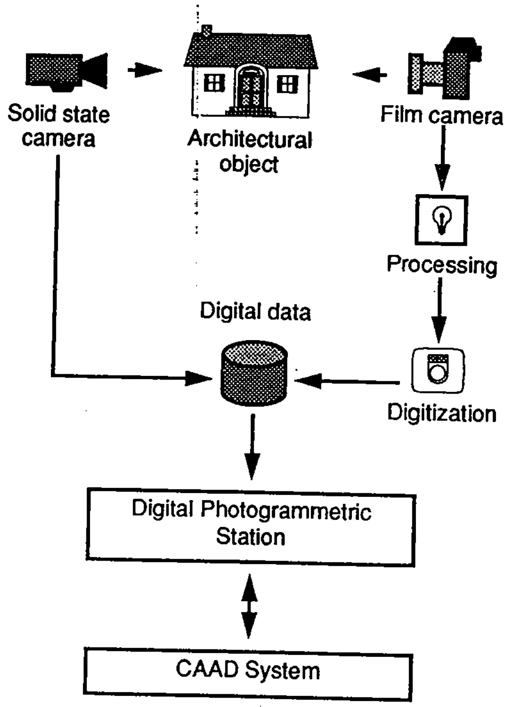


Figure 1 Data flow and hardware of a digital system for Architectural Photogrammetry.

processing performance for semi-automatic and automatic measurement algorithms, and a high resolution display for the visualisation of imagery, processing steps and results.

The hardware platform of the DIPS and the CAAD-system can be identical, but the integration of the software of both systems into one package has not been attempted. An interaction between and/or integration of the CAAD-System and the photogrammetric processing system will be necessary in the future. The CAAD-System can support interactive measurements by an operator and will be required to provide a priori information for automatic measurement procedures.

All tasks, from image acquisition to the transfer of CAD-data, are performed with the software package DEDIP (Development Environment for Digital Photogrammetry, *Beyer, 1987*). It provides, among others, modules for image acquisition, interactive measurement of pixel coordinates, a bundle adjustment program, and measurement of architectural features. Figure 1 shows data flow and hardware components involved in a digital system for Architectural Photogrammetry.

3. IMAGING SYSTEMS FOR ARCHITECTURAL PHOTOGRAMMETRY

Imagery for Architectural Photogrammetry can be acquired with film cameras and subsequent digitization or by digital imaging systems. Only the latter are addressed here as the characteristics of the former are well known. Devices of this type can be standard solid-state cameras with a video recorder or a computer with framegrabber, still video cameras, video cameras, and several types of high resolution cameras.

All cameras using one of the widely used video standards provide imagery with approximately 512 x 512 pixels. Until the availability of High Definition Television systems, which will have 1920 x 1035 pixel, the cheap off the shelf systems will be limited to this image size.

There are a number of cameras available which provide for imagery with a much larger number of pixels. The largest area array charge-coupled device available today has 4048 x 4048 sensor elements, but the price for a complete system with such a sensor is still in the order of US$100.000.-.

There are several other ways to obtain imagery with more information. The ProgRes 3000 (*Kontron, 1990*) uses a sensor with very small apertures combined with a piezo controlled displacement in the sensor plane. The partial images are assembled thereafter. Another approach uses a standard sensor and the reseau scanning principle (*Wester-Ebbinghaus, 1986*) to attain imagery with 5500 by 7050 pixel (Rollei RSC). There are also several systems with linear arrays and mechanical displacement devices. All these have the disadvantage that the image acquisition requires at least several seconds. This needs a stationary object and constant lighting conditions.

The current technology of still video cameras uses an analog recording technique for intermediate storage of the imagery. This leads to a significant degradation of the radiometric and geometric characteristics of the imagery. Still video cameras with digital recording techniques are currently appearing on the market. Even currently available still video cameras provide sufficient geometric accuracy to map an architectural object. Well defined points spanning several pixel can be determined with an accuracy of 1/5th to 1/10th of a pixel. But their resolution is not adequate for architectural objects. For example imaging an object of 20 m onto a 512 x 512 pixel image requires that the features of interest span at least 20 cm on the object. This is far too large for most applications and renders the current still video cameras almost useless for such tasks. This problem is demonstrated in Figure 2, which shows on the left an image taken of a church and on the right an enlargement of the indicated area. The corner of the building can still be identified, but measuring finer details of the corner is impossible.

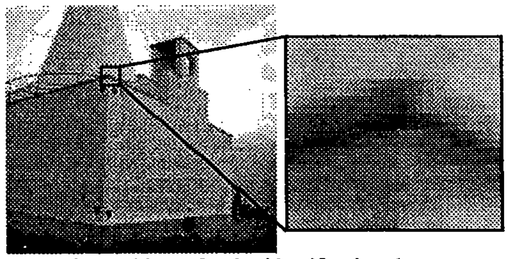


Figure 2 Problem of point identification due to insufficient sensor resolution.

The possible improvement of high resolution imaging systems is demonstrated in Figure 3. It shows zoomed portions of a close-range testfield. The images were taken with a standard solid-state camera (Figure 3 a) and the high-resolution camera ProgRes 3000 (Figure 3 b). The great difference in resolution of these two cameras is conspicuous. This demonstrates that high resolution cameras are required for the demanding requirements of Architectural Photogrammetry.

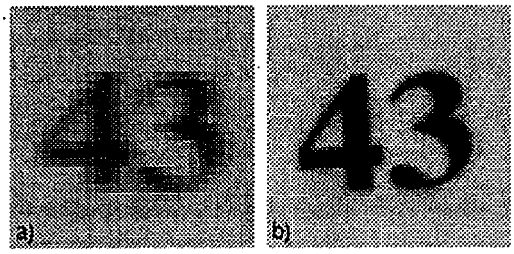


Figure 3 Comparison of standard solid-state camera (a) and ProgRes 3000 (b) with images of a testfield.

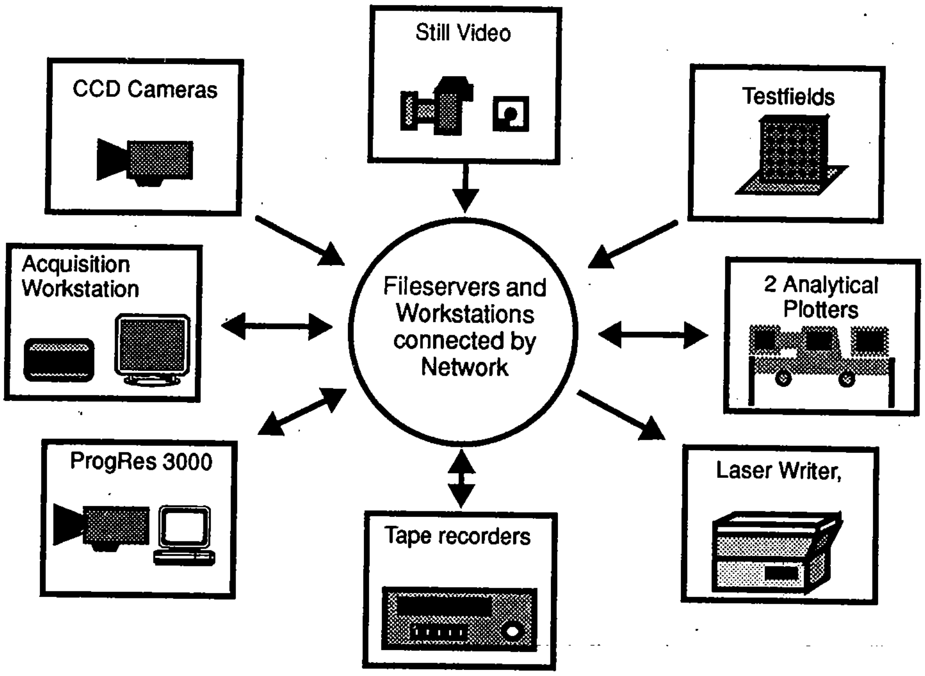


Figure 4 The Digital Photogrammetric Station and its peripheral devices.

4. THE DIGITAL PHOTOGRAMMETRIC STATION

The data analysis is performed within the Digital Photogrammetric Station (DIPS II, *Grün, Beyer, 1991*), as shown in Figure 4. The DIPS consists primarily of a network of workstations from SUN-Microsystems, to which special purpose systems like the image acquisition workstation, the analytical plotters, personal computers with interfaces for special cameras, and other input and output devices are connected. The image data of this test was digitized from the still video recorder described above with the acquisition workstation of the DIPS. Latter consists of a SUN-3E and image acquisition boards from Datacube. The ProgRes 3000 uses an interface board on a PC-AT type computer which is also connected to the network.

5. MEASUREMENT TECHNIQUES

Before the three-dimensional information of architectural relevant features can be extracted by photogrammetric methods (e.g. bundle adjustment), their position in the images must be determined. The advantage of a fully digital system for Architectural Photogrammetry is the use of digital images. These images make semi-automatic and automatic measurement methods possible. In the following the measurement approaches for basic geometric primitives and the major software aspects are addressed.

5.1. Development Environment for Digital Photogrammetry

The main software component of all measurement techniques of the digital system for Architectural Photogrammetry is DEDIP. As a part of the Digital Photogrammetric Station (DIPS), it allows to perform all tasks from image acquisition to the extraction of the three-dimensional data within one program. The program uses the SunView window system. Major functional modules of DEDIP are:

- Image handling and display,
- Input and output of images,
- Acquisition of images with a framegrabber,
- Interactive and semiautomatic measurement in images,
- Extensive routines for the radiometric and geometric analysis of images,
- Bundle adjustment program with self-calibration,
- Input of topologic information,
- Data transfer to CAAD-system.

All modules are used in this project, but only the measurement aspect is of major concern at this point and will be discussed in more detail in the following.

5.2. Point location

The simplest method to determine the location of architectural relevant features in the images is to use the cursor as a manual measuring device. This is basically identical to the measurement technique used in many systems employing a digitizer, such as Rolleimetric, Elcovision, etc.

In DEDIP the regions of the images, in which the coordinates are to be determined, are displayed on the screen and the operator measures the coordinates of corresponding points with the cursor. Figure 5 shows a typical configuration of the workstation screen for the manual measurement of points. The images were zoomed to improve the precision of the manual measurements. Here only two images are displayed, but several regions of interest can be viewed simultaneously. A screen layout with four images was efficiently used in several projects. The measured coordinates are indicated with crosses and their respective numbers, as shown in Figure 5.

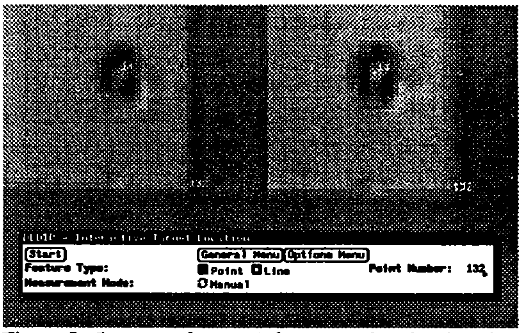


Figure 5 Layout of screen for manual point location. Here two images are displayed simultaneously.

This measurement technique does not exploit the additional capabilities offered by semi-automatic and automatic measurement methods which can be applied on the digital images.

5.3. Feature location

In this project Least Squares Template Matching (*Gruen, 1985*) was applied to measure the precise position of signalised points. It uses a template (artificial image of the feature) as reference and determines the position via an iterative procedure through the least squares fit of an affine transformation between template and patch (image region). Initially, the patch is taken at the approximate position from the image. This can for example be indicated by the operator in an interactive measurement mode. In subsequent iterations the patch is resampled from the data of the image using updated values for the affine transformation with a user definable interpolation algorithm. Figure 6 shows an enlargement of a part of the original image, the patch at the initial position, the patch after convergence of the algorithm, and the template.

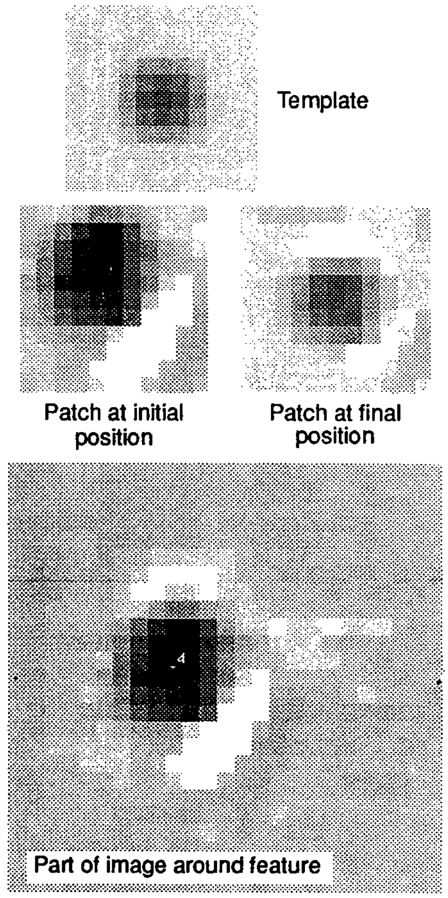
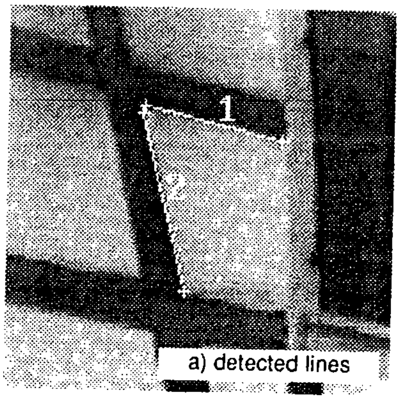


Figure 6 Image with point and number at final position, patches at initial and final position, and template of a target measured with least squares template matching.

Least Squares Template Matching provides a very high precision. In practical applications an accuracy corresponding to a tenth of the pixel spacing can be achieved for well defined features. Under laboratory conditions accuracies of a few hundreds of a pixel have been achieved. Least Squares Template Matching can be used to measure signalised points as well as architectural features, provided an artificial template can be generated. It is therefore a very precise and general measurement method.

5.4. Point location via line following

A major problem in measurement of architectural relevant features is the identification of the points in the images. The vertices describing these architectural features are often not well defined for photogrammetric tasks. In these cases the linear boundaries of the object contain more information than the vertices. The measurement technique shown here takes advantage of this. It first locates the linear elements of the feature to be measured and then derives the vertices/corners as intersections of these lines. Figure 7 shows an example of this technique. The initial position of the linear element is indicated by the operator with the cursor. Starting from this, the line is tracked by the algorithm using the first partial derivatives of the image. The result of the line following is a polygon with a step width of one pixel. If the result of this process is satisfactory, a straight line is fitted onto the polygon (see Figure 7a) This is done for all lines in the image. In a second stage the points defining the architectural features are computed as intersections of selected straight lines (see Figure 7b).



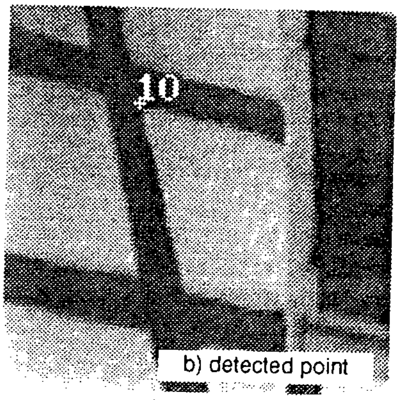


Figure 7 Example for point location via line following. Line no. 1 and line no. 2 define point no. 10.

6. PROJECT GIOVA

6.1. Architectural object

The church "Chiesa di Nostra Signora di Fatima" in Giova (Switzerland) was chosen to demonstrate the functionality of the current digital system for Architectural Photogrammetry. Giova is located in the southern alps near Bellinzona, the capital of the canton Ticino. The architects M. Campi and F. Pessina designed this church which was built in 1984-88. It stands in a privileged and dominating position, nearly 800 metres above the valley Mesolcina at the edge of a plain. The church is 14 m in length and 10 m in width and height.

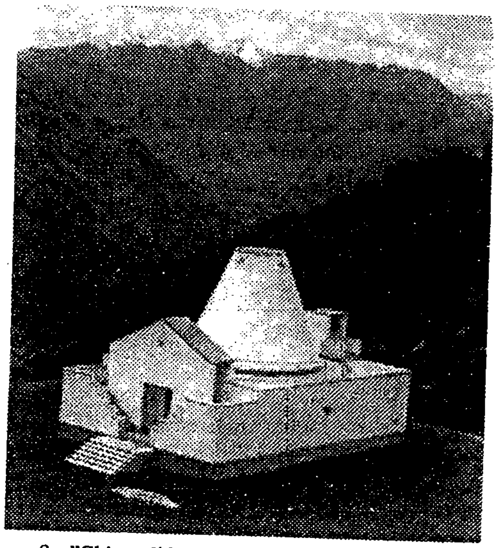


Figure 8 "Chiesa di Nostra Signora di Fatima" in Giova (viewed from north-east).

6.2. Data acquisition

A Canon CI-10 colour still video camera with a 9 mm lens was used to take the images. It employs a CCD image sensor of 8.8 by 6.6 mm² with nearly 380'000 sensor elements and records the images on still video floppy disks. The digitized images have a size of 508 by 466 pixels. This results in a pixel spacing of 15.3 µm in horizontal and 12.9 µm in vertical direction.

The camera arrangement was restricted by the dimensions of the church (14x10x10 m³) and the terrain on which the church is located (see Figure 9). A steep slope to the south and the west of the church make an ideal camera arrangement for photogrammetric tasks impossible. Thus a stereo pair was taken of the north and east facade each, and three images had to be used to cover the west and south facades due to the smaller object distances.

The reference data for the photogrammetric network was determined by theodolite. Therefore 20 targets were fixed on the facades of the church and used as control points. Each facade with the ideal camera arrangement shows four targets and each facade with the non-ideal arrangement shows six targets.

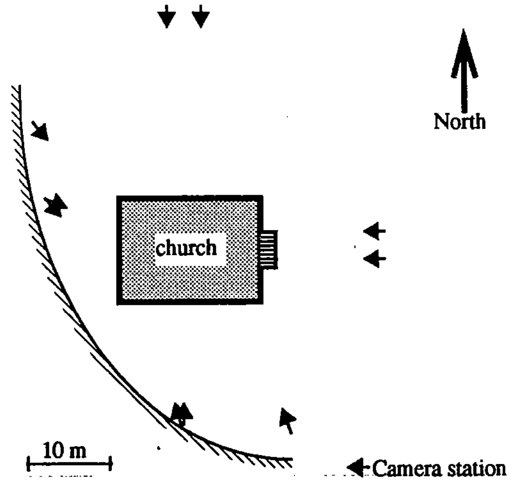


Figure 9 Object and camera configuration.

6.3. Photogrammetric analysis and results

To obtain precise calibration parameters for the camera a testfield calibration was performed beforehand. The following 10 additional parameters were determined: three parameters of the interior orientation, a scale in x-direction, a shear, and parameters for the radial and decentering distortion.

First the image coordinates of control points and architectural features have to be measured. This was done with the measurement techniques described in section 5.

The three-dimensional object coordinates were computed with a bundle adjustment using the geodetically determined control points and the calibration parameters from the testfield calibration.

Figure 10 shows a plot of the results in AutoCAD, which is used as a CAAD-system. Up to now the data transfer from DEDIP to AutoCAD has only been solved rudimentary. The results which the photogrammetric processing system delivers are 3D-coordinates of single object points. Topologic information must be added interactively by an operator on the screen. The three-dimensional object coordinates and the topologic information are automatically written into an ASCII-file, which can be read by an AutoLISP-program. The automatic generation of topological information is part of the future work.

The precision of the photogrammetric analysis is analysed with two methods. First the theoretical precision of object coordinates was determined with a bundle adjustment. The results indicate that a precision corresponding to 1/3rd of the pixel spacing in image space was achieved. The theoretical precision of the object point coordinates is 2.2 cm within the plane of each facade, and 4.0 cm in depth. The second method compares distances of the CAD-model to the corresponding distances of the construction plan. Thirtyseven architectural relevant distances, ranging from 0.5 m to 13.8 m, were chosen. The average relative

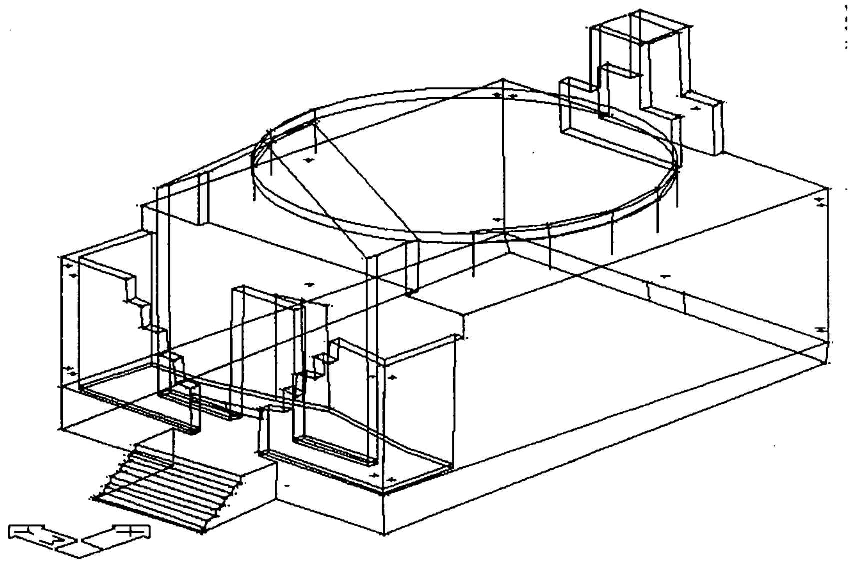


Figure 10 Results of photogrammetric analysis, represented in AutoCAD.

distance error between CAD-model and construction plan is 0.5% or 1:200. This analysis includes all deviations of the actual building from the plan. But it agrees very well with the theoretical precision of object coordinates. There a distance of 10 m can be determined with a standard deviation of 5 cm.

These results are indeed very encouraging considering the low resolution of the still video camera used. The results are also only of an initial nature as a detailed analysis with other measurement techniques is being performed.

7. CONCLUSIONS AND OUTLOOK

An overview of the digital system for Architectural Photogrammetry being developed at the ETH Zurich was given. Some of the basic measurement methods to determine geometric primitives were described. These methods can be extended in such a way that the operator can select feature classes to be measured. A priori information on each feature class can be used to support the operator. Such a system would provide a high level of automation as compared to existing measurement approaches. A major problem to be solved is the connection of semantic information to the three-dimensional data. To solve this problem an interaction between a Digital Photogrammetric System and a CAAD-system is conceivable and desirable. The system could furthermore be supported by information from a CAAD-system and/or an expert system. This includes knowledge on architectural styles, the construction of features, and objects build of several lower level features. Measurement routines adapted to special characteristics of features could be selected automatically. The data representation would therefore ideally be performed in a format easily convertible to that of a CAAD-system. The features already measured could be used to reconstruct the object through CAAD and to support the interactive measurement and/or guide the automated recognition and measurement through visualisation.

8. ACKNOWLEDGEMENTS

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Implementation of GIS Technology to Architectural Photogrammetry

Wednesdey, October 2nd, 1991, 17:00 - 18:00

Chair: M. Carbonnell

A DIGITIZED INFORMATION SYSTEM FOR THE DOCUMENTATION OF MONUMENTS

by

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Abstract

In this paper an extended description of a digitized information system's philosophy for the documentation of monuments is made. This system is capable of handling all kinds of graphical and non-graphical information for a specific monument. The structure of the system is described in detail and various methods of data input are discussed. Lastly, reference is made to an attempt of using this system for a monument in Thessaloniki in order to gain experience for the generalization of the use at town or country level.

KEY WORDS: Monuments, documentation, GIS

1. INTRODUCTION

The task of creating an archive to record all-available information is a major factor that helps the documentation and the future restoration of a monument. Under the term "documentation", we mean the recording, supplementing and filing of the existing material about the architecture, geometry, history, age, changes and use of a monument and its surrounding environment. This material may come from different sources, may be gathered in different ways and it is of great importance for many scientists. Under the term "monument", we mean any structure with prominent archaeological, architectural, historical or cultural interest. According to this definition there can be many monuments in countries with a rich historical and cultural background, as Greece.

Frequently this large number of monuments and the variety of shapes as well, are a significant problem for the preservation of the historical and architectural heritage (Zahopoulou et al., 1986). Many agencies and individual experts provide support in monument documentation and maintenance and have established a considerable volume of material. On the other hand, this material is usually scattered among various branches of the civil service and personal libraries, and it is not always kept in the most suitable conditions. Consequently, the main problem lies in the inability to study the existing material and, by extension, in the neglect which is the fate of work and research carried out laboriously and with intellectual effort.

In this spirit, the best solution may be a Geographical Information System (GIS) (Onsrud and Dansby, 1989); a system of computer aided tools for the digital collection, storage, research, analysis, transformation and production of spatial data about the real world, in which representations of measurements and non-graphical data are combined for a series of specific aims and goals. This may be achieved by the use and collaboration of the proper software and hardware (Doukas and Savvaidis, 1990).

Such a digitized information system can very well be used for monument documentation given that it is adapted to the specific needs of the problem's frame. The structure of this system will be discussed in the next paragraphs.

2. STRUCTURE OF A DIGITIZED INFORMATION SYSTEM FOR THE DOCUMENTATION OF MONUMENTS

The ultimate aim is to design, feed and supplement a relational database which will form the nucleus of the corresponding GIS containing all the information, in whatever form, that is connected to a specific monument. The structure of this system depends on the different categories of information that have to be entered into and the aims put by the end-users. GIS systems work in a dynamic way. Software (S/W) consists of different programs and utilities performing different tasks (modular programming and structure). All subprograms can work independently. There is much freedom for GIS improvements and modifications (in S/W and hardware-H/W). Theoretically the only limit in this procedure is the capability of H/W-S/W itself.

A GIS application for the documentation of monuments may contain the following basic categories of information (fig. 1):

1. General information about the monument.

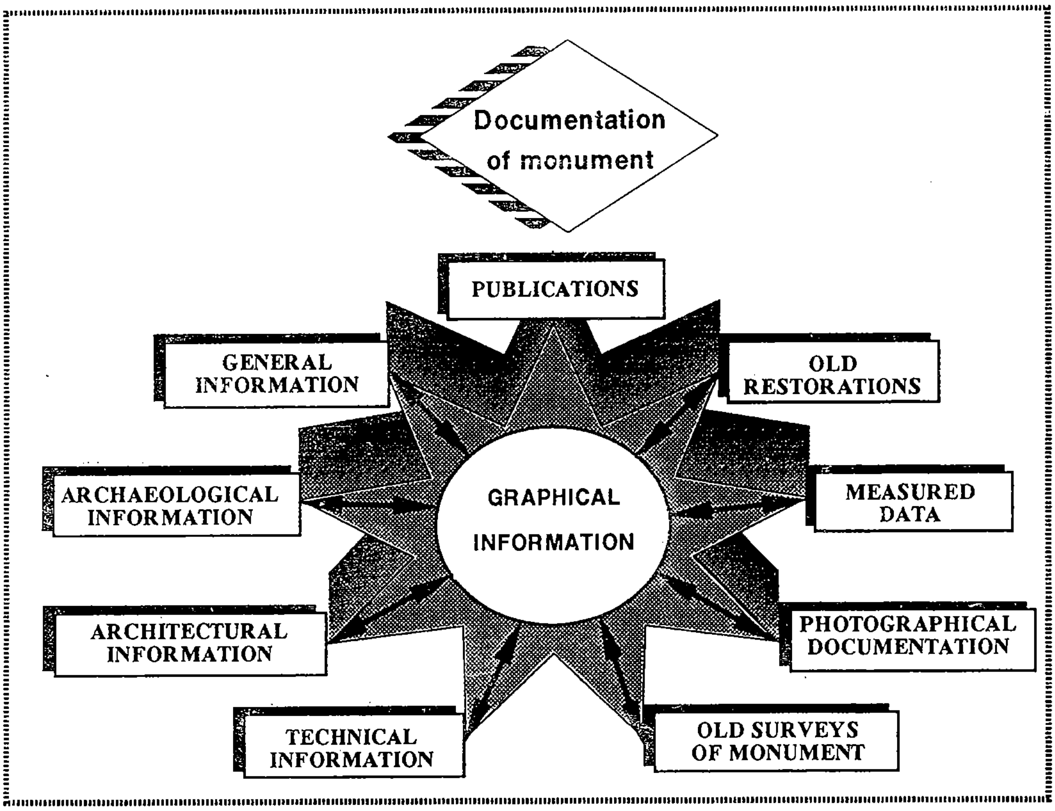


Figure 1. Basic structure of a digitized information system for the documentation of monuments

In Table 1 the procedures leading to the development of a GIS are shown (Harrison and Dangermond, 1989).

2. Archaeological information.

TABLE 1. GIS LIFE CYCLE

LIFE CYCLE	Tracks and Activities: DESIGN	ACQUISITION INSTALLATION	DATA BASE	APPLICATIONS	TRAINING SUPPORT
❶ Feasibility Assessment	•Orientation •Needs •Requirements •Cost and Benefit •Perspective				
❷ Design and Procurement	•D.B.* design	•HW/SW** Specif/tions			
	•Application definition	•Tender documents	•Physical D.B. design	•Specifications	
	•HW/SW Concept	•HW Vendor Contracting	•Pilot study	•Prototype creation	
	•Organization	•HW/SW Acquisition			
❸ Implementation			•Data standardization		•User training
	•Impl.ementation strategy	•HW/SW Installation	•Data conversion	•Application creation	•Administrator training
		•System integration	•DB/Library creation	•Documentation	•Programmer training
	Funding and Financing strategy	•System programming	•Product creation		•Application training
❹ Operations and Maintenance					•Ongoing education
		•System upgrade	•Update procedure definition		•Contracted support
			•Service bureau to users	•Application enhancement	•Onsite support
					•Funding program

Note: * HW/SW = Hardware/Software ** D.B. = Data Base

3. Architectural information.

4. Technical information.

5. Information about old and planned restoration campaigns.

6. Measurement data.

7. Photographical documentation.

8. Information about old monument surveys.

9. Publications about the monument.

10. Graphical information of different types.

From the above stated categories of information, (1) to (9) are non-graphical or descriptive information while reference to maps, diagrams, sketches, digitized photographs, slides and videos involve graphical information (category (10)).

The database fitted to the specific GIS should combine the capacity to handle graphical information with the capacity to handle descriptive information and with the capacity to structure topology and models for the correlation of data from one category to another.

This requirement presupposes the presence of powerful graphical operations (input-handling-creation-production), a suitably-structured database of descriptive information (storage-retrieval algorithms-response time) and a powerful S/W package adjusted and adapted to the specific requirements and needs. Usually, the S/W has a graphical editor with full 2D- and 3D-drawing capabilities, raster graphics handling routines etc.

Output units other than conventional (printers, plotters etc.) can be used. Results can be obtained on slides, audio-visual devices, video tapes etc.

Animation techniques for the representation or the simulation of events could enhance dramatically the system's potential resulting benefits like:

- Representation of events with time at different speeds.

- Representation of events that never occured, or occured at an earlier epoch, or it seems impossible to occur.

- Detection and preservation of events for further study.

- Study of picture frames or elements for maintenance purposes.

- Comparison of events that occured at different epoches (or even different places).

The philosophy of the structure of the GIS in combination with its S/W-H/W capabilities has to be ready to implement (now or in the near future) multimedia techniques and applications (i.e. interactive information manipulation based on computers and audio-visual means).

The multimedia era is already present in many fields with extraordinary results opening new horizons for research and education (Bellas, 1989).

A brief description of the earlier mentioned GIS categories of information for the documentation of monuments is to follow.

2.1. General information about the monument

In this category basic data about the monument are included (fig. 2). Such data are the

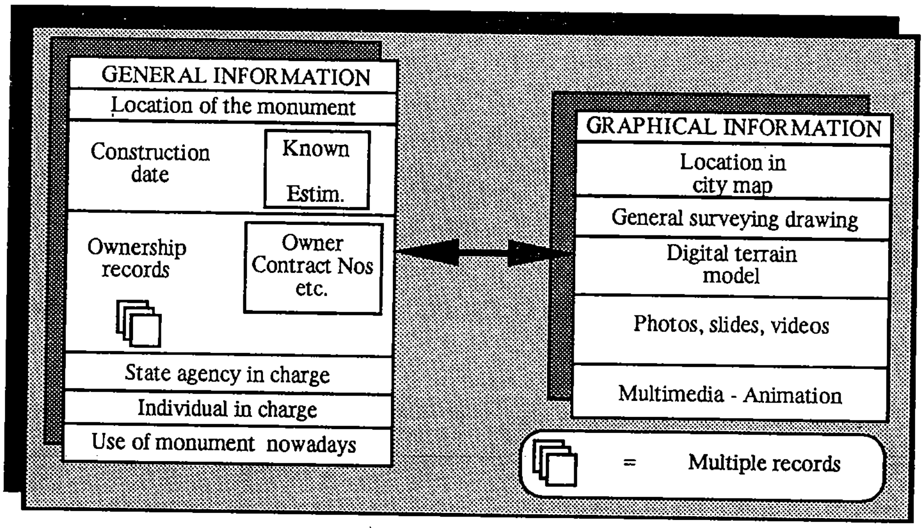


Figure 2. Correlation of general information to graphical information

location of the monument, the estimated (or known) time of construction, ownership records, the state agency responsible etc.

These descriptive data are correlated to different maps of the area, a general surveying drawing and the corresponding terrain model. General photos, slides and videos can also be used here.

2.2. Archaeological information

This category of information contains brief but complete data about the history of the monument, the archaeological excavations carried out at the spot (Zahopoulou et al., 1986, Savvaidis et al., 1988) with details about the chief archaeologist, year of excavations, important findings and other similar and worth-mentioning information (fig. 3).

Graphical information correlated to the above stated descriptive information includes general and detailed excavation plans and sketches.

A lot of valuable information can be produced by using the GIS tools (multi-layered drawing, colors, libraries of symbols etc.). Photographs or slides of excavation phases and findings can be digitized and entered into the system. Such data can be processed and printed/plotted in conventional ways or can feed dedicated multimedia applications (representations, simulations, tour of procedures, educational scenarios).

2.3. Architectural information

Architectural information (combined with archaeological data) is probably one of the largest categories of information in the GIS under consideration.

Descriptive data in this category include information about the building materials and techniques, foundation, masonry, wooden-stone-marble structures etc.

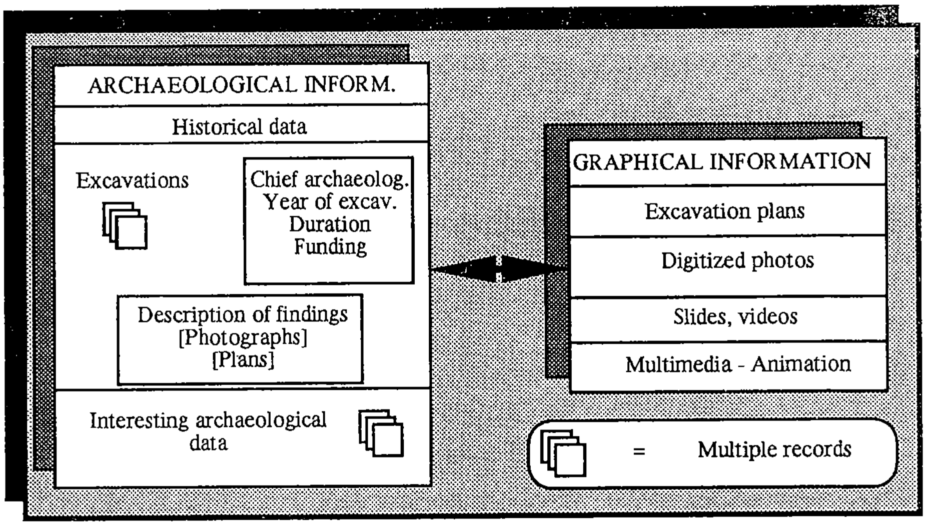


Figure 3. Correlation of archaeological data to graphical information

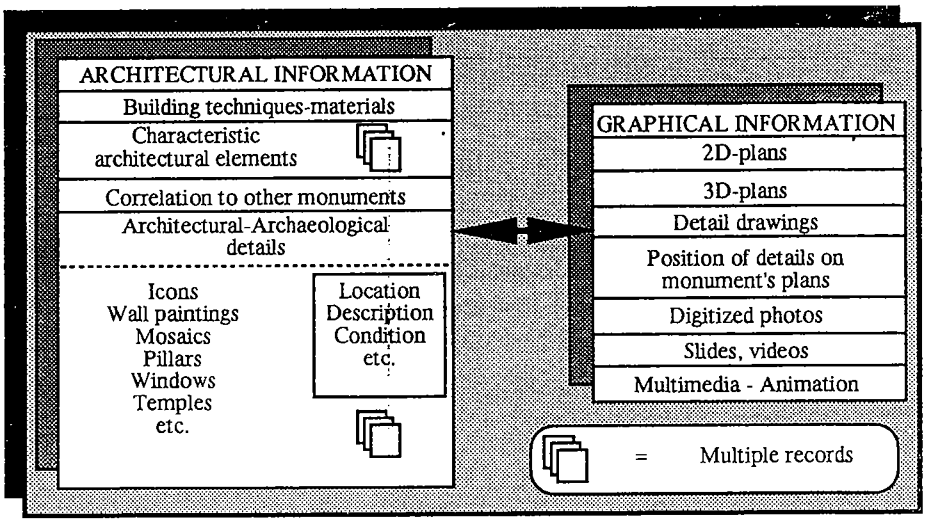


Figure 4. Correlation of architectural information to graphical information

Brief description of other architectural elements of interest are also entered into this category (fig. 4).

The corresponding graphical information contains digitized 2D- and 3D-plans of the monument, computer generated shadow and/or color models, drawings of interesting and characteristic details, digitized photographs etc.

2.4. Technical information

This category of data is supplemented with particulars from studies of the static and dynamic condition of the monument. The information can contain the type of foundation, existing damage and cracks, deformations, settlements etc. Furthermore, information about all-existing utility networks, fire-protection, heat-sound insulation is given here (fig. 5).

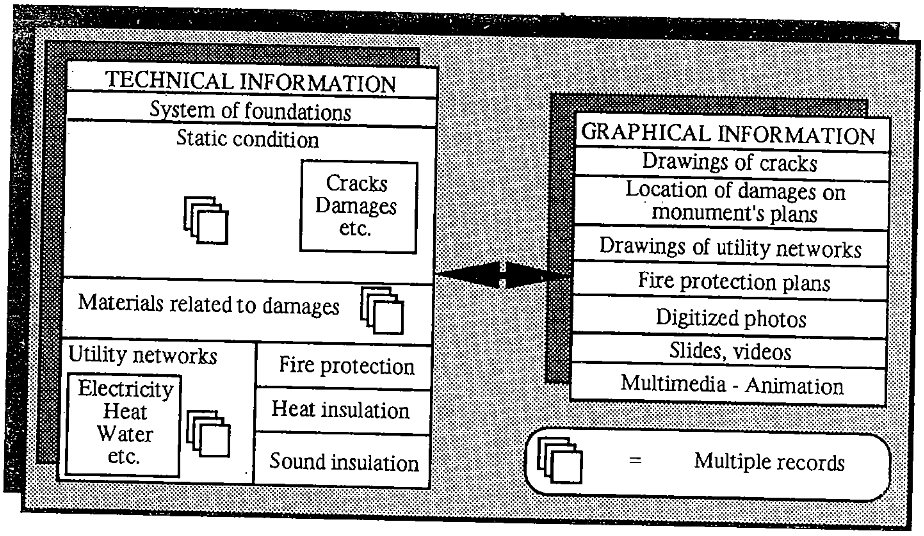


Figure 5. Correlation of technical information to graphical information

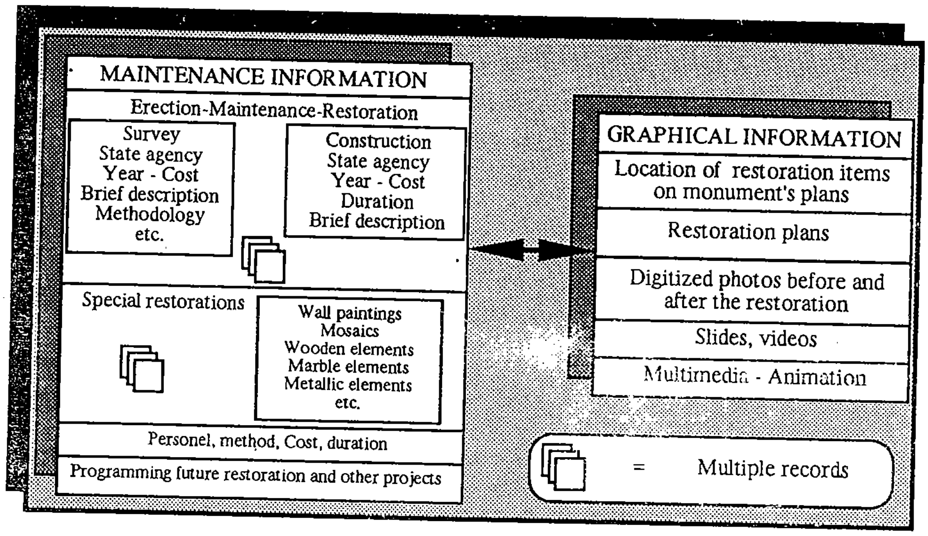


Figure 6. Correlation of information about past restoration campaigns to the graphical information

A lot of graphical information can be entered into this category containing detailed drawings of cracks, the position of damages on the monument plans, drawings of the utility networks, digitized photographs of places with damage etc.

The combination of descriptive and graphical information can result into valuable conclusions about the static and/or dynamic condition and behavior of the monument. Restoration studies will then become easier and more efficient.

2.5. Information about old and planned restoration campaigns

This category of information contains the available data about maintenance and restoration works carried out in the monument in the past. Input data include both elements of the

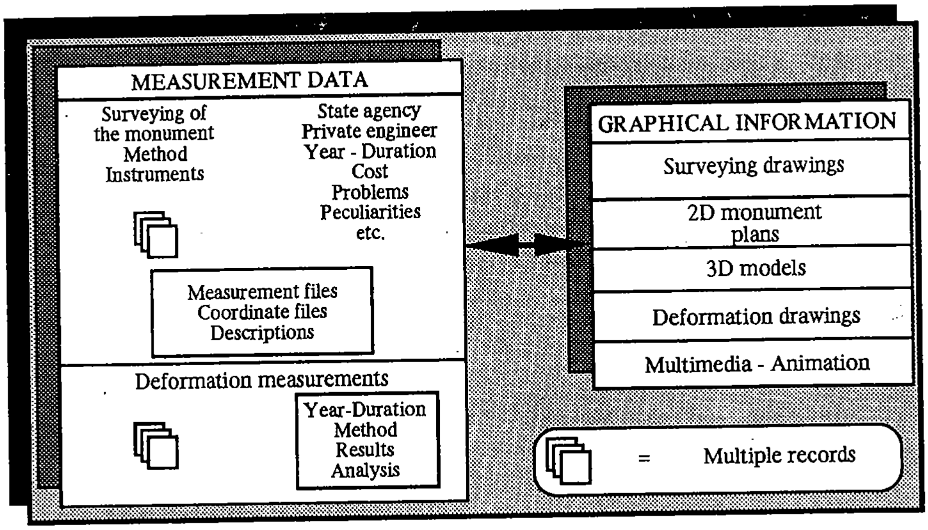


Figure 7. Correlation of measurement data to graphical information

studies and the works done. Special attention is paid to restoration and maintenance of mosaics, wall paintings, portable icons and other elements with archaeological, religious or architectural importance. Organization schedules of future works may be entered into this category as well (fig.6).

The corresponding graphical information contains restoration plans, position of restorated items on monument plans etc.

2.6. Measurement data

This category of information includes all geometry data that are the base of the development of graphics. These data are coordinates of points (measured or digitized). All files of measurements and point coordinates are included here (Badellas and Savvaidis, 1981, Zahopoulou et al., 1986, Savvaidis et al., 1988). Part of the measurement files may include deformation data of the monument and the surrounding area measured at different epoches (Doukas, 1988, Doukas et al., 1990, Badellas and Savvaidis, 1990) (fig. 7).

The descriptive information is related to virtually all digitized drawings of the monument. Animation techniques can play an important role in the study of the monument's deformations.

2.7. Information about past surveying campaigns

In this category, information about measurements of the monument carried out in the past is included. Digitized old maps and diagrams contribute to the study of the monument's shape (fig. 8).

2.8. Photographical documentation

This category of information includes digitized photos, slides or special video films of aspects of the monument, of exterior-interior details and of the general environment in which it is located.

With suitable equipment and commercially available S/W, it is possible to compile selected digitized photographs with digitized plans of the monument resulting into the reproduction of plans with photographical detail on ar-

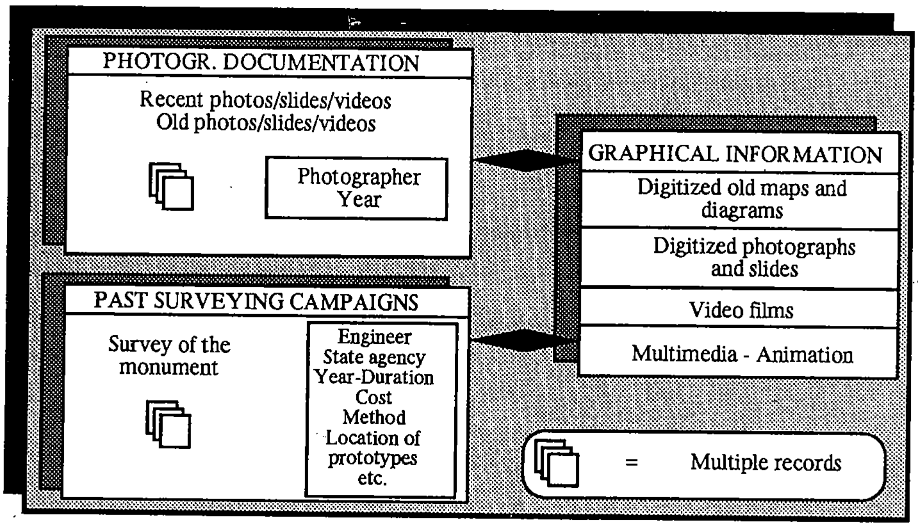


Figure 8. Correlation of photographical documentation and data of past surveying campaigns to graphical information

chitectural scales (fig. 8).

An important and very promising dimension of this category is that it is possible to draw attention to and show specific parts of the monument as a whole, by using special data processing to produce integrated audio-visual shows (multimedia applications) for education or even tourism. Being in this revolutionary dimension, the creation and publication or books, calendars etc. is easy feasible if we recall the desktop publishing potential.

3. DATA INPUT - OUTPUT

Given that the digitized information system will be fed with a multiplicity of data of various categories, it has to be able to accept data by a variety of methods and means.

Descriptive information is entered into the database by using S/W based procedures (keyboard input, read-in ASCII files etc.) (Doukas and Savvaidis, 1990).

Old maps, maps and all drawings not based on measurements, can be entered into the GIS through digitizers or CCD optical scanners. When using optical scanning methods, the resulting digitized images are in raster format. Special S/W is needed to transform them into vector format in order to correlate them to other digitized vector plans. Optical scanning can be also used for the digitizing of photographs and slides while the use of video-films calls for special S/W-H/W (interfaces, frame grabbers etc.).

The creation of the graphical database containing the 2D- and 3D-plans of the monument is performed with the use of special dedicated graphics S/W (CAD) based on measured data. Measurement of the monument results into coordinates of discrete points used for drawing of plans, faces, sections, 3D models etc.

Surveying a monument can be made in different ways:

A. The classical geodetic method with measurement of triangulations, traverses and polar coordinates of detail points (Zahopoulou et al., 1986, Savvaidis et al., 1988).

B. The combination of classical geodetic method with 3D-measurement systems incorporating electronic theodolites, servotheodolites, laser units and CCD cameras.

C. The classical photogrammetric method.

D. The simpler photographical-photogrammetric method incorporating an almost ordinary 35mm camera with grid and the special S/W.

The few last years new experimental methods for the measurements of buildings (and monuments) have been introduced, such as:

• optical scanners of large objects with the use of a laser beam (Wehr, 1989).

• 3D-systems using two or more specially designed CCD cameras (Riechmann, 1989).

In order to achieve maximum benefit, the GIS must have the capability of using different interfaces to accept data from new sources or new instruments and methods.

The system must provide output to various units for different scopes. Indicatively, it can make possible:

º The production of plans (or maps) of various types, on transparent or other kinds of paper.

º The production of reports on screen or on paper.

º The production of slides.

º The production of video films (at an advanced stage of the system's operation).

4. PRINCIPLES AND DESIRABLE FEATURES OF THE GIS

The accomplishment of the above mentioned requirements presupposes the presence of powerful graphical features (input-handling-production) and a suitable structured database for non-graphical data (storage-retrieval algorithms-response time). Furthermore, the digitized information system for monuments must also meet the characteristics of the generalized GISs, such as data compression solutions, supporting of many users and tasks, levels of user access, back-up etc. (Doukas and Savvaidis, 1990).

The philosophy of what are called open-ended systems should be applied to the database, governed by the following principles:

① The principle of uniformity and correlation: Under this principle, the various data are arranged in uniform groups with the common characteristic always being sought in its simplest form. Subsequently, the various correlation models can be developed separately as they emerge from the needs of the users whenever.

② The principle of data format knowledge: Under this principle, it becomes feasible to use (to incorporate into the database) all the most recent technological achievements in data processing and storage mechanisms. In this way it is possible to make full use of recent developments without being forced to discard any of the work done in the past.

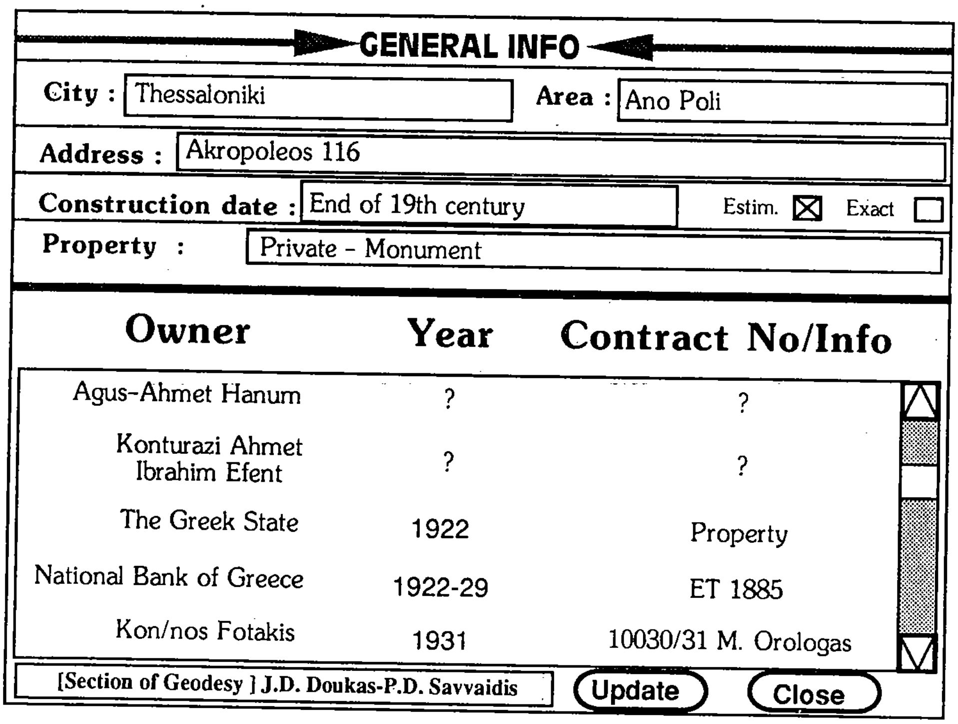
By seeking to use the principle of uniformity and correlation referred to above, the GIS will be able to respond very rapidly to questions seeking information or to decision-planning questions (data queries). In this way the GIS becomes a powerful tool, not only for the documentation of the monument but also for the complete study of all-available data and for the programming of future restoration projects.

5. APPLICATION OF THE DIGITAL INFORMATION SYSTEM FOR A SPECIFIC MONUMENT

The Section of Geodesy (Department of Civil Engineering, Aristotle University of Thessaloniki) has started the development of a digitized information system for the documentation of monuments based on the principles and the philosophy described above. The system is planned to work under the two most widely used operating systems for personal computers (MS-DOS® and Apple Macintosh®).

An example of the performance of this GIS, concerning the manipulation of both graphical and descriptive information, is described in this paragraph. The example deals with an old building located at the upper town of Thessal oniki (Ano Poli), 116 Acropoleos Str. The building was constructed during the end of the 19th century, a period when the place was occupied by Turkish invaders.

All information about the monument's history was found in the archives of Vlatades Monastery and in the old Turkish cadastral books dated from 1906. It is maybe worth mentioning that in these books (ESAS and HULASA) the Turkish authorities recorded a lot of data about the properties of Thessaloniki. Other information regarding the different owners of the building were found in Greek state agencies.


GENERAL INFO

City : Thessaloniki   Area : Ano Poli

Address : Akropoleos 116

Construction date : End of 19th century   Estim. ☒ Exact ☐

Property : Private - Monument

Owner	Year	Contract No/Info
Agus-Ahmet Hanum	?	?
Konturazi Ahmet Ibrahim Efent	?	?
The Greek State	1922	Property
National Bank of Greece	1922-29	ET 1885
Kon/nos Fotakis	1931	10030/31 M. Orologas

[Section of Geodesy] J.D. Doukas-P.D. Savvaidis   Update   Close

Figure 9. General information about building's location, owners etc.

Descriptive information about the building includes historical background, building techniques, building morphology, damages and planned restoration campaigns.

The building was measured in detail by using geodetical methods. A photographical survey was carried out as well (Kyriazopoulos and

Safaridou, 1990). Files containing the coordinates (x, y, z) of all detail points and files containing scanned photographs were also created from the above data.

The H/W requirements are met by an IBM® AT compatible PC (1Mb RAM, 40 Mb hard disk, co-processor) or an Apple Macintosh® (2Mb RAM, 40 Mb hard disk, co-processor).

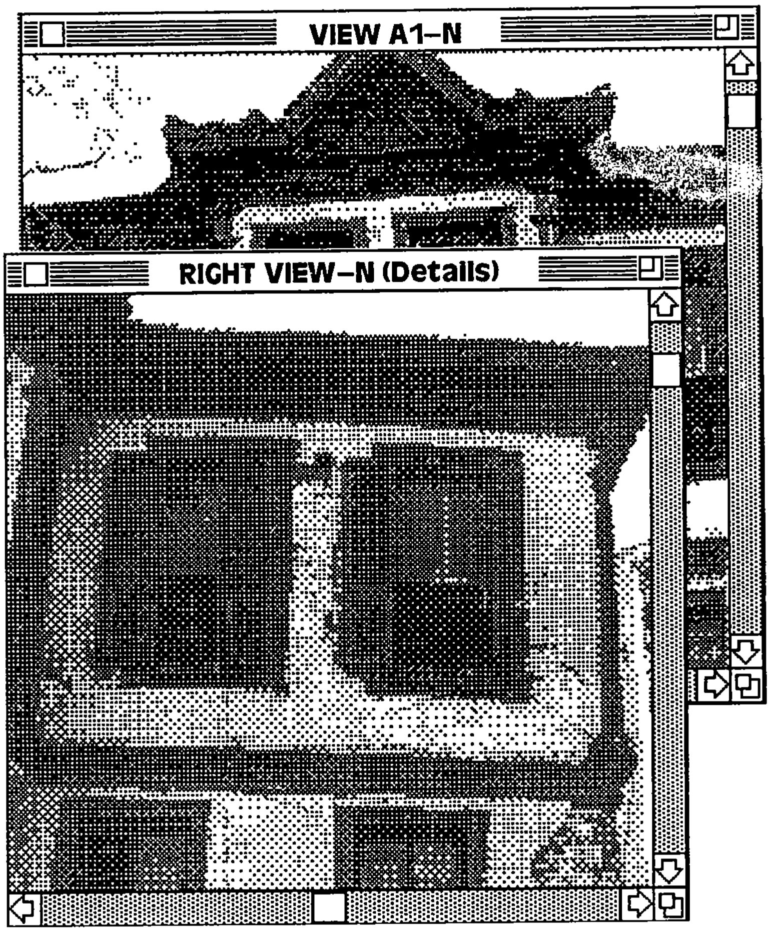


Figure 10. Multiple windows with digitized photographs of building's views

Figures 9 and 10 contain sampled screen dumps which show the way the available information is displayed. Multiple windows are available on the computer's monitor for the presentation of both graphical and descriptive information. An example of this system's capability is shown in fig. 11 were multiple windows illustrate the phases from a digitized photograph and building's drawing after its geodetic measurements to the final output of the retouched view.

An optical scanner with 300 dpi resolution was also used.

The S/W requirements are met for the present by commercially available packages (databases, CAD, image processing etc.) which are under tests in order to obtain the best combination for each computer platform. On the other hand, several utility programs are under development in order to complete a user friendly working environment.

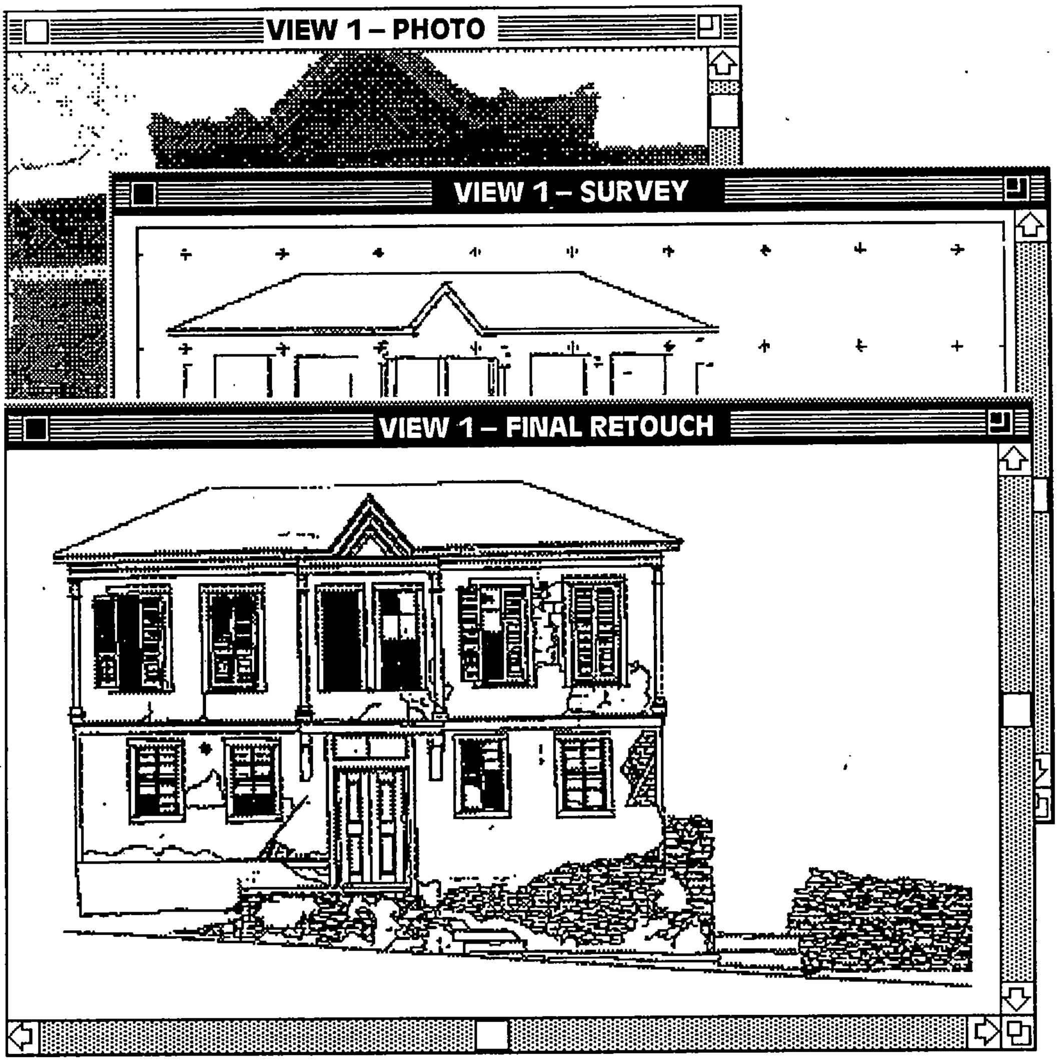


Figure 11. Multiple windows showing phases, from digitized photographs and drawing based on geodetic measurements, to the final building's retouched view

6. CONCLUSIONS

The use of a properly adapted GIS for the documentation of monuments can be of great assistance to the study and processing of all-available data. The GIS is a dynamic system and therefore, it can also be used for the continuous monitoring of all the changes on a monument.

The cost of H/W may be kept as low as the specific demands of the end-user permit. The cost of S/W is not high, compared to the benefits.

The cost effective procedure may indeed help the systematic research and the (re) organizing of restorations, a task which is impossible to be performed with conventional techniques.

GIS and multimedia-can also open new horizons for the documentation, education, research and the presentation of the cultural, architectural, historical and religious heritage.

The development of a low cost GIS described in the previous paragraphs seems to give very promising results. The integration of the system by entering into all-available categories of information is to be done. Such a system can be established for a single monument or a group of monuments with extraordinary importance. Experience derived from the extensive use of the system, after its completion, will lead to the organization of a larger GIS at city level.

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DOCUMENTATION OF CASTLES IN A SPECIAL G.I.S.

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1. Introduction

Although archaeological and architectural restitutions of monuments have undergone considerable developments and improvements over the years, they have generally been developed independently from each other isolated to a great extent from other activities related to each.Unfortunately, due to the lack of collaboration and interdisciplinary cooperation, the products of the various scientific approaches to a particular monument are usually scattered and extremely difficult to collect and use efficiently. Even more difficult is the collation and modification of the enormous amount of existing information arising from various sources for many practical reasons: e.g. matters of scales, reference frames etc. Many countries and institutions have already tried to face up to the problem by organising systematic archives related to monuments.

As was reported in an earlier C.I.P.A. meeting, the modern alternative answer is the creation of a Special Geographic Information System - G.I.S. A special G.I.S. not only constitutes an updated archive, making use of the highest degree of automation, but it allows the correlation of data and thus the creation and retrieval of new information as well. A G.I.S. is a combination of human and technical resources, together with a set of organising procedures, which result in the collection, strorage, retrieval, dissemination and use of land information in a systematic manner. The G.I.S. methodology has been developed, initially, for administrative and financial aid in urban planning and development, but recentrly it has been used for the efficient documentation and management of monuments.

In this respect, national, local and other special GIS´s, Byzantine, Classical etc have been developed. One such special system would be a system related to monuments. The structure of such a system would be complicated and very critical for its success. It could be established at a local level, especially in countries with many monuments, or at a district or national level. It could also be structured for particular subjects such as a GIS for the Church, Christian, Classical, Cycladic, Roman or Medieval monuments. A GIS based on particular subjects is more uniform and thus easier to establish and operate. A GIS based on districts is more diversified but the benefit of its operation has a more general appeal. It is not difficult to foresee that systems of both kinds will be operating in several countries. The integration of these systems will constitute the larger systems which will follow as a "second generation".

The proposal put forward by this paper is the establishment, in Greece, of a special information system containing the documentation of Castles. This is of national importance for the simple reason that previous archaeological activities in Greece have, over the years, tended to focus on classical and pre-classical monuments and castles-usually medieval; Venetian and Byzantine taking a very second place. For this reason, the documentation on castles is extremely limited, but they can, on the other hand, unlike other antiquities, serve a positive modern purpose as tourism or recreation centres etc. Presently, conference centres, research facilities, even prisons are making full use of suitably adapted castles.

This paper discusses the structure of an information system of such a kind and describes the first stage of a pilot project which is being developed in the Laboratory of Photogrammetry of the National Technical University of Athens. The system used counsists of

- referring to hardware: the cheapest instrumentation possible - e.g. Stereocord G2 connected to a PC AT286 for photogrammetric restitutions
- referring to software: AUTOCAD for the editing of analytical photogrammetric restitutions and digitized data, and selected sections of ARC/ INFO (PC version), which is a general GIS package.

As a pilot project, the castle on Acrocorinth was chosen. The main reason for this is that Corinth is wihtin easy reach of Athens. It proved to be a successful choice because of access to a wealth of material coming from two main sources / Carpenter & Bon (1936)/ and / Theodorou et al (1990)/.

2. Information contained in the Special GIS

The structure of the system follows the basic figure of all GIS´s (see fig.1).

After a thorough study of complex aspects and characteristics an efficient system may be planned. However in this early stage of structuring a GIS only a general analysis of the information to be contained is most important. This factor defines almost all the others. Determination of the kind of information to be contained is a specialised interdisciplinary and scientific task, demanding a detailed examination of all aspects of

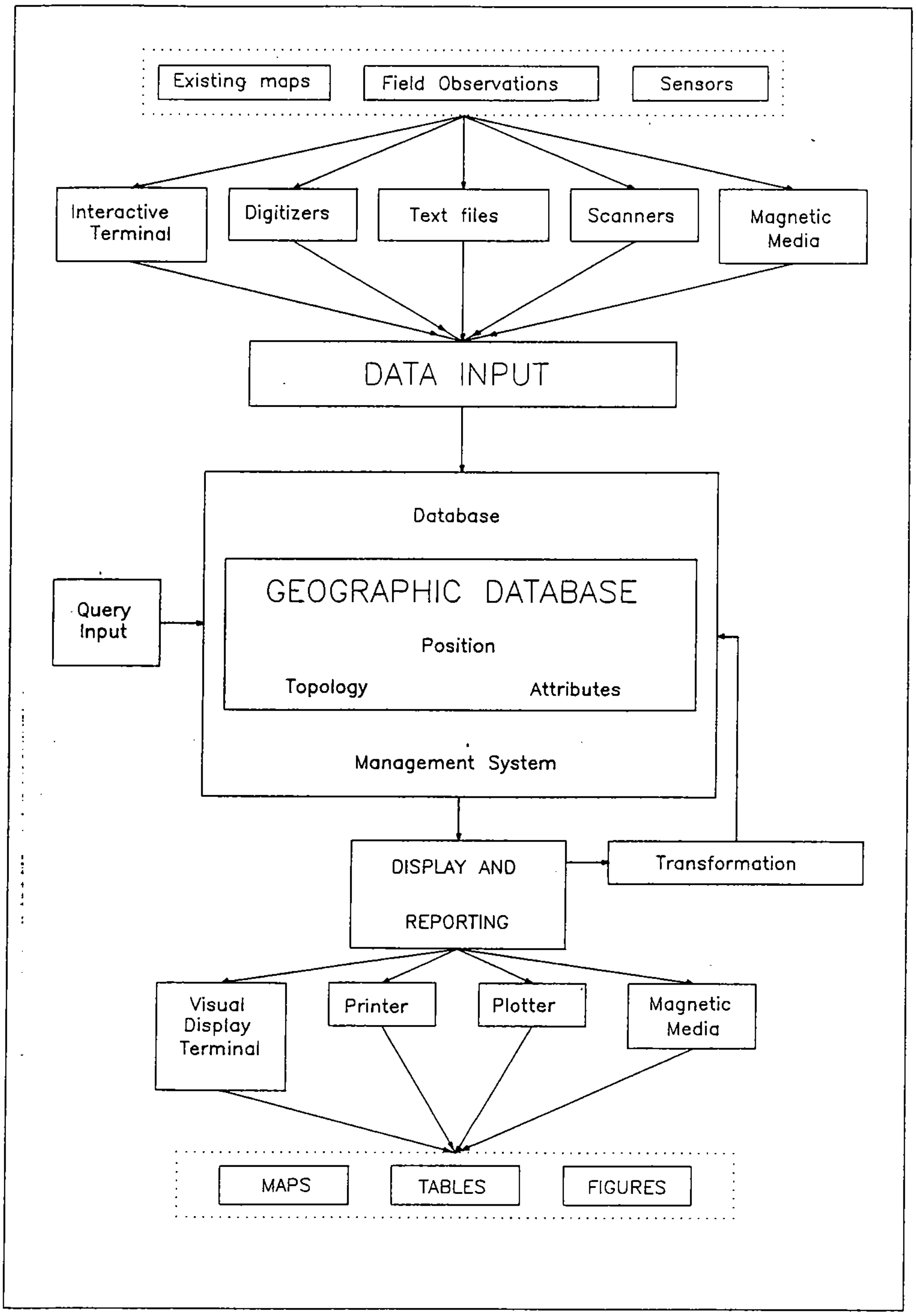

Fig. 1 Typical structure of a G.I.S.

GIS such as: hardware demand, man-hour cost etc.

According to the experience of the Laboratory, the following groups of recorded information were identified:

1. General information:	location of the monument, land use, ownership, administrative information, meteorological data etc.
2. Historical information:	Dates of constructions, occupations, battles, important visits etc.
3. Publications:	Books, reports, manuscripts etc.
4. Images:	Post-cards, photographs, aerial photographs, images from other sensors, video etc.
5. Measurements:	Topographical, architectural and technical measurements, surveys, maps, coordinates, digital terrain models etc.
6. Archaeological information:	Results of archaeological excavations etc.
7. Architectural infrormation:	Style of constructions, masonry, style of columes etc.
8. Technical information:	Building material, quarries, pedological, geological, utility networks.
9. Caltural information:	Languages spoken, fairs, population etc.
10. Pieces of art:	Ikons, statues, idoles etc
11. Restorations and interventions:	Dates of restorations and interventions, plans and surveys of restorations and interventions etc.

The data will be stored in digital and alphanumeric form in the data base which constitutes the heart of the system. A fundamental question concerns the data acquired from pictures and plans.

As the amount of data derived form an image is large and the number of pictures relating to a given monument profuse, powerful computers are needed. Peripheral scanning facilities are also needed for the digitizing of images, but as yet they are uncommon. Although, in the long run the handling of image data will become commonplace, it does not seem indispensible at the moment to have all images in digital form.

Similar reservations may be made in digitizing plans. The digitizing of all the plans of the monuments in a district is both time-consuming and expensive. Thus, for the time being, the digitizing should be carried out selectively.

The ability to use both raster and vector data is important, however, even in this early stage.

3. The pilot project

As has been already mentioned, the Castle on Acrocorinth was chosen. Southwest of the ancient city of Corinth rises the rock of Acrocorinth, an important mass of limestone, abrupt and isolated on every side, on the west a narrow and lower ridge connects it with more distant hills. It is the oldest castle in continous use in Greece after the Acropolis of Athens.

The circuit of the wall is about 3,000 m and the surface included 240,000 m^2. More information, distributed into the groups given above, is as follows.

3.1. General information

Acrocorinth is located southwest from Corinth. The coordinates of its centroid are:

X= - 8.150 m Y = 15.600 m

in azimouthal projection centered at:

$\varphi = 37^o\ 50'$ $\lambda = -0^o\ 40'$ from Athens.

The highest point is 575 m above sea level.

It belongs to the prefecture of Corinth and to the county of Ancient Corinth. Archaeologically it belongs to the 6th sector of Byzantine and Medieval Monuments, which has its central office in Patras and a local office in Ancient Corinth.

3.2. Historical information

Attack by Mommios who distroyed the north and west section.

The castle is first discribed in literature by Procopios, who reports about the king Ioustinianos 527-565 a.C.

8th and 9th century	: distructions by Slavic inventors
886-912 a.C.	: reconstructions by king Leon VI
1147 a.C.	: attack by Normands
12th century	: repaired by Byzantins
1210-1250	: Villeardoin
1250-1350	: Franks - John of Gravina
1358-1394	: Acciajuodi
1400-1404	: Knights of St. John
1458-1687	: Turks
1687-1715	: Venetians
1715-1821	: Turks
1821-	: Greeks

3.3. Publications

There are many publications referring to Acrocorinth. Some of them are given in the bibliography (1, 2 ,4 ,8, 9).

3.4. Images

There are photographs from amateur cameras, post-cards and pictures taken during excavations which require systematic classification. Only one of the references contains about 100 photographs! Also, there are many aerial photographs which cover the monument, the first dating from before 1936 and the rest taken periodically since then.

There exist coloured aerial photographs and satellite images from Landsat and Spot. Although no special investigation was carried out it is considered certain that several videos of the castle already exist.

3.5. Measurements

Topographic or any other kind of measurements do not exist. Yet, there are old sketches drawn from a cartographic view point (Fig. 2), which can be included into this group of information, and old topographic maps. The first map was made by Coroneli in the 17th century (Fig. 3).

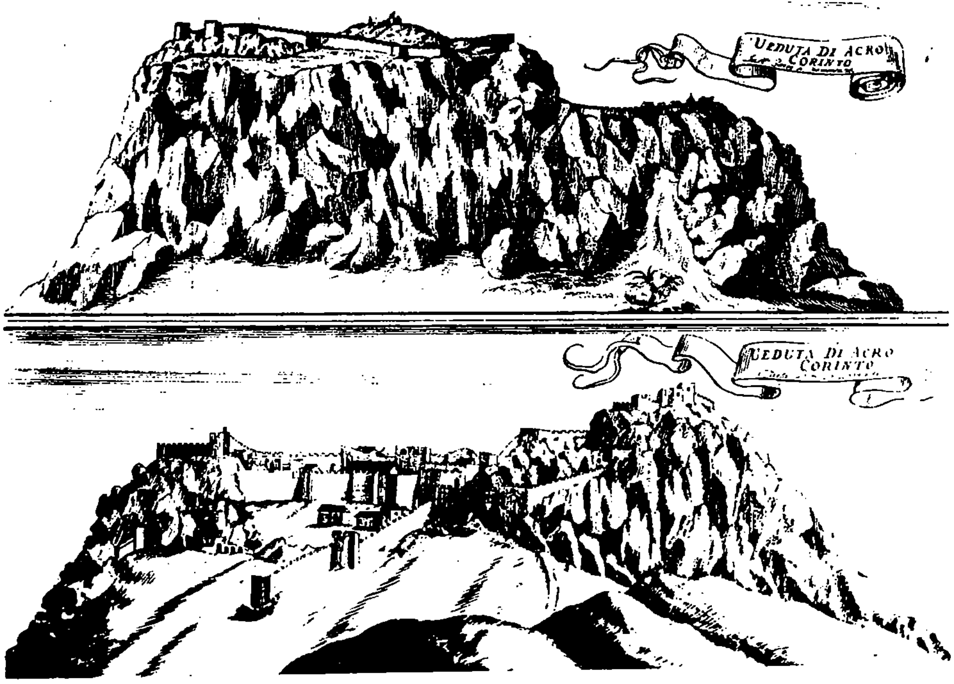

Fig. 2 Old sketches of Acrocorinth

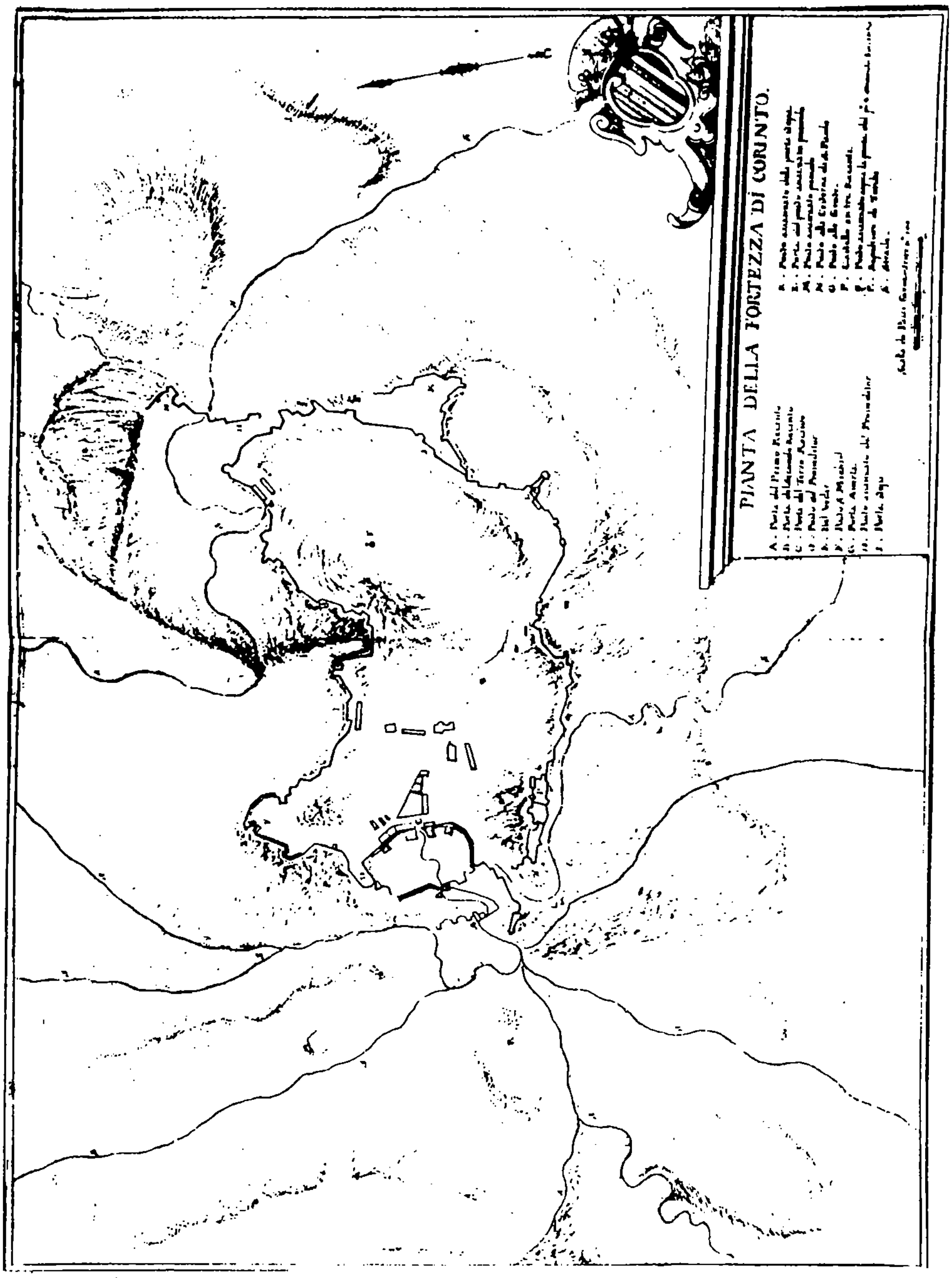

Fig. 3 A17th century Survey of Acrocorinth

The most complete survey of the castle was carried out in 1931 by Fritz van Schagen and Joseph Eigenman, at a scale of 1:1000 and was published in 1936. There are also numerous detailed surveys completed during excavations in about 1930.

The latest measurements are:

- the photogrammetric restitution of the three gates of the castle (Fig. 4) and
- the altitudes of the castle wall

excecuted by the Photogrammetric Laboratory of the National University of Athens and completed a short time ago. These digital data were properly combined with the data derived from the digitizing of

- the map (1:1000) of 1931 and
- the relevant sheet of photogrammetric diagram of 1: 5000, that cover the whole country,

so that a complete degital restitution of the planimetry and the altimetry of the area achieved.

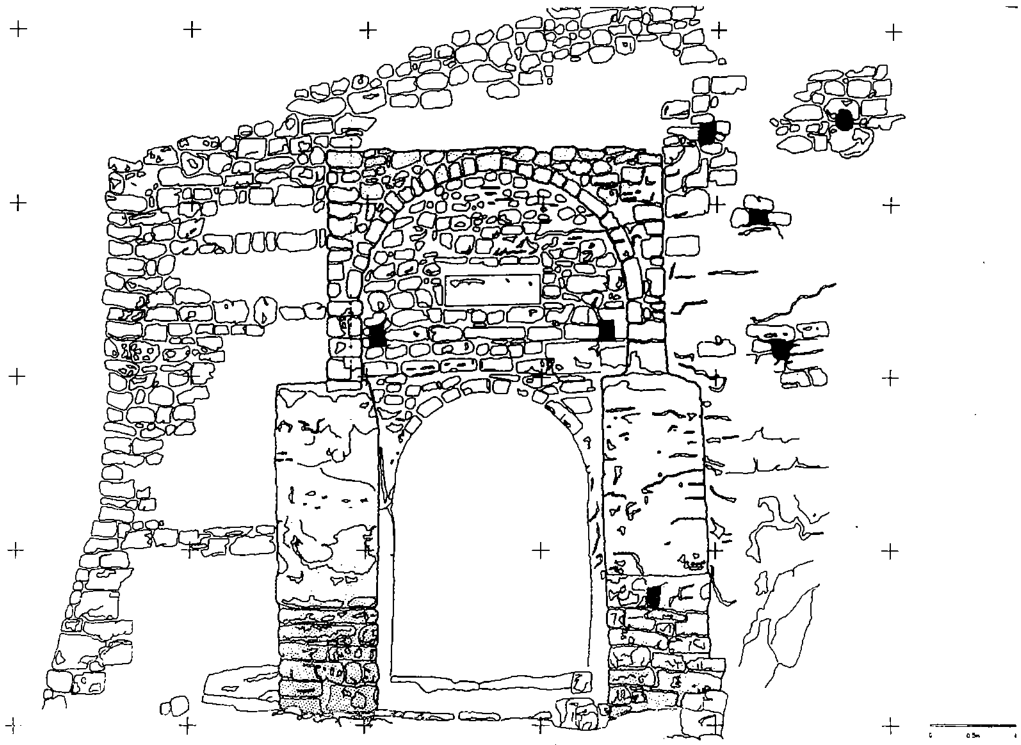

Fig. 4 First Gate of the Castle of Acrocorinth

3.6. Archaeological information

There is a great deal of archaeological information. The large blocks (up to 1.07x 0.92 m) characterised as megalithic imply that the first construction of the castle was carreid out by the end of 7th century b.C. and the beginning of the 6th century b.C. Other archaeological evidence shows constructions that are of the 4th century b.C. etc.

3.7. Architectural information

Plenty of architectural information is available: ancient Greek temples, paleochristianic churches, minarets mosques etc.

Fourteen types of masonries have been indetified by Theodorou et al (1990) and photographs and plans are given (Fig. 5)

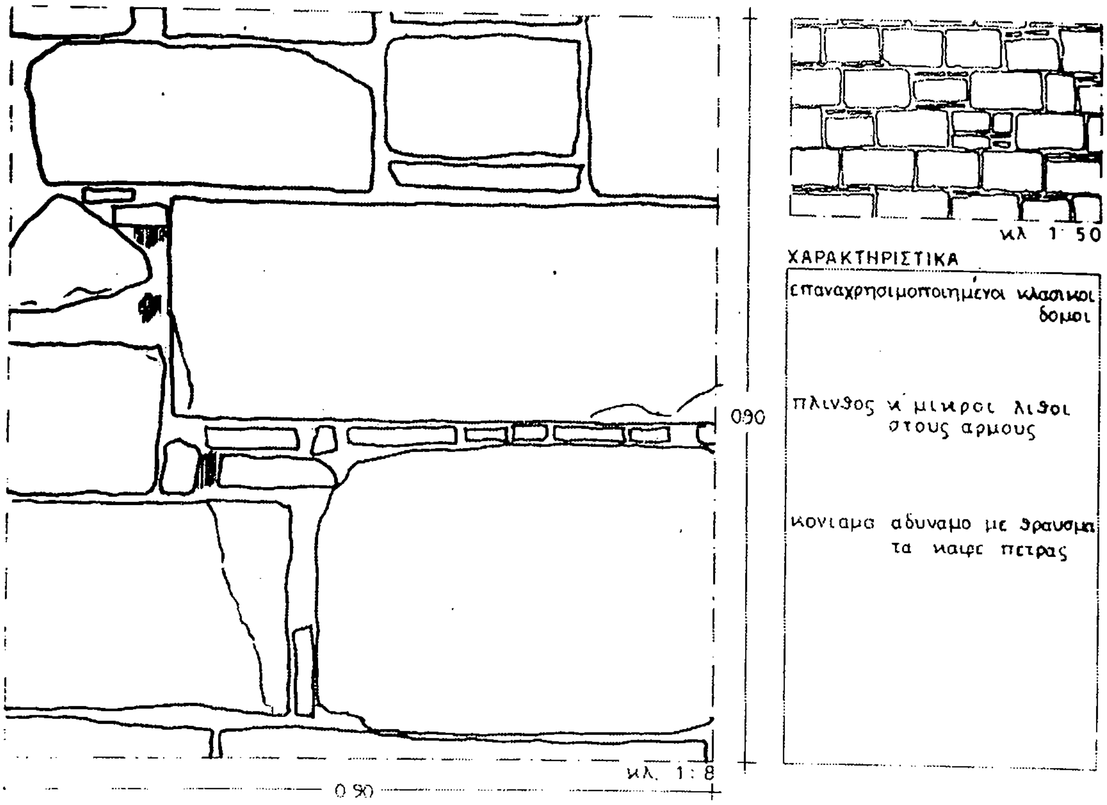

Fig. 5 Paleochristianic masonries

3.8. Technical information

There are many wheels, water tanks and a bridge which give much technical information.

Also a quarry has been indentified inside the castle and marked on the survey of 1931. There is much technical information related to the military function of the castle, such as the constructions for use of cannons.

3.9. Cultural information

Detailed analysis .even of the existing data will reveal a lot of cultural information. There are several sources giving information about the population of the castle at particular periods or the number of soldiers defending the castle in particular battles.

Also the saints that were mostly respected at the Castle are shown in the existing churches.

3.10. Pieces of art

Nothing came out through our research in that field.

3.11. Restorations and interventions

Since the castle has had a life of about 27 centuries, many rebuildings, interventions and modifications have taken place through that period.

In 146 b.C. the castle was destroyed by Mommios. It was rebuilt in Roman times following the classical foundations and using the old material. This is the reason

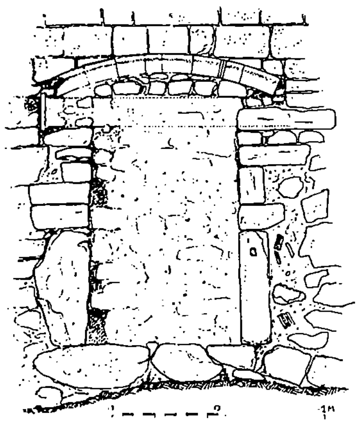

Fig. 6

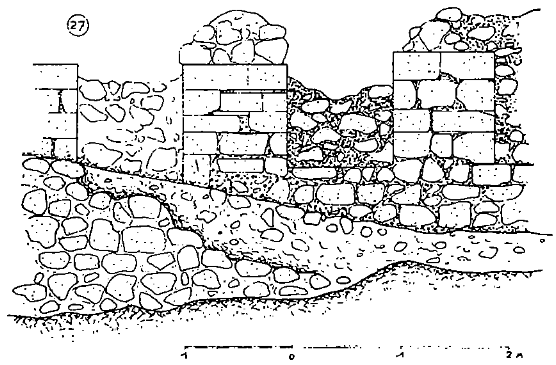

Fig. 7

why the study of the castle is greatly complicated. There were new parts of the castle added such as the two new lines of defence of the west side of the castle built by the Franks in 13th and 14th centuries. There are also minor interventions such as the walled-up gates (Fig. 6) or the rebuilt of wall-tops (Fig. 7).

Of particular interest are the plans for future interventions, such as the plan for new pedestrian paths (Fig. 8), which were derived through ARC/ INFO programme by combining the analytical topographic information of the area with the proposal mentioned by Theodorou et al (1990).

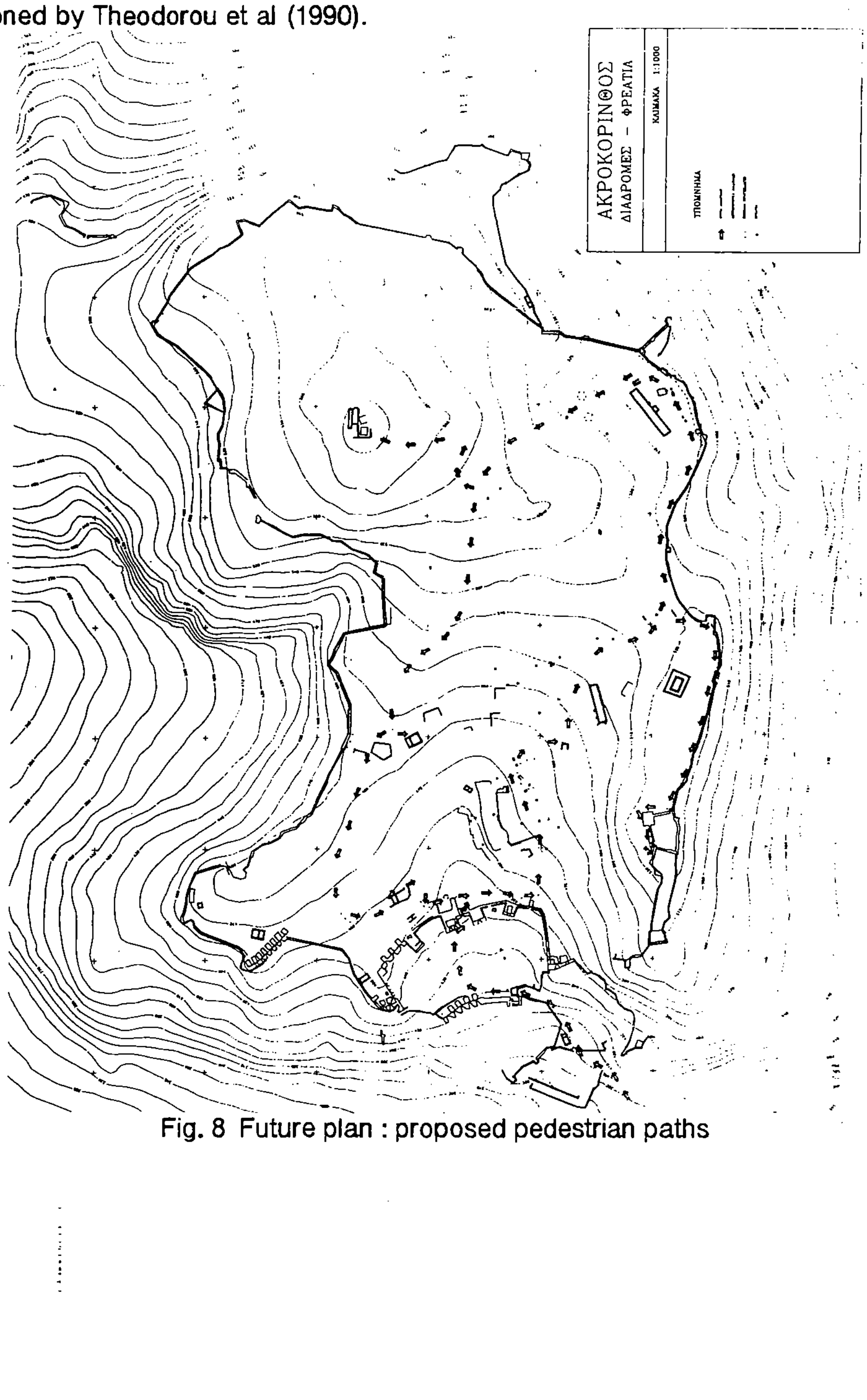

Fig. 8 Future plan : proposed pedestrian paths

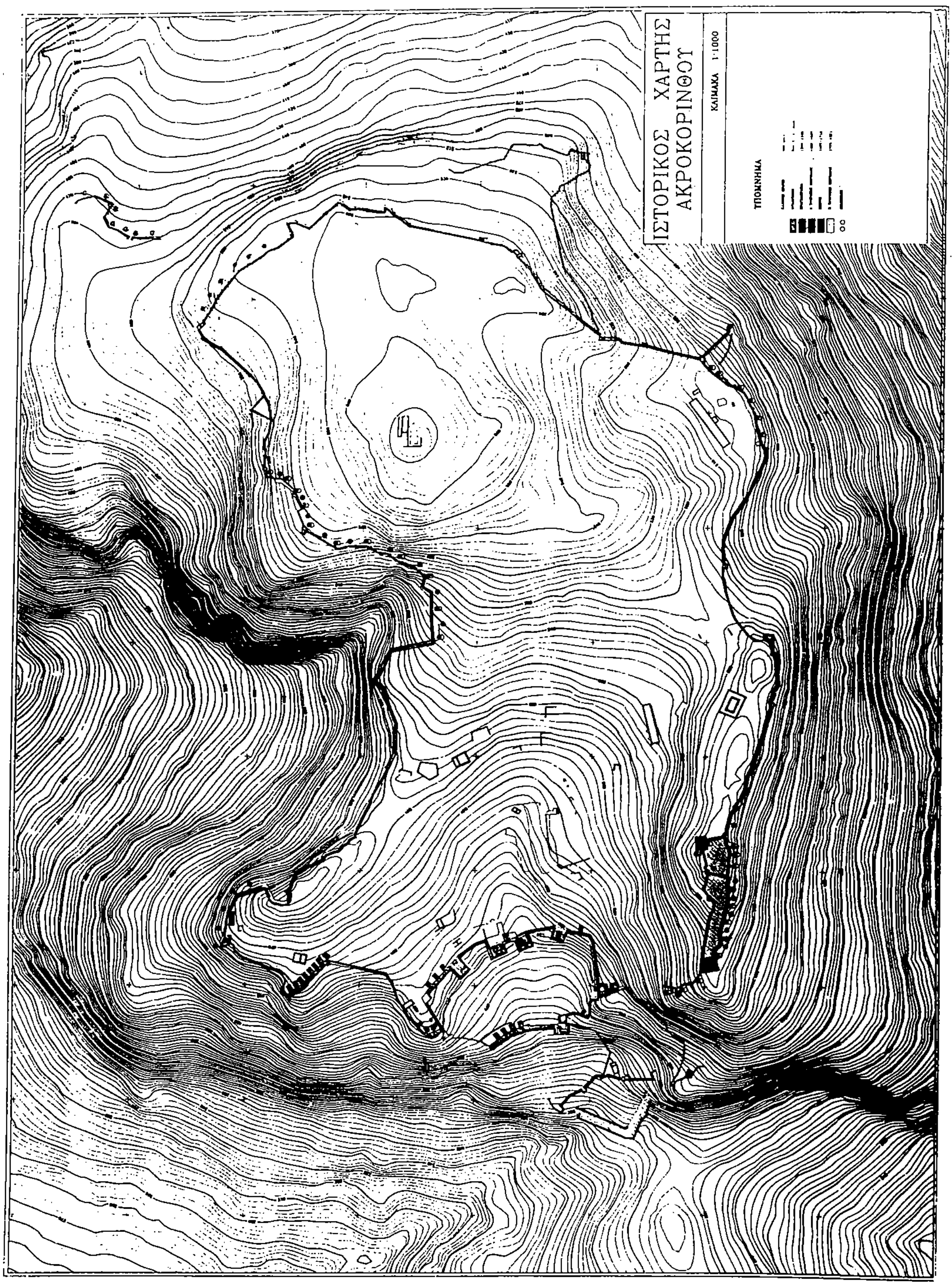

Fig. 9 Historical map : parts of the Castle been built in various periods (original in color)

4. Outputs of the system

After the integration of the systematic classification and insertion of all the necessary relevant to the castle information, a powerful tool for studing, managing, protecting and optimally using the castle will be developed.

A great advantage of the system is the provided ability to combine and modify existing data. For instance the combination of historical, archaeological and architectural evidence produced a new map, where the dates of construction of different parts of the monument are shown (Fig. 9).

Also maps giving various views of the castle in combination with other data may be made, e.g. the 3 - dimensional view of the castle together with the proposed pedestrian paths.

5. Conclusions

New technology gives more efficient tools for studying, protecting and managing our monuments. Hardware and software demands for this application are becoming more common, easy to operate and affordable.

The expected benefit from the use of these systems is great, especially for a country which has such a wealth of monuments but a low organisational level and thus has a tremendous task to undertake. The state has the means to introduce such systems. Thus the next important step should be the proper initiation and funding by the authorities of a complete system such as the one envisaged in this paper.

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THE IMPLEMENTATION OF A VECTOR GIS TO THE SURVEY OF A CASTLE

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Abstract

In this paper the utilisation of a modern vector GIS package in the survey of a large medieaval castle is being described. The survey was carried out by modern geodetic and photogrammetric equipment, using specialised methodology.

The fieldwork has been planned and carried out in such a way, to exploit the capabilities of the package and ease the phase of on-screen restitution. All data was directly transfered to the package and the whole restitution was carried out using a computer (processing, editing, plotting etc.).

The results of the survey and its integration to the package are evaluated in terms of accuracy, cost and effectiveness.

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1. Introduction

St. George's castle in Argostoli, Cephalonia is a unique example of early 14th century defensive architecture. The castle was built in several stages by the various conquerors of the island, mainly the Venitians. It served as the main defensive construction of the island against all invaders, as it controls the entrance to the large natural harbour of Argostoli. It also has a unique view over almost all the southwestern part of this large Ionian Island.

It is situated on top of a very steep hill about 10 km southwest of Argostoli. The main outer wall as it stands today encircles an area of approximately 20.000 sq.m. The outer wall features three impressive towers, one at the northwest corner, over the harbour, one at the north side, where the hill is less steep, and the third and biggest at the east corner, controlling the one and only gate to the castle. The actual height of the outside wall varies from 7 m to 14 m above the ground surface.

Inside the wall there are various constructions the main of which are smaller, and probably older internal walls and numerous buildings. There are several ammunition stores, a couple of churches, houses, defensive constructions etc. Most of them are in ruins, but there are a few that are still in good condition today. The last time the castle was used as a defensive construction was by the Nazi occupation during World War II. Today the inside of the castle is almost totally covered by 20 m high pines and other kinds of lower wild vegetation, which make an eventual survey even more difficult.

2. Fieldwork

The survey was carried out on behalf of the National Archaeological Fund. The requirements of the survey were a 1:100 plan (Fig. 1), several horizontal and vertical cross sections mainly through the dungeons and the elevations of one of the defensive towers at a 1:50 scale (Figs. 2,3).

A combination of geodetic and photogrammetric techniques were implemented during the survey. For the geodetic measurements an electronic theodolite (WILD T1000) was used, together with a Husky recording unit with PanTerra field system and a WILD DI1000 EDM. In appropriate situations, where the points of interest were inaccessible, or for the cross sections, a WILD DIOR 3002 (EDM without reflector) and laser beam (GLZ1) combination were employed. The advantage of this instrumentation was the possibility of assigning special codes to the points measured, in order to facilitate the restitution in the GIS package later. The points were divided into the following main groups:

a. Detail points, which included points on buildings, walls and other structures.

b. Detail points, belonging to and defining cross sections.

c. Spot heights, including trees and subdivided to points that would take part to the DTM calculation later and those that would not.

A feature code was attached to each of these points, characterising the string to which each of these points belonged. This code assignment to points was followed during all geodetic measurements as well as during the photogrammetric restitutions with the help of the relevant facility of ADAM MPS-2 3D digitizing software.

Two main traverses were established, one encircling the castle from the outside and the other inside it. The co-ordinates of the 67 stations were determined by triangulation in the National Network. The determination of the station heights was carried out by double run levelling using height control points of the National Network. Thus all plans would refer to the same reference system, a fact which would enable the eventual interpretation of the plans by the users.

The photogrammetric instrumentation comprised a WILD P31 metric camera, a 60x60 mm² non-metric one and an ADAM MPS-2 analytical plotter. Stereo coverage of the cone shaped defensive tower was taken,, mainly with the metric camera. Details that would not appear on the main photography were later covered using the non-metric camera. The analytical stereo restitution instrument allowed for stereopairs with different principal distance at the cameras. This was very convenient for this case as the new pairs did not need the determination of new control points.

For the compilation and construction of the three dimensional model of the castle and the surrounding area (a zone of 20 m width around the outer wall) approximately 6000 detail points were observed and measured (including the small number of control points for the photogrammetric survey), 1500 of which belonged to the horizontal and vertical cross sections.

The execution of the whole project took about 25 days and 5 nights of fieldwork for a survey party of three persons. Sometimes it was necessary to work after sunset (20:00 hrs) for improving the visibility of the laser beam. During these hours the DIOR 3002 and GLZ1 laser measurements were performed for the cross sections. The mean daily duration of the fieldwork was 10 hours. A back up of the measurements was performed on a daily basis using the Oracle back up unit connected directly to the Husky. As a further safe guard the data were also transfered to a PC.

The main difficulties encountered during the fieldwork were

a. The heat (temperatures in July 1990 reached high 30's in the shadow),

b. The thick and wild vegetation, which obstructed theodolite sights, camera angles and party movements,

c. The steepness of the ground, which at places reached over 100% and finally
d. The huge number of scattered ruins that could not be distinguished and interpreted very easily from the natural ground features.

Solution could only be provided for the last difficulty, by on-site interpretation of the various features. Hence knowledge of the history of the castle and of its various construction phases was of utmost importance at the time of the fieldwork.

3. The PanTerra System

For the phase of computations, restitution and evaluation of the field measurements the PanTerra System was used. PanTerra is a really 3D ground modelling system which includes GIS facilities. The hardware requirements of the package are:

- a 386 based PC with maths co-processor
- 2Mb of RAM and a Hard disk
- one alphanumeric and one graphic monitors with high resolution (eg. Hercules + VGA, or NthEngine + VGA respectively)

The system accepts data from plain Surveying, Photogrammetric surveys, digitizing or plane ASCII files produced by other data collection systems. Data output may be either plotted, printouts or ASCII files, which may be used by other restitution systems.

PanTerra's graphical Data Base includes the following features:

- point: name, X,Y,Z co-ordinates and feature code
- link: a live link that connects two points, with the feature code and the shape of the link in the horizontal and vertical planes as attributes
- node: a point through which more than one links pass, with feature code as attribute
- string: a serial connection of two or more links, with name and feature code as attributes
- parcel: a closed area, the boundary of which is defined by links from the same or different strings. Its attributes are name, area, perimeter, region, strings involved, class and type
- text: which automatically attaches to the above items
- family: grouping the above elements according to similar properties

The graphical Data Base has the important facility of layering and holding up to 251 surfaces. Managing information between the layers is also possible. The attribute Data Base of the system is structured in fields that may be combined with files and the input and output screens.

The two Data Bases are in constant interactive mode, hence geometric properties may be connected directly to qualitative attributes. Hence queries based on either the attribute or the graphical Data Base may be executed.

4. Implementing the GIS package to the field measurements

The raw field survey observations were transfered directly from the Husky to the PanTerra. All geodetic calculations, including triangulation adjustment, intersections, traverse adjustments, levelling and reduction of individual point observations, were performed entirely with the relevant facilities of PanTerra. This resulted to the determination of X, Y and Z for all points observed, while at the same time the field coding was taken into account. On the other hand ASCII files produced by the ADAM MPS-2 3D digitizing software were also imported to the PanTerra System. Hence a first model of the castle was produced on the screen. Using the editing facilities of the package the graphical result was refined and the final form of the model was completed.

At this stage the DTM option was executed for the calculation of the natural ground model. Only points coded accordingly during the stage of field measurements and that of the photogrammetric restitution took part in this calculation.

The 3D model of the whole castle with the surrounding zone surveyed was thus possible. For the operations with the PanTerra, ie. the computations, the refinement of the model and the DTM calculation, a week's work for two persons was necessary. The PanTerra package provides the possibility of producing user defined perspective views, profiles through the DTM and the model strings, display of selected elements of the model for further investigation (eg. display of only the fallen or semi-covered walls, in order to interpret and envisage the initial structure). Many more GIS facilities are also offered by the package, which when efficiently exploited may contribute decisevely to the study of today's situation, but also to the detailed and accurate documentation of a site like St. George's Castle in Cephalonia.

Following a detailed interpretation of the graphical output, qualitative attributes were assigned to selected geometric entities of the graphical Data Base. Such properties included construction date, building material, use of the object, current structural situation etc.

It was established that for the most efficient execution of such a project, perfect organisation and co-ordination as far as code assignment is concerned, is of utmost importance. Electronic equipment for recording of field measurements enable this task and it remains to the user to exploit their abilities to the full.

5. Conclusion

All required plans were produced by appropriate projections of the model on pre-defined planes. The accuracy achieved was that required for the 1:50 plans.

The fact that all measured points form part of the Data Base constitutes a major advantage for eventual future usage. The Castle is now fully documented, both geometrically and historically, in the GIS package. This fact may form the basis of a General Archive for all monuments of our country.

Figure 1

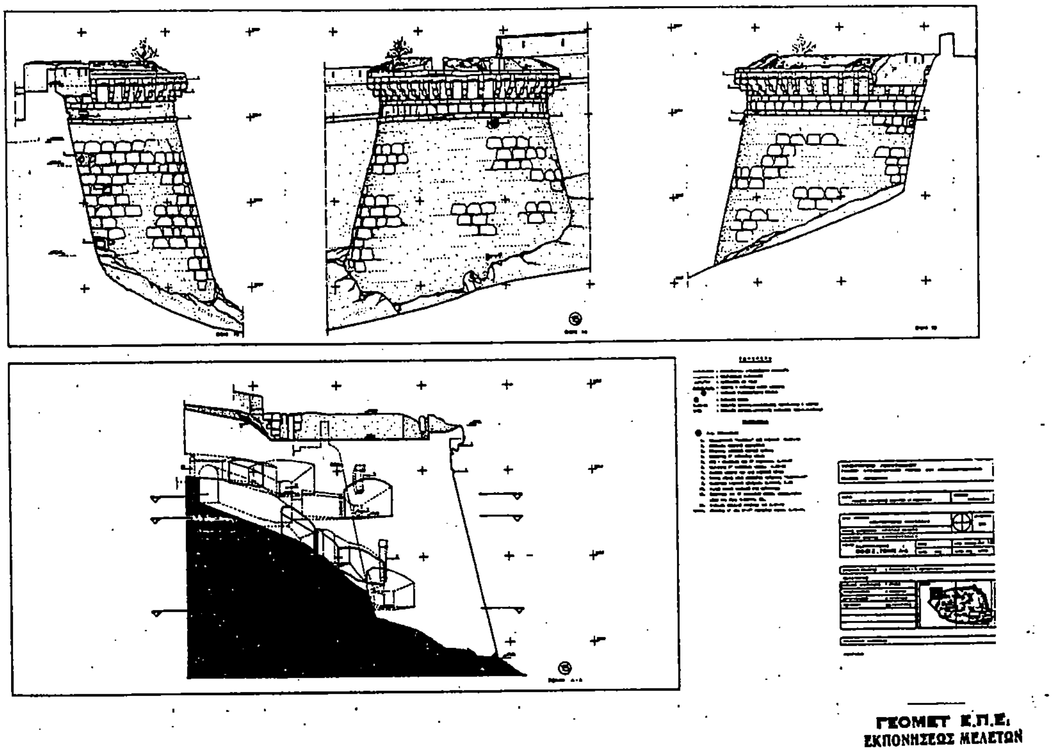

Figure 2

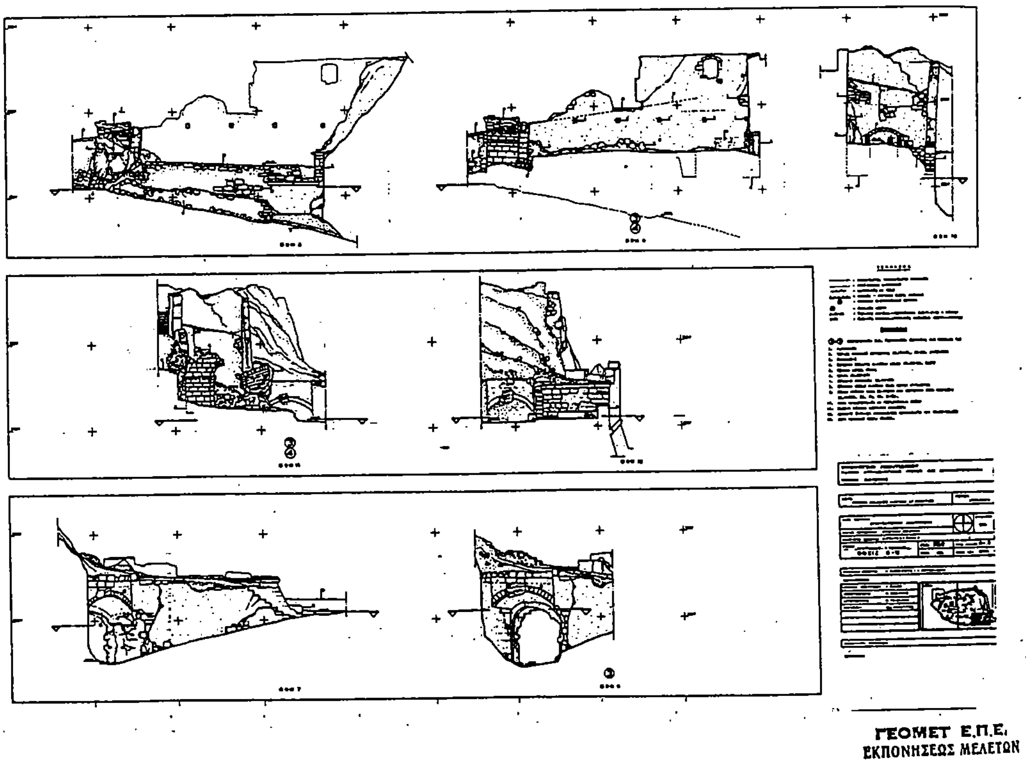

Figure 3

Development of Instruments, Methods and Techniques

Thursday, October 3rd, 1991, 9:00 - 11:00

Chair: J. Jachimski

Dipl.-Ing.
Torsten Kludas
Jenoptik Carl Zeiss Jena GmbH
Application Photogrammetry

XIV. INTERNATIONAL CIPA SYMPOSIUM
2.-5. Oktober 1991
DELPHI , Greece

T E B I A S

- terrestrial single model evaluation with the analytical stereoplotter DICOMAT

1. The DICOMAT - System

Features

DICOMAT is a powerful analytical stereoplotter for all photogrammetric applications. The use of special transformation equations and an optimum distribution of intelligence between the measuring instrument and the operator computer ensure a maximum of flexibility and versatility.
This analytical plotter system consists of a mechanical measuring instrument with control panel, control electronics, operator computer including peripherals and the user software required for the individual applications.
Because of his universal real-time algorithm and a very high measuring accuracy (≤ ± 2 μm) the DICOMAT is able to work in a wide range of application fields.

Main applications

The DICOMAT - system works for plotting of metric photographs, detailed metric photographs, amateur photographs, visualized scanner scenes of any focus for data collection in the fields of aerophotogrammetry and terrestrial photogrammetry.
The plotting in non-planar systems of coordinates is a special property for working in architecture or industrial photogrammetry with the DICOMAT - system.
The especialy real-time algorithm - developed by **MARK** in 1987 - provides DICOMAT with universal characteristics so that the range of application can easily be expanded.

DICOMAT's real-time algorithm

In contrast to other well-known analytical plotting machines the collinearity equation of central perspective is not used in the DICOMAT, but the general image equation

$$x' = f_1(x,y,z) \qquad y' = f_2(x,y,z) \tag{1}$$

which is developed by the theorem of **TAYLOR**.
According to the theorem of Taylor each function being (r+1)-times continuously differentiable can be developed in the environment of a point Po(xo,yo,zo) to:

$$\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} f_1(x_o,y_o,z_o) \\ f_2(x_o,y_o,z_o) \end{vmatrix} + \mathbf{F_x dx} + \tfrac{1}{2}\mathbf{dx^T F_{xx} dx} \tag{2}$$

$\mathbf{F_x}$ and $\mathbf{F_{xx}}$ are the matrices of the partial derivatives.

If the evaluation is not be made in the coordinate system (x,y,z), but in a coordinate system (x,y,z), for which the following relations holds true

$$\mathbf{x} = \begin{vmatrix} x \\ y \\ z \end{vmatrix} = \begin{vmatrix} u(\bar{x},\bar{y},\bar{z}) \\ v(\bar{x},\bar{y},\bar{z}) \\ w(\bar{x},\bar{y},\bar{z}) \end{vmatrix} \tag{3}$$

Taylors formula must be rewritten as follows:

$$x' = x_o' + \mathbf{F_{\bar{x}} d\bar{x}} + \tfrac{1}{2}\mathbf{d\bar{x}^T F_{\bar{x}\bar{x}} d\bar{x}} \tag{4}$$

If systematic errors are still contained in the images, the final image coordinates must then calculated by

$$x_k' = g(x',y') \tag{5}$$

By application of Taylor's formula follows:

$$x_k' = x_{ko}' + \mathbf{G_{\bar{x}} d\bar{x}} + \tfrac{1}{2}\mathbf{d\bar{x}^T G_{\bar{x}\bar{x}} d\bar{x}} \tag{6}$$

Now this formula can be used for the especial mathematical model of taking process as like the central perspective or the evaluation of scanner scenes.
The central perspective, for example, is discribed with the known collinearity equations

$$\begin{vmatrix} x' \\ y' \\ -c_k \end{vmatrix} = \frac{1}{\lambda} \mathbf{A^T} \begin{vmatrix} x - x_{o1} \\ y - y_{o1} \\ z - z_{o1} \end{vmatrix} \tag{7}$$

This equations will be treated by the theorem of Taylor in the way before, now Taylors formula must be rewritten as follows:

$$\begin{vmatrix} x' \\ y' \end{vmatrix} = \begin{vmatrix} x_o' \\ y_o' \end{vmatrix} + \begin{vmatrix} \alpha & 0 \\ 0 & \beta \end{vmatrix} \left[\begin{vmatrix} \mathbf{K_1} \\ \mathbf{K_2} \end{vmatrix} \mathbf{d\bar{x}} + \tfrac{1}{2}\mathbf{d\bar{x}^T} \begin{vmatrix} \mathbf{R_1} \\ \mathbf{R_2} \end{vmatrix} \right] \mathbf{d\bar{x}} \tag{8}$$

This is the DICOMAT's real-time formula with the matrices of the partial derivatives

$$\begin{aligned} \mathbf{K_1} &= \mathbf{G_{1x} \cdot F_{1x} U_{\bar{x}}} & \mathbf{R_1} &= \mathbf{G_{1x} \cdot F_{1x} U_{\bar{x}\bar{x}}} + \mathbf{G_{1x'x'}} \\ \mathbf{K_2} &= \mathbf{G_{2x} \cdot F_{2x} U_{\bar{x}}} & \mathbf{R_2} &= \mathbf{G_{2x} \cdot F_{2x} U_{\bar{x}\bar{x}}} + \mathbf{G_{2x'x'}} \end{aligned} \tag{9}$$

$$\mathbf{d\bar{x}} = \begin{vmatrix} d\bar{x} \\ d\bar{y} \\ d\bar{z} \end{vmatrix} ,$$

$$\alpha,\beta = f(\mathbf{A},\ \mathbf{U_{\bar{x}}},\ x,\ y,\ z)\ . \qquad (10)$$

The DICOMAT works in the following way:

The object space is subdivided into spatial segments.
The elements $d\bar{x}, d\bar{y}, d\bar{z}$ are given by the operator over the input elements (handwheels, footdisk) in the real-time formula. All the other elements (x_o', y_o', $\mathbf{K_1}$, $\mathbf{K_2}$, $\mathbf{R_1}$, $\mathbf{R_2}$, α, β) are computed by the host computer with special transformation subroutines. This elements are computed and stored for each segment. The transition from one segment to a neighbouring segment is always associated with a change of the entire parameter set.

The total transformation is split into three catenated partial transformations

$$\begin{aligned} \mathbf{x} &= U(\bar{x}) \\ \mathbf{x}' &= F(x) \\ \mathbf{x_k}' &= G(x') \end{aligned} \qquad (11)$$

We call this the U-, F-, and G-Transformation.

U-Transformation: to transform into another object coordinate system, like
- earth curvature, refraction
- cylinder or spherical coordinate systems
- special map projections
- multimedia photogrammetry

F-Transformation: to restore the mathematical model of the photographic process, like
- central perspective
- scanners

G-Transformation: to correct systematic device and image errors, like
- film deformations
- distortion
- instrument errors

2. The TEBIAS - Software

Description of TEBIAS

TEBIAS is one of the program packages for data acquisition in the DICOMAT - application software.
The program is used for terrestrial single- and double-image elevation to restitute survey photographs and photographs of unknown interior orientation.
The TEBIAS program package is structured as follows:

Data management

MANCA
Management of terrestrial camera data
to serve the build-up and management of terrestrial survey and photographic camera parameters.

MANPD
Management of terrestrial project data
serves the build-up and management of projects to be processed with the possibility to restitude both single and double images as well as to employ different cameras.

MANOP
Management of operator data
to define the personal operator data in working with the DICOMAT input elements (handwheels, footdisk) for direction, rotation and transmission.

MANGEO
Management of geodetic data
to form files for every project containing data of geodetic observations made in an object space, like for

- geodetic (control) points
- projection centres
- distances, coordinate differences, directions
- base components

Orientation

STATUS
to define the status of the actual model with parameters like project name, camera number or overlap area for examples.

INNOR
to establish the functional relation of interior orientation and instrument coordinates by measuring fiducial marks or margical points of picture gates, respectivly.

EXOR
to serve the selection of problem-specific programs for the exterior orientation:

LINTRA
permits photos taken by photographic cameras to be restitude the interior orientation of which is not known, or approximately known (11-parameter-linear transformation).

RESEC
is based on the functional model of spatial resection the use of which requires knowledge of interior orientation data.

RELOR
is used to ascertain the **rel**ative **or**ientation elements of a stereopair of known interior orientation after bridging.
There are two algorithms possible to select:
(1) Independent photo pairs (algorithm by **HINSKEN**)
(2) Conjunction of successive photographs (algorithm by **SCHUT**)

ABSOR
serves the ascertainment of the **abs**olute **or**ientation elements of a stereopair after relative orientation.
There are two methods foreseeing:
(1) Absolute orientation by the help of the geometry of planar objects (house fronts for example)
Minimum: one distance made for geodetic observations
(2) Spatial similarity transformation with control points
Minimum: three control points for geodetic observations

BUNDLE
to improve the results from the absolute orientation by the help of additional observations in a bundle adjustment

REGEN
to **regen**erate the stereomodel with all known orientation parameters by computation of the transformation parameters. By the help of this program it´s possible to use the universal algorithm of the DICOMAT with all advantages to transform into other planar or non-planar coordinate systems, as like
- cylindrical coordinate systems
- spherical coordinate systems
- planar coordinate systems of an house front
- underwater coordinate systems

Calibration

The calibration process for determination of the camera´s (survey or photographic camera) interior orientation data based on the functional model of the bundle method.
The **CALIBR** programm (**Calibr**ation of cameras) is used to identify the geodetic observations made and to calculate the approximate values of the unknown quantities to be determined. Included in this operation is the reduction of the directions measured in the object space to the camera projection centre.

XIV. INTERNATIONALE SYMPOSIUM
2.-5. Oktober 1991
DELPHI, Griechenland

Dipl.-Ing.
Kludas, Torsten
Jenoptik Carl Zeiss Jena GmbH
Geschäftsbereich Photogrammetrie

Vortrag zum Thema:

TEBIAS - ein Programm zur terrestrischen Bildauswertung mit dem analytischen Auswertesystem DICOMAT

Das von der Jenoptik Carl Zeiss Jena GmbH entwickelte **DICOMAT** ist ein leistungsfähiges, analytisches Auswertesystem für alle Anwendungen der photogrammetrischen Stereoauswertung höchster Genauigkeit. Maximale Flexibilität und Universalität werden durch die Nutzung spezieller Transformationsgleichungen zur Realisierung des Echtzeitprozesses und einer optimalen Intelligenzverteilung zwischen Meßgerät und Anwenderrechner erreicht.
Der Echtzeitalgorithmus des **DICOMAT** geht aus von der Anwendung der TAYLOR-Formel auf eine allgemeine Abbildungsgleichung zur Bestimmung der Beziehungen zwischen Bild- und Objektkoordinaten. Mit Hilfe der TAYLOR-Formel ist es möglich, die Kollinearitätsgleichung als allgemeine Abbildungsgleichung auf nicht ebene Koordinatensysteme anzuwenden. Dieser Fakt gewinnt besondere Bedeutung auf dem Gebiet der terrestrischen Photogrammetrie, da man somit in der Lage ist, in beliebig krummlinigen Koordinatensystemen auszuwerten.

Das Programm **TEBIAS** wurde als ein universelles Softwaremodul von der Technischen Universität Dresden entwickelt, um die Vorzüge des **DICOMAT** auch in der terrestrischen Photogrammetrie voll auszunutzen. **TEBIAS** dient der digitalen Ein- und Zweibildauswertung terrestrischer Bilder bekannter oder unbekannter innerer Orientierung beliebigen Maßstabs. Es gestattet alle Aufnahmedispositionen der Ein- und Mehrmedienaufnahme und die Auswertung in verschiedenen ebenen und nicht ebenen Koordinatensystemen. Damit ist das **DICOMAT**-System in den Bereichen der Architektur-, Industrie- oder Unterwasserphotogrammetrie erfolgreich einsetzbar.

Im Vortrag werden einige dieser Anwendungsbereiche anhand von speziellen Beispielen näher erläutert.

AN ENHANCEMENT OF THE DLT METHOD FOR ARCHITECTURAL PHOTOGRAMMETRY APPLICATIONS

D. Th. Panagiotidis

ABSTRACT

An enhancement of the DLT method is presented. The enhanced DLT model comprises of the 11 DLT parameters, plus one for radial distortion, plus a polynomial of 10 additional parameters. All the unknown parameters for the two photos are incorporated in one Least Squares Solution. The additional parameters are checked to see if they are correlated or insignificant and if so they are discarded from the solution.
The method is tested with real data on two test fields and specific architectural monuments. A wide variety of non metric cameras covering an extended range of price , plus one metric camera are used.
Finally an economic data reduction system is proposed. This comprises of a non metric camera, the software described above, a microcomputer, a size A3 digitizer and a size A3 plotter.

INTRODUCTION

The DLT (Direct Linear Transformation) method is an analytical self calibration method that was developed to allow the use of non metric cameras in close range photogrammetry applications. (Abdel-Aziz & Karara, 1974). The DLT method makes no use of fiducials and is well accepted by photogrammetrists.
The success of the method depends on how well the distortions caused by non metric cameras are compensated for. The enhanced DLT model provides an improvement to solutions proposed until today. Even though the use of non metric cameras reduces the cost most applications of the method still incorporate the use of highly expensive instruments such as stereocomparators. It will be shown that by using a digitizer there is no significant loss of accuracy, while the cost can be considerably reduced.

THE MATHEMATICAL MODEL OF THE DLT METHOD

The DLT method allows the Direct Linear Transformation from picture coordinates to ground coordinates, bypassing the intermediate stage of trans forming the picture coordinates from the comparator system to picture system. The DLT equations are the following:

$$x = \frac{L_1X + L_2Y + L_3Z + L_4}{L_9X + L_{10}Y + L_{11}Z + 1} \qquad y = \frac{L_5X + L_6Y + L_7Z + L_8}{L_9X + L_{10}Y + L_{11}Z + 1}$$

The 9 parameters of interior (c, x_o, y_o) and exterior (ω ϕ κ X_o Y_o Z_o) orientation are interpreted through the 11 parameters L_i.

A linearization of the DLT equations leads us to the following equations, regarding the observation of a single point i in picture j (Dermanis 1989):

$$\mathbf{b}_{ij} = \mathbf{A}_{ji}\,\dot{\mathbf{x}}_j + \ddot{\mathbf{A}}_{ji}\,\ddot{\mathbf{x}}_i + \mathbf{v}_{ji}$$

where $\dot{\mathbf{x}}_j$ is the vector of unknown parameters L_i and $\ddot{\mathbf{x}}_i$ the vector of ground coordinates. More specifically:

$$\dot{\mathbf{x}}_j = \begin{bmatrix} \delta L_1 & \delta L_2 & \delta L_3 & \delta L_4 & \delta L_5 & \delta L_6 & \delta L_7 & \delta L_8 & \delta L_9 & \delta L_{10} & \delta L_{11} \end{bmatrix}_j^T$$

$$\ddot{\mathbf{x}}_i = \begin{bmatrix} \delta X & \delta Y & \delta Z \end{bmatrix}_i^T$$

$$\mathbf{v}_{ji} \begin{bmatrix} v_x & v_y \end{bmatrix}_{ji}^T$$

$$\mathbf{b}_{ji} = \begin{bmatrix} x-x^0 & y-y^0 \end{bmatrix}_{ji}^T$$

The design matrix is formed from the following submatrices which contain the partial derivatives of the DLT equations to the unknown parameters Li and the ground coordinates:

$$\dot{\mathbf{A}}_{ji} = \begin{bmatrix} \frac{\partial x}{\partial L_1} & \frac{\partial x}{\partial L_2} & \cdots & \frac{\partial x}{\partial L_{11}} \\ \frac{\partial y}{\partial L_1} & \frac{\partial y}{\partial L_2} & \cdots & \frac{\partial y}{\partial L_{11}} \end{bmatrix}_{ji} \qquad \ddot{\mathbf{A}}_{ji} = \begin{bmatrix} \frac{\partial x}{\partial X} & \frac{\partial x}{\partial Y} & \cdots & \frac{\partial x}{\partial Z} \\ \frac{\partial y}{\partial X} & \frac{\partial y}{\partial Y} & \cdots & \frac{\partial y}{\partial Z} \end{bmatrix}_{ji}$$

For each pair of observations of photo coordinates of a point i in picture we assume the following equations:

$$\begin{bmatrix} \dot{\mathbf{N}}_{ji} & \bar{\mathbf{N}}_{ji} \\ \bar{\mathbf{N}}^T & \ddot{\mathbf{N}}_{ji} \end{bmatrix} \begin{bmatrix} \dot{\mathbf{x}}_j \\ \ddot{\mathbf{x}}_i \end{bmatrix} = \begin{bmatrix} \dot{\mathbf{u}}_{ji} \\ \ddot{\mathbf{u}}_{ji} \end{bmatrix}$$ where:

$$\dot{\mathbf{N}}_{ji} = \dot{\mathbf{A}}_{ji}^T P_{ji} \dot{\mathbf{A}}_{ji} \qquad \dot{\mathbf{u}}_{ji} = \dot{\mathbf{A}}_{ji}^T P_{ji} \mathbf{b}_{ji}$$

$$\ddot{\mathbf{N}}_{ji} = \ddot{\mathbf{A}}_{ji}^T P_{ji} \ddot{\mathbf{A}}_{ji} \qquad \ddot{\mathbf{u}}_{ji} = \ddot{\mathbf{A}}_{ji}^T P_{ji} \mathbf{b}_{ji}$$

$$\bar{\mathbf{N}}_{ji} = \dot{\mathbf{A}}_{ji}^T P_{ji} \ddot{\mathbf{A}}_{ji}$$ and

$$\mathbf{P}_{ji} = \mathbf{C}_{ji}^{-1} = \begin{bmatrix} \sigma_x^2 & \sigma_{xy} \\ \sigma_{yx} & \sigma_y^2 \end{bmatrix}_{ji}^{-1}$$

Since the picture coordinates are measured with the same accuracy and are not correlated we assume that $\sigma_x^2 = \sigma_y^2 = \sigma_0^2$ and the weight matrix $\mathbf{P}_{ji}$ is replaced by $1/\sigma_o^2 \times \mathbf{I}$.

The systematic errors were treated as follows:

a) Radial lens distortion. A third degree polynomial was chosen.

$\delta_r = K_1 \, r^3$ and the corrections for the x and y picture coordinates are

$$\Delta x_{rad} = x' \, K_1 \, r^2 \qquad \Delta y_{rad} = y' \, K_1 \, r^2$$

b) Other distortions of lens and film. One of the models suggested by Ebner was chosen, containing 12 additional parameters.

$$\Delta x_{ad} = b_1 x + b_2 y - b_3(2x^2 - 4ba) + b_4 xy + b_5(y^2-2ba) + b_7 x(y^2-2ba) + \\ + b_9 y((x^2-2ba) + b_{11}(x^2 - 2ba)(y^2 - 2ba) + x_0$$

$$\Delta y_{ad} = - b_1 y + b_2 x + b_3 xy - b_4(2y^2-4ba) + b_6(x^2-2ba) + b_8 y(x^2-2ba) + \\ + b_{10} x((y^2-2ba) + b_{12}(x^2 - 2ba)(y^2 - 2ba) + y_0 \qquad \text{where} \quad ba = b^2/3$$

The enhanced suggested DLT model is the following:

$$x + \Delta x_{rad} + \Delta x_{ad} = \frac{L_1 X + L_2 Y + L_3 Z + L_4}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

$$x + \Delta x_{rad} + \Delta x_{ad} = \frac{L_5 X + L_6 Y + L_7 Z + L_8}{L_9 X + L_{10} Y + L_{11} Z + 1}$$

The solution with the observation equations method becomes:

$$\mathbf{b}_{ij} = \begin{bmatrix} \dot{\mathbf{A}}_{ji} & \mathbf{D}_{ji} \end{bmatrix} \begin{bmatrix} \dot{\mathbf{x}}_j \\ \mathbf{y}_j \end{bmatrix} + \ddot{\mathbf{A}}_{ji} \ddot{\mathbf{x}}_i + \mathbf{v}_{ji}$$

Matrix $\mathbf{D}$ contains the partial derivatives to all the distortion parameters, while the parameters themselves are contained in vector $\mathbf{y}$.

SELECTING A POLYNOMIAL OF ADDITION PARAMETERS

The selection of a polynomial of the suggested form for the compensation of systematic errors and generally of any form introduces an empirical solution to a complicated problem such as self calibration.

Usually one would choose a polynomial with many parameters aiming to cover all kinds of systematic errors. This automatically introduces the need of examining the determinability of the unknown parameters. There is a possibility that some parameters be overdetermined by others, while others may be correlated, resulting in a weak solution, or insignificant.

On the other side it is almost impossible to compensate for the distor tions of any non metric camera by introducing a general polynomial of addi tional parameters, since the use of another camera or even the same one, but with different focusing, and the lack of proper film flattening, will make necessary the introduction of new distortion parameters.

Therefore one faces the problem of selecting only the necessary parameters for the compensation of distortions. (Panagiotidis, 1991). In this project the following procedure was applied:

The strongly correlated parameters were detected and discarded from the solution. The selection took place after the inverse of matrix N was computed and after the correlation coefficients were calculated. A threshold was chosen, above which a parameter was considered correlatd. Gruen (1985) suggests the value of 0.9 for this threshold. In this project we also tried 0.75 and 0.65. A t-test followed to find out whether the contribution of a considered parameter in the overall compensation was significant.

APPLICATION OF THE ENHANCED DLT METHOD

The project followed these stages:

1) Establishment of test fields, 2) Use of an extended number of non metric (and metric) cameras, 3) Software development, 4) Consideration of the effect of various factors in accuracy, 5) Suggestion for the development of an analytical system.

The test field allowed the positioning of targets on two planes 4 meters apart. Plane No 1 contained 16 targets and No 2 27. Targets of 5.5 cm diameter were used with 1 mm diameter centre (Fig. 1).

Ground control was provided by a triangulation network. From 4 stations all the directions and 5 distances were measured. The network, with overall 47 points and 367 observation equations, was adjusted as a three-dimensional one with program ICONA3 (Rossikopoulos, 1986). Two stations were fixed in X and Y and one in Z. The a-posteriori value of variance was 1.06 (a-priori=1) and the semiaxes of error ellipsoids of targets varied from 0.4 mm to 0.8 mm for X and Y and from 0.1 mm to 0.2 mm for Z.

The final values for the ground coordinates from the adjustment were cosidered true and were used for the evaluation of the DLT results.

A second test field was also set up to test non metric cameras with the DLT method. 14 targets (7 on each plane) were used. Ground control was also provided by a triangulation network and a three - dimensional least squares adjustment.

CAMERA	Pr.Dist mm	BASE m	DIST. m	B /Y	CONVERG. grad	CODE
Pentax Me S	50	1.0	7.0	1/7.0	2	MES502
Pentax Me S	50	1.4	7.0	1/5.0	3	MES501
Pentax Me S	50	2.7	7.0	1/2.6	13	MES504
Pentax Me S	50	3.2	7.0	1/2.2	15	MES503
Pentax Me S	80	3.2	11.0	1/3.4	8	MES801
Pentax Pr A	50	1.0	7.0	1/7.0	1	PRA501
Pentax Pr A	50	1.4	7.0	1/5.0	5	PRA502
Pentax Pr A	28	0.8	4.0	1/5.0	1	PRA282
Pentax Pr A	28	1.4	4.0	1/2.9	12	PRA281
Zenit E	52	2.5	8.5	1/3.4	8	ZEN501
Zenit E	52	3.3	8.5	1/2.6	11	ZEN502
Hasselblad	80	2.5	6.3	1/2.5	12	HAS801
Kodak	40	1.2	7.0	1/5.8	3	KOD422
Kodak	40	3.2	7.0	1/2.2	13	KOD421
P-32	64	1.0	4.0	1/4.0	13	P32641

Table 1. The settings tested on test field No1.

Aim of the project was the testing of an extended variety of amateur cameras, as well as the behaviour of the method in extreme or difficult conditions. Former publications (Abdel-Aziz & Karara, 1974) had already proved the fidelity of the method, but in rather favourable conditions considering the number and distribution of control points, base length and distance of photography.

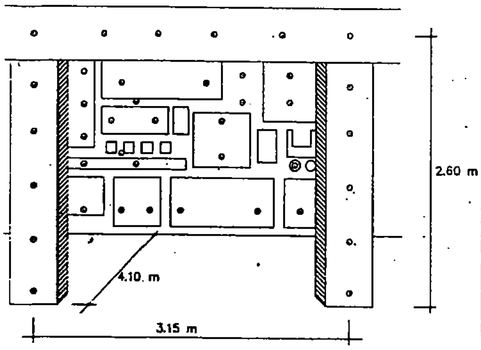

Fig.1 The test field

CAMERA	LENS mm	X	Y mm	Z	conv grad	B/Y
PENTAX ME Super	50	0.5	0.6	3.6	3	5.0
PENTAX ME Super	50	1.1	1.1	6.1	2	7.0
PENTAX ME Super	50	0.6	0.6	2.0	15	2.2
PENTAX ME Super	50	0.5	0.5	3.2	13	2.6
PENTAX ME Super	80	0.7	0.8	4.5	8	3.4
PENTAX PROGRAM A	50	0.6	0.4	3.2	5	6.0
PENTAX PROGRAM A	50	0.7	0.6	4.1	1	7.0
PENTAX PROGRAM A	28	3.0	2.4	19.9	12	2.9
PENTAX PROGRAM A	28	6.3	2.6	24.8	1	6.0
HASSELBLAD 500 C	80	0.4	0.2	1.3	12	2.5
ZENIT E	50	0.7	0.8	3.5	8	3.4
ZENIT E	50	0.8	1.0	2.5	11	2.6
KODAK	42	4.8	4.1	22.3	3	5.8
KODAK	42	1.6	1.6	8.3	13	2.2
WILD P32	64	0.4	0.5	1.5	13	4.0
WILD P32	64	0.9	0.6	2.8	2	4.0

Table 1.General Results

On test field No 1 the cameras shown coded in table 1 were used. Photography took place between 11.00 and 14.00 in natural daylight. Agfapan 25 and 100 ASA was used in all cameras. Five shots were made with each camera- lens combination.

Negative scale was 1:167 for Kodak, 1:78 for Hasselblad, 1:64 for Wild P32 and varied from 1:135 to 1:147 for the rest. Next the negatives were placed on stereocomparator Wild STK-1, and the photocoordinates were measured stereoscopically in two sets. The standard deviation of the readings was found to be 2.8 microns (out of a sample of 50 repeated readings).

RESULTS

Most applications of the DLT method apply redundant control. Abdel- Aziz & Karara, (1974) suggest redundant ground control and use 33 points as control points. All points are also used by Karara (1974). Fraser (1982) uses 57 control points, while in many publications this number is not mentioned.

To investigate the effect of the number of control points in accuracy, there were many solutions all with redundant control. 12 control points were used as the basic solution for all camera-lens combinations. All other possible solutions were also tested (i.e. with 6, 7, 8, 9, 10, 11 points, 16 and finally all points available).

In all cases the basic solution of 12 control points produced satisfactory results. For X and Y coordinates the R.M.S. of differences (from ground control) varied from 0.5 mm to 1.0 mm, while for Z (depth) from 1.5 mm to 6.5 mm, with the only exceptions of the cheapest Kodak camera and the wide angle lens Pentax 28 mm (See Table 2).

Comparing the results with distances measured on site the diferences varied for the best cameras from 0 to 1 mm with standard deviation of 0.5 mm (sample of 28 distances) and from 1 to 5 mm with s.d. of 3.5 mm for the others.

One can also conclude that 9 control points is a critical point and represent the minimum requirementes. Also 12 control points are a safe and and economical solution.

The effect of the additional parameters was investigated also by means of solutions with redundant control. In the following charts on can compare solutions (Table 3):

a) with only radial lens distortion compensation, b) as case (a) plus 10 additional parameters, c) automatic selection of parameters with correlation check and t-test.

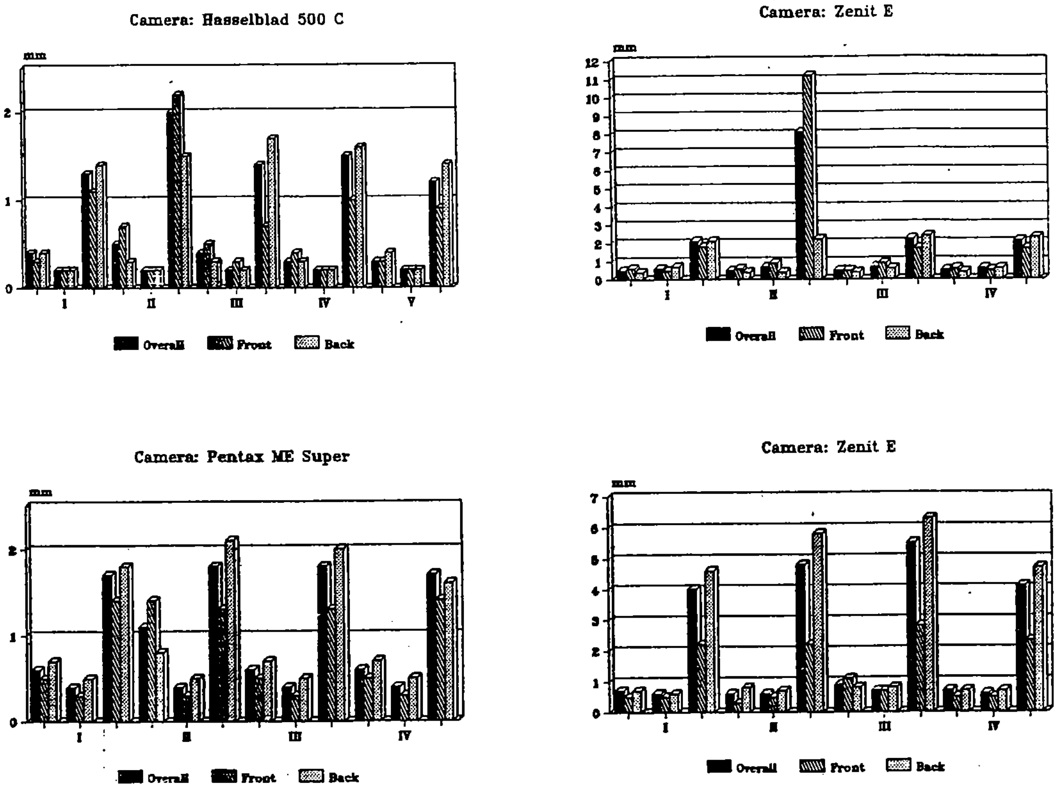

Table 3. The effect of the additional parameters

The charts relate to three non metric cameras. The three bars' groups represent values for X, Y, Z coordinates and independent values for each plane of the test field are given. One can reach the following conclusions:

1) Compensation for only radial lens distortion seems to be enough for the correction of pic coordinates and the user could easily stop there.

2) In cases of good cameras (Wild, Hasselblad, Pentax) but also in cases of good settings, it is sometimes difficult to come to conclusions since the achieved accuracy can reach the limits of the ground control accuracy.

3) In all cases the addition and keeping of all additional parameters led to significant decrease of accuracy (comp. cases II with I, III, IV).

4) The results with both tests are of the same quality, if not better, to those with only radial distortion compensation (comp. case IV with I).

5) There are no residual systematic errors, while these appear if all additional parameters are incorporated.

6) The increase in accuracy from the radial-distortion-only solution to the one with both checks is of the 5-20% order for the X, Y plane and of 5% for Z (depth). Regarding length measurements on site this increase is 5-10% respectively.

USING A DIGITIZER INSTEAD OF A COMPARATOR

In all cases the stereocomparator Wild STK-1 was used for the measurement of photo coordinates. The STK-1 is a very precise instrument, large in size and expensive. Therefore it was decided to try the method using a less precise (and less expensive) comparator. Since there was no such comparator available, the readings of the STK-1 were used to simulate two comparators with accuracy of reading 10 and 100 microns respectively. The input values for case MES503 were used (12 control points).

The results are given in the next table and one can see that accuracy in the order of 10 microns in the comparator reading is enough to produce satis factory results, while in extreme cases one can accept coordinates with accuracy in the order of about 100 microns.

ACCURACY of READING	sX mm	sY mm	sZ mm
1 μm	0.6	0.6	2.0
10 μm	1.0	1.1	6.0
100 μm	8.0	8.2	52.3

Achieved accuracy with real data (1 micron) and simulated data (10 and 100 microns)

Modern digitizers tend to reach these levels of accuracy (10-30 microns), having good chances to be included in instrumentation lists. Therefore after that simulated test, a series of adjustments followed using digitizers for the measurement of coordinates. Two digitizers were used: Houston Instruments Hipad plus 9018 and Hitachi.

Enlargement prints were made from the original negatives (ratio 4:1). The prints were made on the rectifier WILD E4, to avoid the introduction of further distortions.

CAMERA	Pentax	Pentax	Pentax	Wild P32	Zenit E
PICTURE	NEGATIVE	PRINT	PRINT	PRINT	PRINT
MEASUREMENT	Wild STK1	Hitachi	Houston I	Houston I	Houston I
No of SETS	2	2	2	3	3
CNTR. POINTS	12	12	12	13	13
ACCURACY XY (mm)	0.6 0.6 2.0	2.4 3.0 12.5	2.7 3.2 18.4	2.1 2.0 14.1	2.4 2.5 17.1

Comparative results of comparator and digitizers

The Hitachi digitizer claimed a resolution of 40 lines/mm. For the Houston Instruments Digipad 9018 this value was 100 lines/mm even though its standard deviation was found to be 40 lines/mm for the X and 110 for the Y axes (out of a 100-values sample). The photos used were: a) Prints of Pentax (MES503) on Wild E4 rectifier, b) Prints of Wild P-32 on Wild E4 rectifier c) Prints of Zenit on an amateur Krokus enlarger

The final ground coordinates differed, from those geodetically known, in less than 1 mm in X and Y, while in Z from 2.5 to 5 mm. The differences from lentgh measurements on site varied from 1 to 5 mm. Another case of using a digitizer was a photograph of a facade of Saint Demetrius church in Thessaloniki (Panagiotidis, 1991). Again the Houston Instruments digitizer was used. The ground coordinates of 21 target-points were calculated and the R.M.S. of differences was sX = 6 mm, sY = 6 mm, sZ = 15 mm. These values can be directly compared with values which resulted from comparator observations and equal distribution of control points in two planes.

GENERAL CONCLUSIONS

In conclusion it was proved that the method can be applied on architectural monuments, rich in detail. The method provides an alternative to analog methods, with significant reduce of instrumentation cost. Other advantages are less field work, minimum requirements in personell and the ability to produce practically infinite number of points and make additions whenever necessary. The cost of instrumentation for the set-up described is:

Camera	....	100.000
Digitizer A3	....	250.000
P/C AT or 386	....	400.000
Plotter A3	....	300.000
	total	1.050.000 drs

It is believed that the experience from this project will make evident to engineers that Analytical Photogrammetry methods can produce satisfactory results and be combined with topographic methods, using simple non metric cameras and affordable instrumentation

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RESEAU CAMERAS FOR ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

A large number of projects in architectural photogrammetry has been carried out by means of réseau cameras instead of conventional metric cameras. In this paper, first a brief report on the state-of-the-art of analogue sensor technology for the recording of buildings is given. Following the detailed discussion of réseau technique, two new réseau cameras are introduced, the 4 x 5" METRIKA 45 and the 60 x 120 mm TECHNORAMA 612 M. Technical specifications and, in particular, the film flattening and calibration strategy are outlined. First experiences in the application of these cameras to the photogrammetric survey of architectural objects are presented.

Keywords: Architectural Photogrammetry; Camera; Réseau Technique.

1. RESEAU TECHNIQUE

In recent years, the equipment used for recording architectural objects has changed substantially. This statement holds true as well for the design, size and technical details as for the availability of the imaging systems. Conventional metric cameras such as Wild P31 and P32, Zeiss TMK and SMK (see ATKINSON (1989) for a synopsis of metric cameras) are disappearing from the market for economic reasons. The UMK of Zeiss (Jena) is one of the last genuine metric cameras which is being manufactured up to now. Metric cameras have been effectively used in the recording of buildings and monuments world-wide, but they are too cumbersome and often unflexible for quite a series of photogrammetric tasks.

As a consequence, for many years off-the-shelf standard photographic cameras, that means non-metric cameras of 24 x 36 mm and 60 x 60 mm image format have been applied (GEORGOPOULOS 1990). They are small, light-weight, easy to handle and relatively inexpensive, and provide professional photo-technique such as interchangeable lenses, automatic exposure control, motorized film transport and a wide range of system accessories. Besides, a great variety of films with different emulsions is available.

In order to achieve an accuracy of the photogrammetric object restitution comparable to the metric camera approach such a non-metric camera has to be equipped with a réseau plate, that means a glass plate with cross-shaped marks in front of the film surface (WESTER-EBBINGHAUS 1983 and 1989a; see also Fig. 7). This type of camera is called partial metric or semi-metric and may be represented by some specially adapted Hasselblad, Leica and Rollei models (Table 1).

The réseau allows for the correction of systematic image errors caused by the unflatness of the film surface during exposure and any deformation coming from the photo-processing. The grid crosses are recorded on the film by front-projection at the instant of exposure. The imaged cross positions can be measured and the displacements as against their precisely calibrated counterparts on the réseau plate are used to eliminate the film deformation effects by numerical transformation into the réseau plane. For this transformation, different methods are feasible. Apart from two-dimensional polynomials which apply to the entire image a meshwise interpolation approach is recommendable (KOTOWSKI 1984).

Besides, the réseau establishes an image coordinate system common to all photographs taken by one and the same camera. The position of the perspective centre in image space and the lens distortion can be calculated in relation to this frame of reference by camera calibration (see e.g. FRYER 1989, WESTER-EBBINGHAUS 1989b). Focusing stops ensure that these calibration data, if they are once determined, are reproducible, e.g. within ± 30 - 50 μm for the ROLLEIFLEX 6006 metric. This value applies to the principal distance and the coordinates of the principal point, a value of less than ± 5 μm belongs to the lens distortion (WESTER-EBBINGHAUS 1983; PEIPE 1986).

Such figures are satisfactory for most tasks in architectural photogrammetry. However, the camera can also be calibrated simultaneously with the object restitution process ("on-the-job") if necessary. For this, multi-station photo-triangulation by bundle adjustment is the essential tool to obtain the best fit of all parameters of interior and exterior orientation together with the computation of three-dimensional object coordinates (e.g. KOTOWSKI et al. 1983 and 1988).

An unavoidable drawback of the réseau technique is given by the fact that the réseau has to be measured in addition to the imaged object information. But, in order to meet the accuracy requirements in architectural photogrammetry, normally, it is not necessary to work with the full set of réseau marks, e.g. the 11 x 11 crosses of the ROLLEIFLEX 6006 metric. Nevertheless, one has to determine how many marks must be measured in order to achieve a sufficient numerical film flattening.

Analytical photogrammetric methods of object restitution are fundamental to the efficient application of réseau technique because the camera characteristics are to be modelled mathematically. The image coordinates can be measured not only on a comparator or analytical plotter but on a digitizing tablet as a

Table 1 Réseau Cameras

Manufacturer	Type	Format [mm^2]	Lens [mm]
Leica	R5	24 x 36	15 - 180
Rollei	3003	24 x 36	15 - 135
Rollei	35	24 x 36	40
Pentax	PAMS 645P	60 x 45	45
Hasselblad	IDAC	60 x 60	38,70
Rollei	6006	60 x 60	40 - 350
GSI Inc.	CRC -2 *	115 x 115	65, 90, 120
GSI Inc.	CRC -1 *	230 x 230	120, 240
Rollei	LFC	230 x 230	165, 210
Linhof	TECHNORAMA 612 M	60 x 120	65, 135
Linhof	METRIKA 45	95 x 120	75, 90, 150

* with rear-projected réseau marks

simple and inexpensive device (measurement of enlarged paper prints with ROLLEIMETRIC MR2, ELCOVISION 10 etc.).

The combination of small format réseau camera, digitizer, personal computer and analytical data-reduction software represents an equipment suitable for economical architectural photogrammetry. In addition, photographs taken with film-based cameras can be digitized by a scanner and then measured on a personal computer or on a workstation by means of digital image processing (PHIDIAS (BENNING and EFFKEMANN 1990), DVP (GAGNON et al. 1990) etc.).

2. RESEAU CAMERAS

During the last 10 years, a lot of work in architectural photogrammetry has been successfully performed by means of réseau cameras. Consequently, the réseau technique is well-established nowadays. Réseau cameras available on the market are listed in Table 1.

Keeping in mind that the GSI cameras and the Rollei LFC are specifically designed for industrial photogrammetric applications it becomes obvious that the largest practical format for architectural survey has been 60 x 60 mm. Therefore, two cameras providing a larger usable film format have been newly developed in cooperation of the Institute for Photogrammetry and Cartography of the Bundeswehr University Munich, the BMW company and, of course, the camera manufacturer, the Linhof company in Munich. The METRIKA 45 (PEIPE 1990) and the TECHNORAMA 612 M may fill the gap between partial metric cameras of 60 x 60 mm image format and the metric UMK of 130 x 180 mm (Table 1).

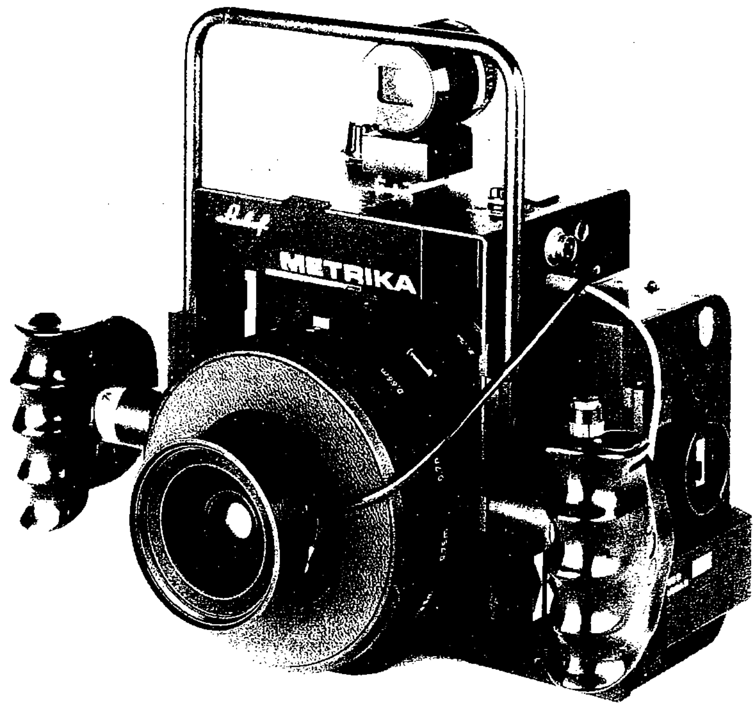

Figure 1 Front view of the METRIKA 45 (90 mm lens)

3. METRIKA 45

The aim was to develop a robust and universally applicable camera which in spite of the 4 x 5" format remains rather handy and fully portable to be used on location and even for hand-held shots.

Figure 1 presents an overall view of the METRIKA 45 and Table 2 gives the technical specifications. The camera housing consists of a black anodized aluminium body with permanently mounted lens in a heavy-duty barrel. Three lens systems, 75 mm and 90 mm wide angle and 150 mm normal lens, are available. Each lens cone is equipped with focusing stops which reproducibly determine a set of interior orientation parameters. A réseau plate is built into the camera body forming a rigid unit with the integrated lens barrel. The réseau plate is interchangeable to enable the use of different grid configurations.

A vacuum rollfilm back (Fig. 2) is attached to the camera-plus-lens housing. Standard 126 mm black-and-white or color rollfilm is suitable. For easy film change in daylight, the film magazine is provided with a hinged cover and a swing-out film carrier that do not have to be removed. Daylight loading cartridges accept approximately 5 m of film, that is equivalent to about 50 exposures.

All the camera operations such as vacuum pump, shutter release and film transport are fully motorized and electronically controlled. Multiple exposures, flash synchronization and simultaneous release of several cameras are possible. A data imprint module is installed in the rollfilm magazine. Exposure metering is only accomplished by external exposure meters.

Table 2 METRIKA 45 specifications

Format	4 x 5" (effective negative area 93 x 116 mm)
Film	126 mm rollfilm (e.g. Agfa Aviphot Pan, Kodak Technical Pan, Agfacolor or Agfachrome Aero)
Lens	1) Schneider Super Angulon 5.6/75 mm (wide angle lens) diaphragm scale f/5.6 to f/45, shutter speed range $^1/_{250}$ to 32 sec and B focusing mount with 16 click stops from 0.65 m to ∞ 2) Schneider Super Angulon 5.6/90 mm (wide angle lens) focusing mount with 16 click stops from 0.65 m to ∞ 3) Schneider Apo-Symmar 5.6/150 mm (normal lens) focusing mount with 13 click stops from 1.2 m to ∞
Réseau options	1) 10 mm grid spacing (9 x 11 crosses cover an 80 x 100 mm frame) 2) some crosses at the border of an 80 x 100 mm frame 3) 2.5 mm grid spacing (crosses cover the entire negative area)
Power supply	rechargeable NC battery integrated into the camera control unit or external power supply
Weight	about 10 kg
Dimensions	about 300 x 365 x 340 mm

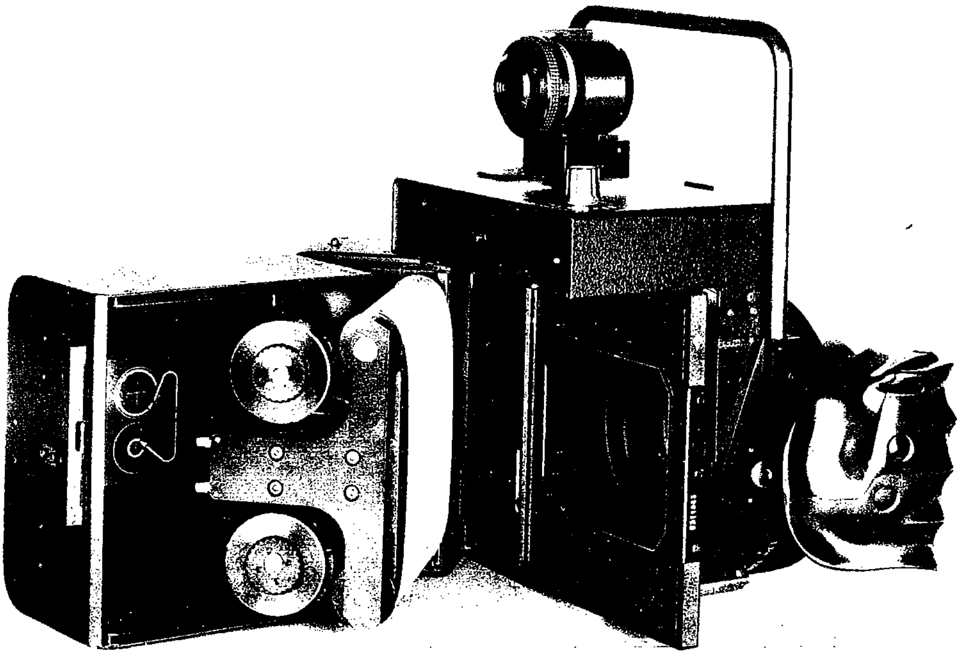

Figure 2 METRIKA 45: on the left the open rollfilm magazine with film cassettes and vacuum plate, on the right the camera housing with lens, réseau plate, control unit, optical viewfinder and handgrip

The METRIKA offers two possibilities of film flattening: a vacuum system and réseau technique. Réseau plates of different grid spacing are available on a custom order basis (Table 2). In general, the dimensionally stable rollfilm is properly flattened against the vacuum plate of the film magazine. Therefore, a limited number of réseau marks at the border of an 8 x 10 cm frame of the camera are enough to determine and eliminate the global film deformation, that means linear dimensional changes of the film. If a higher quality of numerical film flattening is required or the correct flattening is to be proved, respectively, a réseau of higher density (9 x 11 crosses) should be chosen. At last, the réseau with 2.5 mm grid spacing is recommendable to high-accuracy industrial applications only.

Each click stop of the focusing mount defines a special set of interior orientation parameters that has to be determined by a camera calibration procedure. Due to the stability of the METRIKA these calibration data remain unchanged, that means: they don't differ significantly after some months of work. In this regard, the METRIKA can be considered a metric camera. The photographs are suitable for measurement on analytical plotters, mono- or stereo-comparators, and so-called simple (analytical) systems.

In the following, first applications of the new camera in the recording of buildings and monuments are briefly mentioned. The photogrammetric survey of the cathedral of Siena in Italy (KOTOWSKI et al. 1989, FELLBAUM and WOYTOWICZ 1989) has been partially carried out by the METRIKA. Figures 3 and 4 show photographs intended for bundle triangulation and the detailed restitution of the facades. The second example is concerned with the recording of the city hall of Schwäbisch Gmünd performed in cooperation with the Landesdenkmalamt Baden-Württemberg in Germany (Fig. 5)

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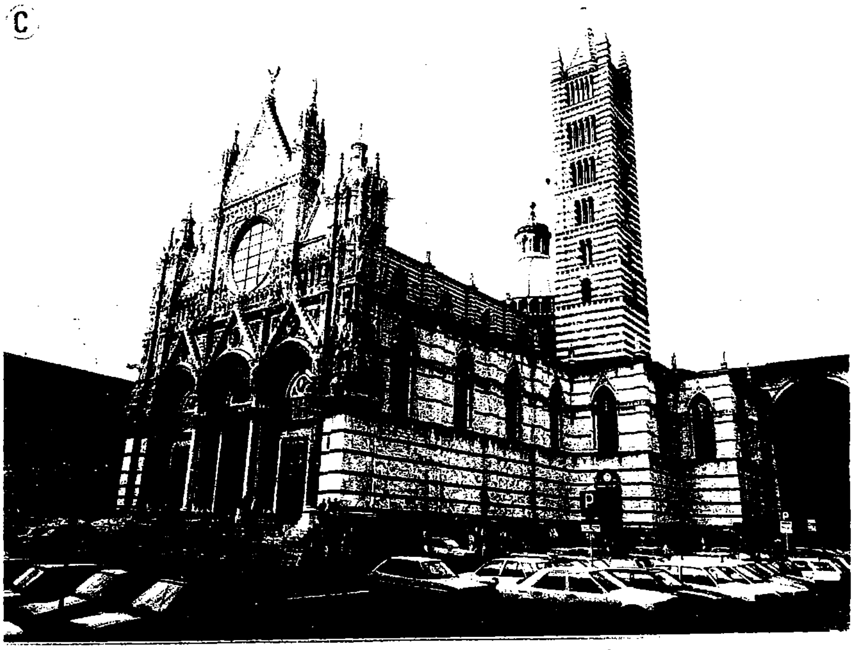
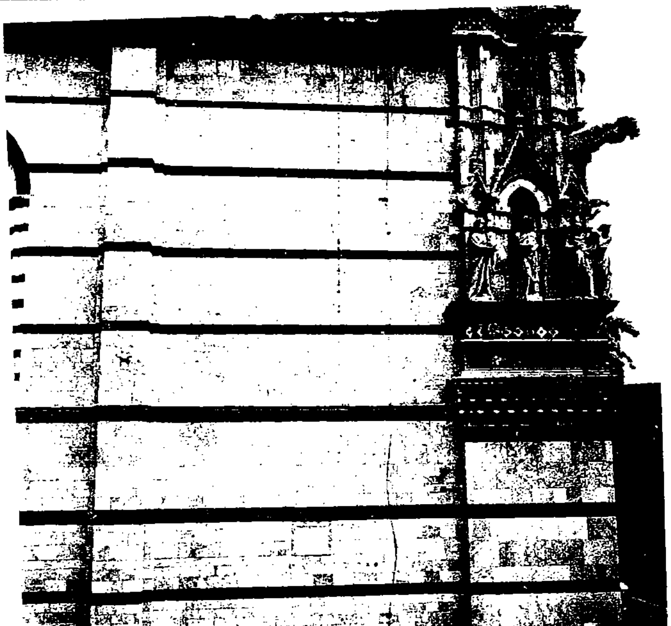


Figure 3



Cathedral
of Siena

Figure 4

4. TECHNORAMA 612 M

The second newly developed photogrammetric camera is based on the Linhof TECHNORAMA 612 PC, a sophisticated imaging system with the uncommon panoramic photo format of 60 x 120 mm (Fig. 6). The panoramic effect does not originate from a panoramic or super wide angle or fisheye lens. But from a standard high quality wide angle or normal lens which is masked to obtain an effective negative area of 55 x 110 mm.

Some technical specifications of the TECHNORAMA 612 M are displayed in Table 3. Any 120 and 220 rollfilm just as appropriate for 60 x 60 mm cameras can be used. Interchangeable lenses of 65 mm (wide angle) and 135 mm (normal lens) are available. The TECHNORAMA is designed as a manually operated camera, without vacuum system, automatic controls or motorized operation, featuring maximum machanical and optical precision.

The conversion from a non-metric into a semi-metric camera is done by mounting a réseau plate (Fig. 7) and installation of click-stop focus settings. For a first investigation, a small grid spacing of 2.5 mm was chosen. Preliminary test results indicate that 5 mm will be sufficient for a precise object reconstruction. Experience regarding the stability of the interior orientation parameters for a long period of time does not exist yet.

The panoramic image format promotes the photogrammetric survey of tall buildings such as church towers and other high-rise objects. On the other hand, stereophotography can be advantageously performed by means of the TECHNORAMA due to the large overlapping model area compared to square 60 x 60 mm photo format. Once again, the first test object for the new camera was the cathedral of Siena (Figs. 8 and 9).

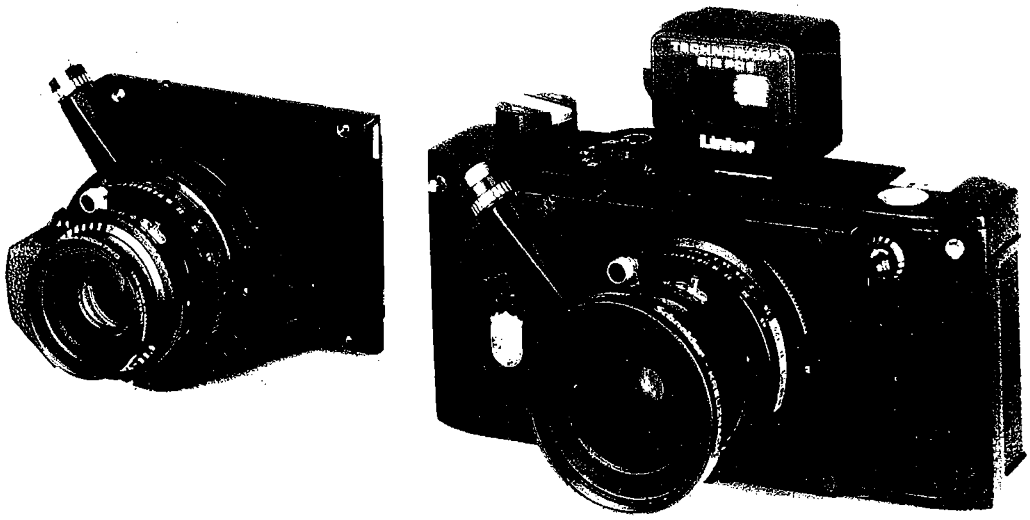


Figure 6 TECHNORAMA 612 M with 65 mm lens and, on the left side, the 135 mm lens

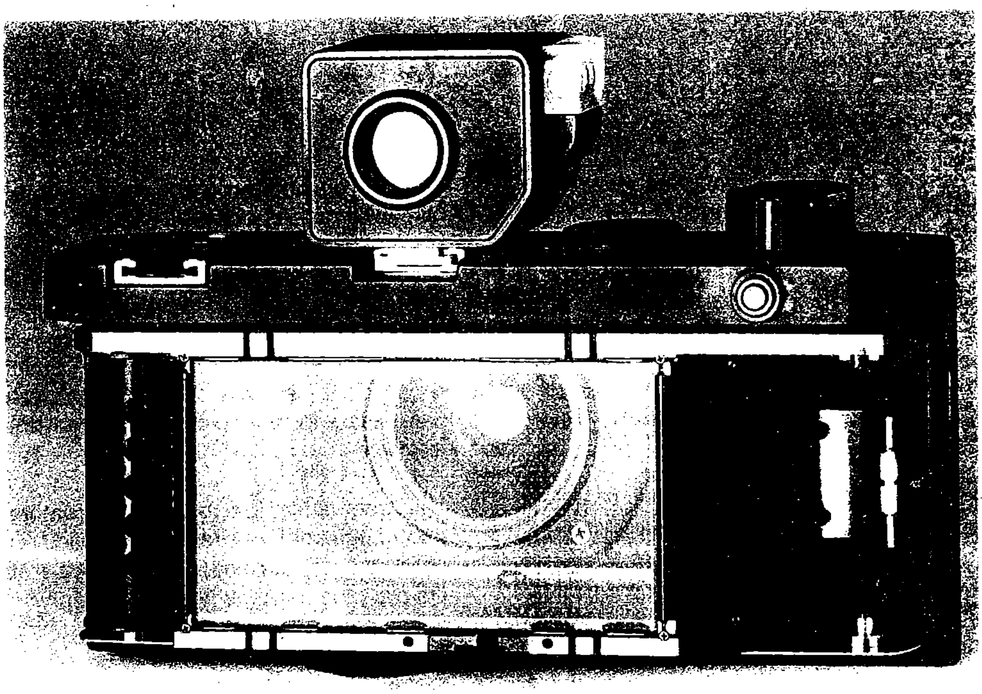
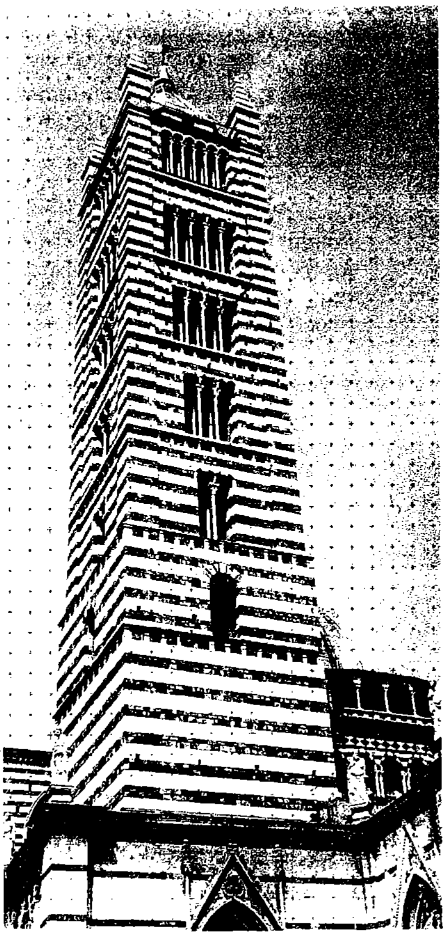
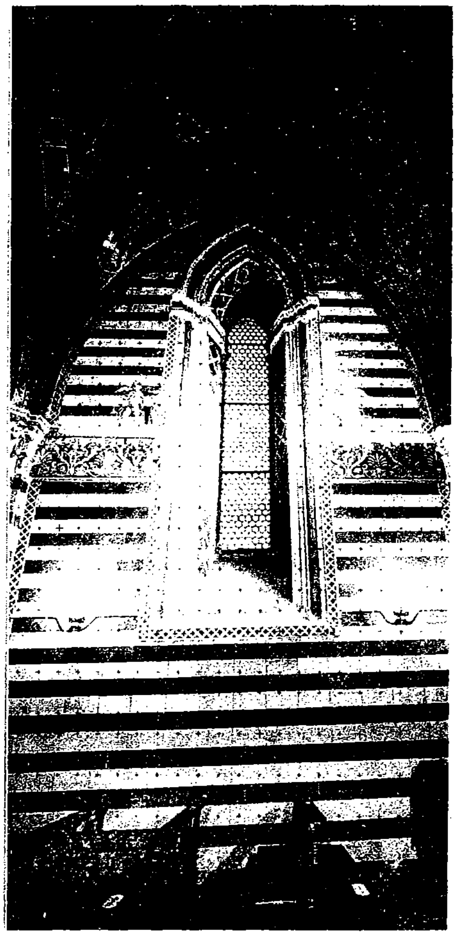


Figure 7 TECHNORAMA 612 M with réseau plate (view from the rear; camera back is removed)

Table 3. TECHNORAMA 612 M specifications

Format	60 x 120 mm (effective negative area 55 x 110 mm)
Film	rollfilm 120 or 220 for 6 or 12 photographs resp.
Lens	1) Schneider Super Angulon 5.6/65 mm (wide angle lens) diaphragm scale f/5.6 to f/45 shutter speed range 1/500 to 1 sec, B and T focusing mount with 12 click stops from 0.9 m to infinity 2) Schneider Apo-Symmar 5.6/135 mm (normal lens) focusing mount with 10 click stops from 3.5 m to infinity
Weight	about 2 kg
Dimensions	about 220 x 150 x 130 mm (with 65 mm lens)

Figures 8 and 9 Siena: tower and baptistry of the cathedral

5. CONCLUDING REMARKS

Réseau cameras are well introduced and proven image acquisition systems in architectural photogrammetry. In combination with analytical data reduction procedures, the réseau technique can be successfully applied. The new cameras presented in this paper overcome the photo format limitations of 24 x 36 mm and 60 x 60 mm cameras.

The development of methods for the photogrammetric recording of buildings and monuments is going on. Next step is the digital approach: digitized analogue photographs or digital images produced with CCD cameras are handled on powerful personal computers and workstations which provide image processing software.

In the near future, there will be a coexistence of several imaging systems, that means metric, semi-metric, non-metric and digital cameras, and also of several data reduction instruments and procedures. All these systems, if they are operational and effective, legitimize themselves. It is an important and serious function of the photogrammetrist to select the tools which fit best to a specific task or to support such a decision.

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Architectural Photogrammetry goes to the digital darkroom

P. Patias*

Abstract

Architectural Photogrammetry can and should benefit from the recent advances in Digital Photogrammetry and Image Processing. The purpose of this research is to suggest the replacement of the conventional darkroom lab by a "digital darkroom", which is composed by a computer, a graphics screen, a scanner and a laser printer.

The whole process includes image enhancement by digital filtering and a photo-grammetric image rectification with analytic means. The input data are scanned metric or non-metric photographs and the output is either a rectified raster image or optionally a vector image in standard formats.

The proposed procedure, which is based on the digital darkroom concept, does not require extensive photogrammetric knowledge and experience and is judged to be very useful for single image restitution for Architectural Photogrammetry.

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INTRODUCTION

Recent technological advances allowed the development of techniques and instrumentation, which otherwise would require extensive computer power and resources (Gruen, 1989, Rüther and Parkyn, 1990). This event actually suggested the replacement of the costly conventional photogrammetric instruments by equipment covering a range of capabilities and prices. The direct benefit for Architectural Photogrammetric applications is the chance to use portable, stable and user friendly equipment, without having to compromise in accuracy requirements or pay the price of the over-killing, highly accurate but very expensive, multi-purpose photogrammetric instruments.

Over the last few years we have witnessed a line of research and production aiming to the development of small, cost-effective systems for stereophotogrammetry (eg. Gagnon et.al., 1990), remote sensing applications (eg. Welch, 1989), etc.. The first such systems to appear were suggesting using a regular digitizer (eg. Faig et.al., 1990), instead of a comparator, to make measurements of photo-coordinates. Although such systems are quite easy to use and require very little experience and training, they are characterized by disadvantages like:

- The digitizer's low pointing precision (acceptable rmse about 127μm).
- Problematic stereoscopic viewing.
- No completeness checking is provided to the user.
- They are based on analytical photogrammetry concepts, that is the picture is not treated as a digital means but the user can only collect and process isolated points and convert them to graphic vectors to be plotted.

Trying to overcome these disadvantages, other systems (like the one suggested by Gagnon et.al., 1990) follow another approach and use scanned photographs and basic procedures of Digital Photogrammetry. However, both kind of systems suffer from shortcomings like: they provide no image processing and photometric enhancement, they only output vector data.

This paper is concerned with the description of the recently developed Digital Rectifier (DR) system (Patias, 1991a). This system can be considered as a hybrid image processing - photogrammetric system, which is based on off-the-self low-cost hardware, powerful software and user friendly interfaces. It can be used very easily and requires only marginal knowledge on computers and photogrammetry (Patias, 1989). While the system is being still enhanced, preliminary tests indicate results over-passing the accuracy requirements for Architectural Photogrammetry projects.

HARDWARE CONSIDERATIONS

The hardware components of the DR-system were kept off-the-self and low-cost. More specifically, for proper performance, the Digital Rectifier suggests :

- A standard IBM-compatible PC with Intel 80286 or 80386 microprocessor (math-coprocessors are used when present but not required) with 640Mb of RAM (cache memory can be taken advantage of,

although not required), at least 40Mb Hard disk and a pointing device (mouse, digipad or digitizer).
- A standard 640x480 by 4-bit (16 colors) VGA card and display monitor (either monochrome or color).
- A standard A4 scanner with resolution at least 300dpi (dots/inch).
- A standard laser printer (with compatible resolution) and optionally a standard vector plotter.

OPERATIONAL ASPECTS

The DR system's basic concept of work-flow is pictured in Fig. 1 and contains the next phases :

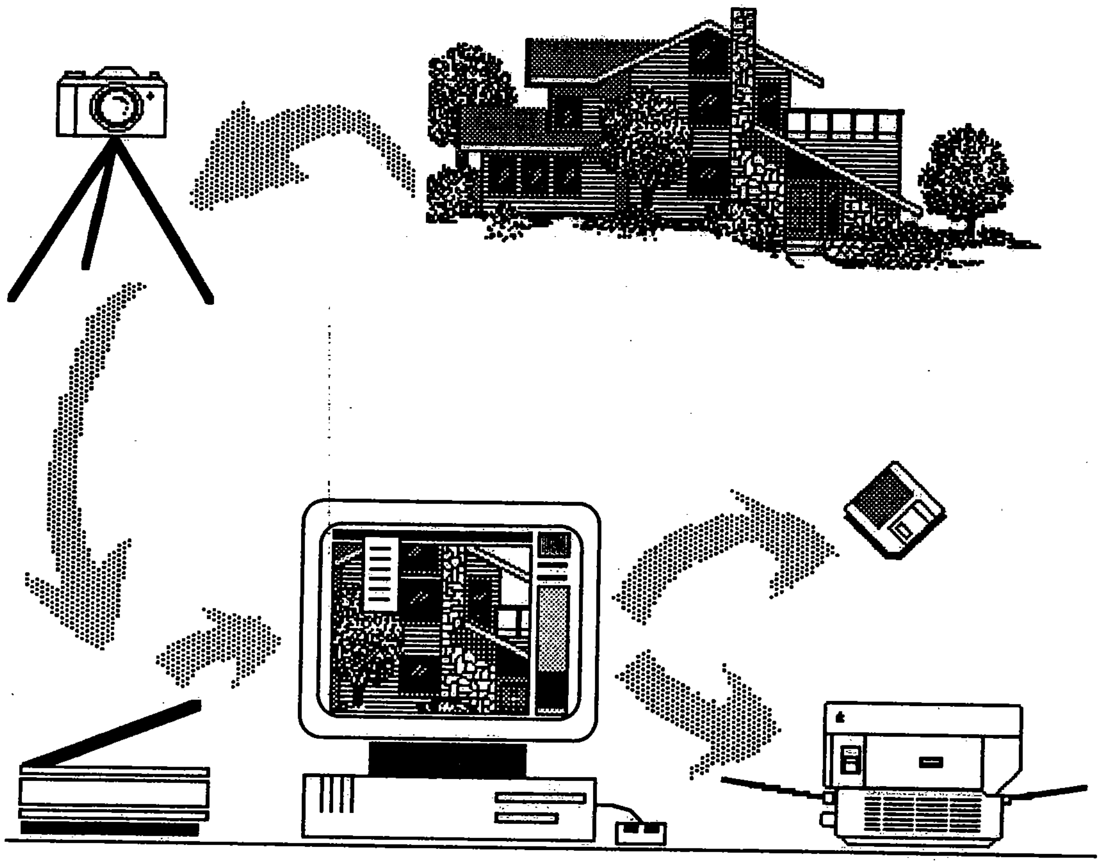

Figure 1. The Digital Rectifier (DR) system concept

1. The data are captured using either metric or non-metric camera.
2. Enlarged paper print is produced through an enlarger.
3. The produced paper print is scanned and stored into the computer.
4. The data processing deals with :
   a. Enhancement of the photometric characteristics of the image so that measurements can be obtained easily and accurately.
   b. Digital rectification of the image using ground control. Then the user has the alternative to either apply the transformation parameters

to collected vector data only or apply them on a pixel-by-pixel and thus rectify the whole picture.

5. Translation of vector data to standard formats for further editing and plotting.
6. Raster reconstruction, resampling and enhancement of the rectified photos, production of digital mosaics, laser printing.

In order to achieve these tasks, the Digital Rectifier is accompanied by the Digital Rectifier-Utilities (DR-U), an image processing module. In Figures 2 and 3 the functions of the DR system and the DR-U are shown :

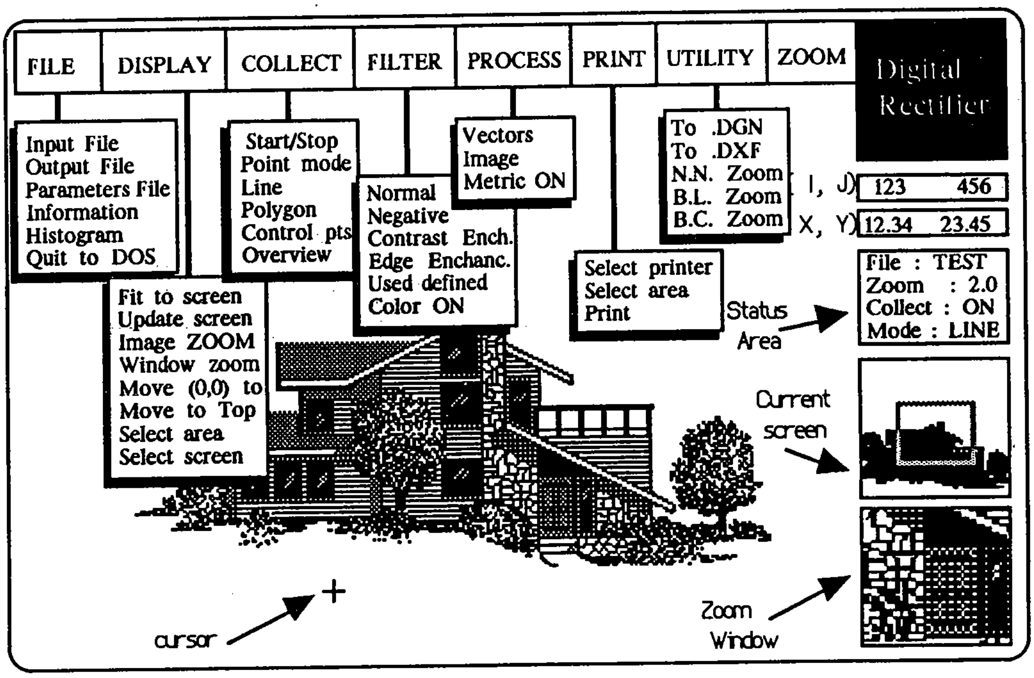

Figure 2. The Digital Rectifier (DR) system functions

1. DATA ACQUISITION - PHOTO ENLARGEMENT

The digital data are captured by scanning the enlarged print. Normally (it depends on the format of the camera) enlargements of x3-x5 suffice (Needham and Smith, 1984), given an A4-size scanner. The purpose of the enlargement is to compensate for the low resolution of the scanners. Photo-enlargements have been used in many applications before (eg. Welch and Jordan, 1983, Faig et.al., 1990) with success.

The DR system can read raster files in most of the standard formats, like TIFF, PCX, GIFF, or regular ASCII files. The scanning procedure can use any scanner, but for better results resolution of 600dpi (pixel size 42μm) is recommended.

The cumulative histogram of the grey values and other relative information regarding the picture (i.e. size of file, number of pixels, etc.) are computed and stored in a file for future reference. If the image have been rectified before, the rectification parameters are stored in the Parameters File and they can be used any time for on-line rectification of the collected points (Konecny, 1979, Patias, 1991b).

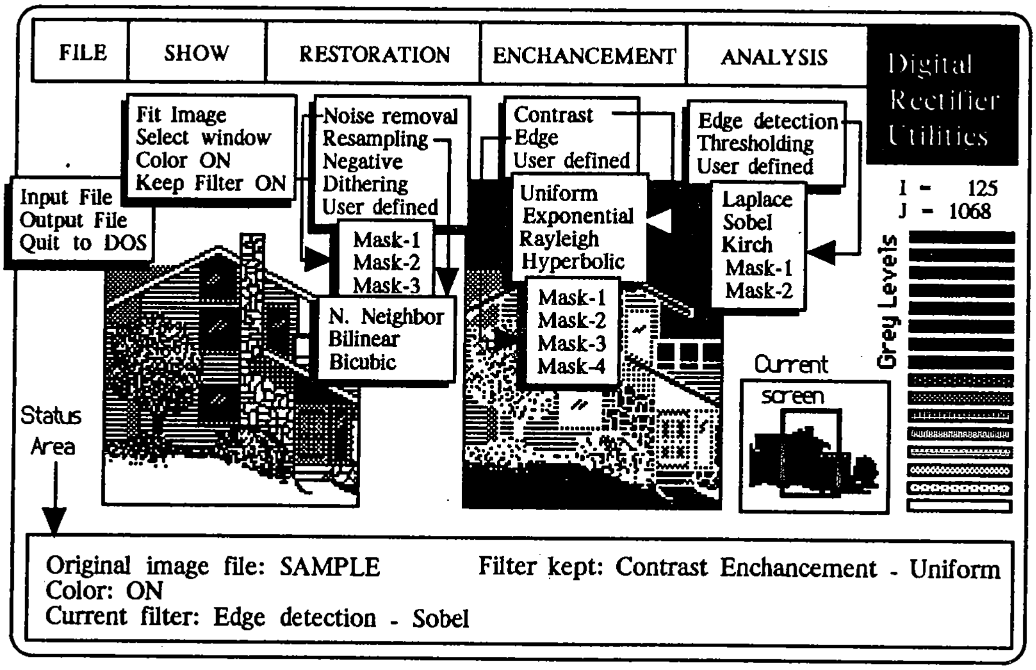

Figure 3. The Digital Rectifier - Utilities (DR-U) functions

2. IMAGE ENHANCEMENT

The image enhancement processes are provided by the DR-U module. The purpose of image enhancement is to change the photometric qualities of the image (eg. Dawson, 1989, Mertsios et.al., 1989, Moik, 1980), so that the collection of the data to be performed with greater ease and accuracy.

During image enhancement the user selects a window of the whole image to experiment with. The original image is displayed and next to that the enhanced counterpart is also displayed, for comparison. During this phase the following tasks can be performed by DR-U:

NOISE REMOVAL

Low pass filtering using convolution of 3x3 kernels is used. The purpose is to eliminate any high-frequency noise present in the image. The user has the option to either use any of the three masks/kernels, which are provided, or design and use its own 3x3 masks. The latter can be entered by any editor and stored in a file. Any number of such files can be created and be used later on by their name.

CONTRAST ENHANCEMENT

Images of poor contrast characteristics usually result in poor recognition of terrain characteristics and thus to low pointing accuracy. The purpose of the contrast enhancement option is to modify the structure of the original histogram, changing in this way the percentage contribution of each (or groups of) grey value to the cumulative histogram. Since the original histogram is already stored, the user is given the alternatives of modifying it in a uniform, exponential, Rayleigh or exponential form (or of course use its own procedure).

EDGE ENCHANCEMENT

Sharpening of the edges is a feature that permits the better recognition of the points (pixels) lying on a line. Therefore more accurate measurements can be obtained. This is done by the edge enhancement option using any of the 4 masks provided by the module.

EDGE DETECTION

For even sharper edges the edge detection algorithms (5 options) can be used.

THRESHOLDING

The purpose of the thresholding is to mask small variations in grey values. It is normally used after edge enhancement/detection in order to further enhance the image and mask everything but the enhanced line features. The user can interactively choose the threshold value by picking the corresponding grey value from the chart at the right (see Fig. 3).

The user has the option of passing more than one filter over the original image. That is he can keep the filtered image and perform another filtering on top. The currently used filter, the filter kept and other relevant information are displayed in the status area at the bottom of the screen. After this initial experimentation and once the user has decided the sequence of the filters to be applied, the whole image is filtered and stored for subsequent use by the DR system.

3. DIGITAL RECTIFICATION

The DR system can perform the rectification either of the collected data only, or of the whole image.

DATA COLLECTION

The whole image is displayed into a small window at the right of the screen from where the user can pick a portion to work with. The chosen portion fills the screen and the collection of the data starts. Using the COLLECT menu the user has the option of collecting control points, feature points, or other features using the line and polygon options. The collected data are displayed in different colors, for completion checking.

The user can follow the cursor movement since its both pixel (I,J) and ground coordinates (X,Y) are continuously refreshed and displayed on the screen. By moving the cursor and pressing the left key the point is registered, while the right key is used to mark the end of a line or polygon.

For better pointing the DR system provides three features: First, the user has additional opportunities to further enhance the image by filtering. Second, he can choose to zoom (as many times as he wants) the displayed image by selecting the area he is interested in. Third, a small zooming window gives him the possibility of having another area displayed with a different zoom factor (other than that of the whole screen). Zooming can be performed with three different algorithms, i.e. using nearest neighbor, bilinear, or bicubic resampling. These algorithms differ from each other in quality, accuracy and speed and the user has the option of using either one by checking the appropriate selection into the UTILITY menu.

The collected data are automatically stored into the desired output file in a generic format. The coordinates of these points are either pixel coordinates (in the case of no previous rectification of the image) or ground coordinates (if a rectification parameters file exist).

Then the user can move to another portion and so on until he finishes the data collection. A final completion check is offered with the "OverView" option. Using this option all the collected data are superimposed on the image and displayed in any portion or the whole image.

VECTOR RECTIFICATION

Once the image and the ground coordinates of the control points (more than 4) are known the standard analytical rectification procedure takes place. The output is a rectification parameters file which establish the relationship between the image and the ground reference frames. By using these parameters in an on-line mode all the collected points, line and polygons are automatically transferred to ground. Subsequently, the user can choose to translate the generic file format to some standard graphic formats like Intergraph MicroStation's .DGN, or Autodesk AutoCad's .DXF for further editing, plotting and connection to databases. It should be pointed out that the translated features remain also as points, lines or polygons into the new files leaving thus only minor editing and touching-up to be done by the user.

RASTER RECTIFICATION AND RECONSTRUCTION

The other option is to rectify the whole image off-line. This is done on a pixel-by-pixel basis using the known rectification parameters. The rectification of an input image f(k,l) produces an image whose grey-level values are functions of non-integer raster coordinates g(x,y). Thus f(k,l) may map between the pixels of g(x,y) or, in other words, many pixels of the output image may have a grey value of zero. Some form of grey-level interpolation or resampling is then needed in order to obtain output values at integer positions (eg. Hood et.al., 1989).

The DR-U resamples the image using the pixel filling technique and gives the user the choice of the interpolation scheme (nearest neighbor, bilinear, or bicubic).

ENHANCEMENT OF THE DIGITAL RECTIFIED IMAGES

In order to improve the appearance of the digital rectified photographs, filtering and contrast enhancement can be applied to the images (Kidwell and McSweeney, 1985). This is accomplished by using convolution with an edge enhancement kernel, increasing therefore the high-frequency component and thus sharpening the images. The next step is the cumulative histogram stretch by using the contrast enhancement option.

DIGITAL MOSAICKING OF THE RECTIFIED IMAGES

One major drawback in analog rectification and mosaicking is the existence of brightness discontinuities along the mosaic seams. In digital mosaicking such problem can be easily overcome. DR's basic concept involves the use of the histogram equalization technique between the adjacent rectified images. Once the rectification of the whole image or the mosaic has been performed and the rectified image's quality has been enhanced, the output can be routed to the laser printer.

SYSTEM PERFORMANCE

In order to assess the pointing precision of the DR system multiple measurements of targeted points have been performed. The photograph was of original scale 1 : 140, while the paper print was a x4 enlargement (therefore a pixel has size 42/4=10.5μm). From 50 such measurements, made by unexperienced people, the standard deviation of the repeatedly determined point positions σ_{xy}= 0.4 pixels (4.2μm), with maximum difference between two determinations of the same point not exceeding 1.3 pixels (13.5μm). Three similar sets of measurements have been obtained using 2x and 4x zooming on the original image and using an image enhancement filter. The computed statistics are shown below:

Table 1. Pointing precision of targeted points using different measurement modes

Measurement mode (n=50)	σ_{xy} pixels (μm)	max.difference pixels (μm)
Original 1x	0.4 (4.2)	1.3 (13.5)
Original 2x	0.3 (3.1)	0.5 (5.2)
Original 4x	0.1 (1.0)	0.2 (2.1)
Enhanced 1x	0.3 (3.1)	1.0 (10.5)

In order to evaluate the system performance, we have conducted the following test. A photograph of Saint Dimitrios, one of the oldest byzantine churches in Thessaloniki has been chosen. The original photograph has been taken by our Wild P-32 camera, c=64.11mm and format 80x60mm. The scale of the original photo was approximately 1 : 220. 19 signalized control points have been used on the church's wall and their ground coordinates were determined through an adjustment of the topographical measurements.

The paper print was a x3 enlargement (approximate scale 1 : 80) and was scanned by the HP Scan-Jet scanner at a resolution of 600dpi (42μm) and 16 grey levels. Two sets of measurements of the photo coordinates of the 19 control points were obtained. The first set consists of the measurements made on our Wild STK-1 stereo-comparator, with a resolution of 1μm, on the original negative. The second set consists of the measurements made by the DR system on the scanned paper print enlargement.

For both data sets the same 4 (minimum) control points at the edges have been used in the rectification process, while the rest 15 points were used as check points. The results obtained are shown in Table 2. The planimetric error vectors v_i between ground and rectified DR measurements and between STK and DR rectification were calculated and the following statistics were obtained :

	Ground - DR	STK-DR
mean v_i =	0.026m	0.007m
rmse v_i =	0.020m	0.006m
max v_i =	0.038m	0.015m

Table 2. X, Y coordinates (m) obtained by topography and rectification using STK-1 or DR measurements.

Point #	Topography		STK rectification		DR rectification	
	X (m)	Y (m)	X (m)	Y (m)	X (m)	Y (m)
1	12.007	25.602	12.010	25.602	12.011	25.602
2	13.939	25.532	13.940	25.536	13.940	25.534
3	15.935	25.545	15.939	25.548	15.944	25.547
4	17.929	25.500	17.934	25.504	17.939	25.500
5	19.951	25.532	19.957	25.536	19.958	25.529
6	19.949	23.659	19.937	23.641	19.936	23.639
7	17.944	23.647	17.946	23.622	17.951	23.618
8	15.937	23.658	15.950	23.641	15.963	23.626
9	13.940	23.647	13.972	23.619	13.990	23.607
10	11.934	23.667	11.967	23.646	11.966	23.643
11	9.942	23.664	10.003	23.632	9.998	23.637
12	13.301	21.564	13.291	21.564	13.285	21.567
13	15.137	21.083	15.113	21.088	15.111	21.089
14	17.301	21.630	17.281	21.633	17.286	21.633
15	17.249	20.022	17.213	20.034	17.213	20.035

These results are not the best that could be obtained since the contrast of the photographs was not good. Actually the inability to precisely point the target is reflected to the STK measurements as well. However they are actual work results and this is the reason why we present them here.

GROWTH POTENTIAL

The Digital Rectifier system is still being enhanced and tested. However, the preliminary tests show that its growth potential is high. At present we are working towards three main objectives. The first is the enhancement of the algorithms using non-metric cameras, so that even better results can be obtained. The second, is the enhancement of the mosaicking algorithms in order to get mosaics of better visually quality (better than the original images), while occupying less computer storage memory. The third, is the ability to make stereoscopic measurements, together with automatically performing interior orientation and stereo-image correlation.

ACKNOWLEDGEMENT

The author wishes to thank Mr. L. Sehides, student in our Department, in converting a concept to a functioning system, with his hard and devoted work. The work of Mr. I. Papaioannou, cartographer, in converting the DR files to standard vector formats and Dr. I. Paraschakis, Assist. Professor in our Department, in working with raster TIFF files is gratefully acknowledged.

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XIV INTERNATIONAL SYMPOSIUM
2-5 October
Delphi, Greece.

VMAP/SGS. A video analytical plotter for efficient and low cost solutions, for Architectural Photogrammetry.

by

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1. INTRODUCTION:

The technical advances of the computer and particularly the scanning technology, are having a serious impact in photogrammetry today:

- The design and use of the new photogrammetric equipment, (ie analytical stereoplotters) is simpler and easier.

- Various applications such as Aerial Triangulation and Orthophoto requiring laborious and time consuming techniques in data collection, are becoming more automated.

- The capability of capturing, storing, displaying and analyzing the various images using digital means, offers us opportunities that would not otherwise exist.

The purpose of this paper is to introduce the ECLIPSE 2000 Analytical plotter, and compare it to conventional Analytical plotters. This comparison will highlight the obtained benefits of using the new computer technology.

2. DISPLAY OF SCANNED IMAGES:

Conventional Photogrammetric equipment use diapositives of aerial photographs/satellites for the creation of stereoscopic models. These models are generated analytically or empirically, and are observed through optical subsystems.

The ECLIPSE 2000 can accept scanned images instead of photo material. Scanned at a resolution to satisfy the accuracy requirements, these images are stored in digital form and displayed on the standard VGA monitor, and viewed with a simple stereoscopic subsystem similar to katoptric stereoscopes.

The ability to display stereoscopic images in digital form is changing radically the design of the new generation of analytical plotters.

It eliminates the need of photo material and expensive hardware.(Photo holders, stepping motors, and mechanical links).

Similarly, the floating mark subsystem found in analytical stereoplotters, has been substituted by a 3 button mouse, that is also used for collecting information, activating the menu and selecting menu options.

The new restitution instrument, solely a computer and a stereoscope, is fully analytical, employing the same mathematical model that conventional analytical plotters do.

3. STEREOSCOPIC SUPERIMPOSITION:

Another big advantage of the ECLIPSE 2000, is its stereoscopic superimposition ability.

The vectors whether generating a new map, or updating old maps) are superimposed and displayed against an overlay of images. This assists in the quality control, and it is the only efficient method of updating existing maps.

4. MONOSCOPIC SUPERIMPOSITION, DIGITAL ORTHOPHOTO:

The ECLIPSE 2000 system, has also the capability to correct the image file, given the Aerial Triangulation, DTM's, or break line information.

The end result is digital orthophoto, and 3-D digital restitution, with monoscopic vision and superimposition

5. SYSTEM EASY TO LEARN AND USE:

Because of its simplicity, the ECLIPSE 2000 is easy to learn and use.

It does not require operators with photogrammetric training, its capabilities for monoscopic digitizing makes it unique for quick cadastral, and resource type of mapping.

Persons with normal stereoscopic vision, are capable of using the system for more precise measurements, including Terrestrial and Architectural Photogrammetry. (Simply the operator locates the cursor on the screen, and digitizes the information as in digitizing tablets.

6. COMPATIBILITY WITH OTHER SYSTEMS:

The data collected with the ECLIPSE 2000 system can be edited and plotted with a variety of plotters(WILD, CALCOMP, HP).

Further, the data can be translated to other systems such as AUTOCAD, INTERGRAPH, ARC/INFO and ASCII.

7. ADVANTAGES - DISADVANTAGES:

Compared to present analytical stereoplotters, the ECLIPSE 2000 has the following advantages:

- It is a PC based restitution instrument, offering 3-D data collection/editing through mono/stereo vision and digital orthophoto.
- It offers unique capabilities for map updating and quick resource type of mapping.
- Its cost is low, compared to other analytical stereoplotters.
- It requires no maintenance, and it occupies small office space.
- It does not require operators with special training.
- It is easy to learn and use.
- When high resolving power is required, the scanning must be performed with high resolution. This creates large files that require increased storage capacity and slow down the image display.

Simple Systems for Architectural Photogrammetry

Thursday, October 3rd, 1991, 11:30 - 13:30

Chair: G. Veis

Adam Boroń, Józef Jachimski
University of Mining and Metallurgy
Cracow, Poland

Accuracy improvement for analogue evaluation of semimetric stereopares

1. Introduction

Semimetric cameras, being accurate, inexpensive and easy to use, are each year more often applied for recording of historic monuments.

As a result of adaptation of the Pentacon Six TL photographic camera for the reseau pictures production, not only the possibility of analytical high accuracy correction of photo-coordinates for distortion and film deformations was achieved, but also the definition of the fiducial plane was improved by the better flattening of the film pressed against the glass-plate. The pictures made using semimetric-reseau camera fit well for high precision recording and can be with good result evaluated by means of analytical plotting techniques.

In the photogrammetric laboratories there are, however, still many analogue plotters (mostly of mechanical solution), and they can be easily rented at present on the inexpensive conditions. It is very likely, that for the recording of historic monuments, usually money-limited, the old analogue plotters will still be used in the predictable future. Therefore it is quite important, for the practical reasons, to reduce influence of photo-coordinate errors on the result of analogue plotting. So, based on the old Porro-Koppe principle, an successful experiment was made to reduce the camera objective distortion and support applications of the semimetric and nonmetric pictures.

2. Pentacon-Six-reseau camera

At the Photogrammetric Research of The University of Mining and Metallurgy (AGH) in Cracow a semimetric camera 60 x 60 mm was constructed [1,2]. This camera was build on the basis of the Pentacon Six TL photographic camera, by equipping it with the 1.6 mm thick reseau plate. Furthermore, a circular level was attached to the camera body and a mark was introduced to the field of view of the camera view finder to enable more accurate angular camera orientation in the field. There also was corrected the position of the zero-mark of the distance scale on the camera objective due to the change of optical properties after a glass plate was inserted to the optical system. Some changes were done to the film flattering device to make there more room for the added reseau glassplate.

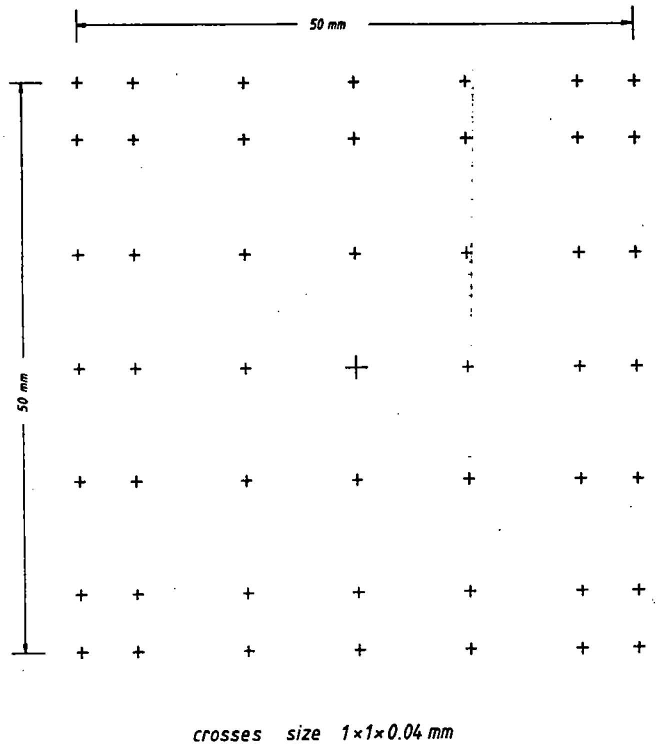

fig.1. The reseau-master-pattern for the Pentacon-Six-TL.

This 60x60 mm semimetric camera allows due to reseau grid, for at least 10 times better accuracy of analytical evaluation then that available with not adapted photo camera. Using the bilinear transformation on 9 reseau control points, performed separately for each quarter of the picture, we can get the average residual deviation of recorded image point equal avr. $m_p = \pm 3.6\ \mu m$. The values of systematic deformations are stable and do not differ among the various pictures more than $\pm$ 0.6 μm, but they are not identical in the separate quarters of photograph and range from $\pm$ 2.6 μm to $\pm$ 4.8 μm.

3. The reductions for camera distortion

Using a flat test field of 121 control points the camera was calibrated and distortion curves were calculated for object distance 4 and 2 m. The differences of symmetric radial distortion f or this two distances does not differ more than 7 μm. The distortion value is shown on the fig 2. Distortion is quite large, up to 113 μm, and picture influenced by such distortion could not give good results in analogue plotting.

So, to reduce the influence of objective distortion on the analogue-mechanical evaluation, an experiment was made based on the old Porro-Koppe law. According to that law we can expect the 100 % distortion reduction when performing the reverse projection of the bundle of rays using the same objective, and placing the negative in the objective focal plane (in the image space). But to get sharp photo-copy of the original picture with the reduced distortion we must place the negative not in the focal plane, but further, in such a distance from the objective, which is proper according to the lens equation (fig.3).

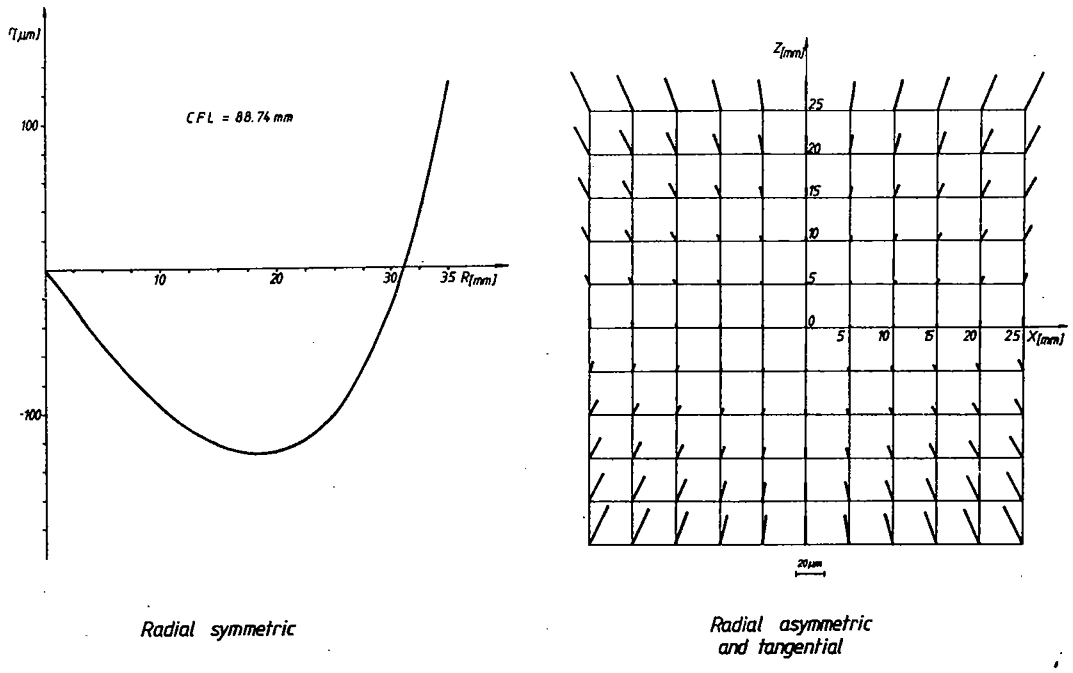

fig. 2. The distortion of camera objective Biometar 2.8/80 focused for the 4 m distance.

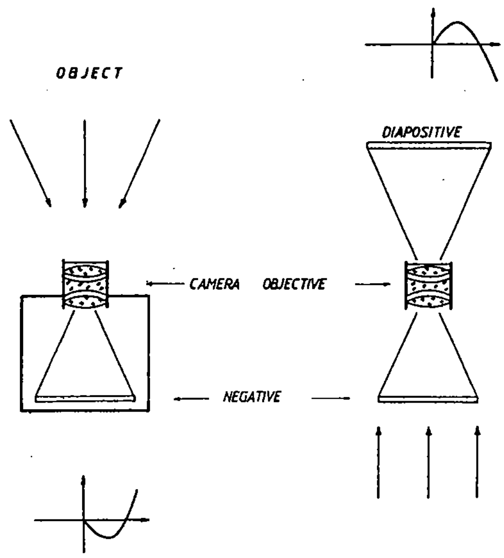

fig. 3. Porro Koppe law in the photo-copying process.

In such an arrangement our distortion can not be fully eradicated this way, but it can be significantly reduced. On the fig. 4 there are shown three distortion curves: of negative (direct light beam), of reverse light beam, and combined. Due to opposite signs and almost the same value of distortion of negative, and distortion of two times enlargement of an original exposed in the reverse light beam, we can reduce the negative distortion over five times, down to 20 µm. It should be taken into consideration, however, that the tangential distortion and nonsymetric component of radial distortion will be properly reduced only if the objective will be in the same $\varkappa$ position, in relation to the negative, as it was at the moment of the field work.

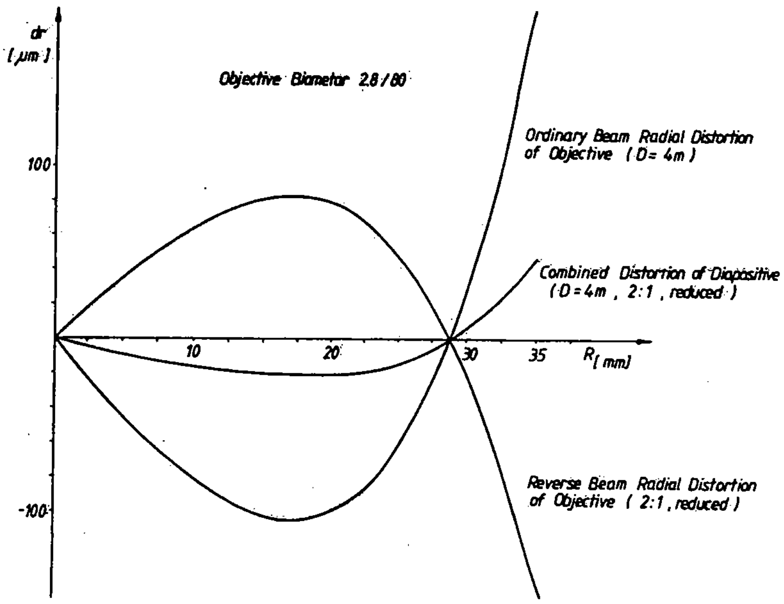

fig. 4. The curves of the radial symmetric distortion: for the negative recorded in the direct beam of light at the object distance equal 4 m, for the enlargement 2:1 of an original made in the reverse beam of light, and for the two times enlarged diapositive copied from the negative in the reverse beam of light using the same camera objective.

Finally, the diapositive made from the original negative by copying it in the reverse light beam using the same camera objective, can be practically accepted as distortion free for detailed plotting of pictures for many projects connected with the recording of historic monuments.

Conclusions

The semimetric camera made at the photogrammetric laboratories of the University of Mining and Metallurgy (AGH) by adaptation of Pentacon Six TL phtographic camera for the reseau-recording of images can provide analytically reduced image coordinates of the accuracy of ± 3.6 μm or even better.

For the analogue evaluation the negatives can be copied in the reverse beam of light using the same camera objective and this way the objective distortion influence can be reduced down to 20 μm.

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"STEREOBIT/20" AND "RESEAU": A NEW PHOTOGRAMMETRIC ANALYTICAL SYSTEM FOR SEMIMETRIC IMAGES. THEORY AND SOFTWARE

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ABSTRACT

The use of semimetric cameras in the architectural applications of photogrammetry is becoming more and more consolidated.

The new "motorized" STEREOBIT/20, a simple but rigorous analytical plotter, based on the "Inghilleri" principle of stereoplotting (only two stepping motors for the parallaxes control) appeared on the market only a few months ago. This instruments is equipped with an 80286 PC-DOS computer. It costs less than 1/4 of the price of the usual analytical plotters. It operates with aerial photos (9"x9") and the smaller terrestrial metric, semimetric or non metric images (slides or paper prints). Accuracy, easy to use, software availability, give to this instruments the best cost/performance ratio.

RESEAU is a user-friendly software specially designed for the semimetric image plotting. It manages all the reseau images available on the market.

Calibration is based on affine or homographic transformations, prepared in a preliminary "calibration" phase and achieved in real time during the restitution phase.

The calibration, orientation and restitution procedures are computer assisted with an efficient user interface based on "pop- up menus".

Theory and software organisation are illustraded in the paper.

1. INTRODUCTION

The increasing availability of a series of "semi-metric" cameras, produced by different manifacturers (ROLLEI, PENTAX, HASSELBLAD, etc.) offers the photogrammetric user new possibilities of taking images in an easier and cheaper way.

Such cameras combine the operational ease and flexibility of the ordinary amatorial cameras with the metric aspects of the classical photogrammetic cameras.

The restitution phase, of course, needs special software for the real-time correction of the plate coordinates, according to the values of the calibrated position of the reseau crosses.

Every analytical plotter can manage such images, provided that a special program is available for this purpose.

However, the cost of an analytical plotter and the complexity of its sophisticated procedures could cancel the advantage of using the low cost and simple semi-metric images.

According to this philosophy, small organisations or single researchers in particular, require a cheap user friendly instrument able to carry out all the photogrammetric functions in a rigorous but simple way.

A very recent instrument of this type was presented a few months ago by GALILEO SISCAM, the main Italian manufacturer of photogrammetric instruments.

A complete package of photogrammetric programs, including the procedures for a general use of semimetric images, has been developed and tested in cooperation with the researchers of the Politecnico di Torino, Dipartimento di Georisorse e Territorio [1].

This paper describes the hardware and

1) The team, directed by Prof. S. DEQUAL has been financially supported by the Italian Ministry for University and Research (MURST 40%).

software performances of the instrument, called STEREOBIT/20.

2. THE NEW "STEREOBIT/20"

Some years ago GALILEO SYSCAM presented a low cost, simplified analytical stereoplotter, called STEREOBIT, where x- and y-parallaxes were manually eliminated by the operator and a Personal Computer gave the XYZ ground coordinates of the collimated points in real time.

A new version of this instrument was produced only a few months ago, giving the STEREOBIT the full performances of an analytical plotter, at less than 1/4 of the price of the analytical instruments available on the market.

2.1 Description

The instrument is based on the "Inghilleri" principle [1974]: the differential x- and y-parallaxes are directly controlled by the computer, by means of only two stepping motors, instead of the four movements usually controlled in most analytical instruments.

The analytical bases are summarized in the next section.

First let's look at the hardware scheme of the instrument (fig. 1).

A main carriage (1) is moved directly by the operator for quick movements or by a pantograph (2) for more accurate collimations.

The floating mark is obtained by stereoscopic observation, through the stereoscope (3), of the marks engraved on two glass plates (4) superimposed onto the photographs.

A secondary carriage (5) moves along x and y directions, allowing differential movements of the left image. Such movements can be driven directly by handweels (6) or controlled by the computer.

In both cases they are transmitted to the carriage by two small stepping motors.

The size of the plate holders permits the observation of the aerial photos 9"x 9" and, obviously, of all the smaller formats of the terrestrial camera images.

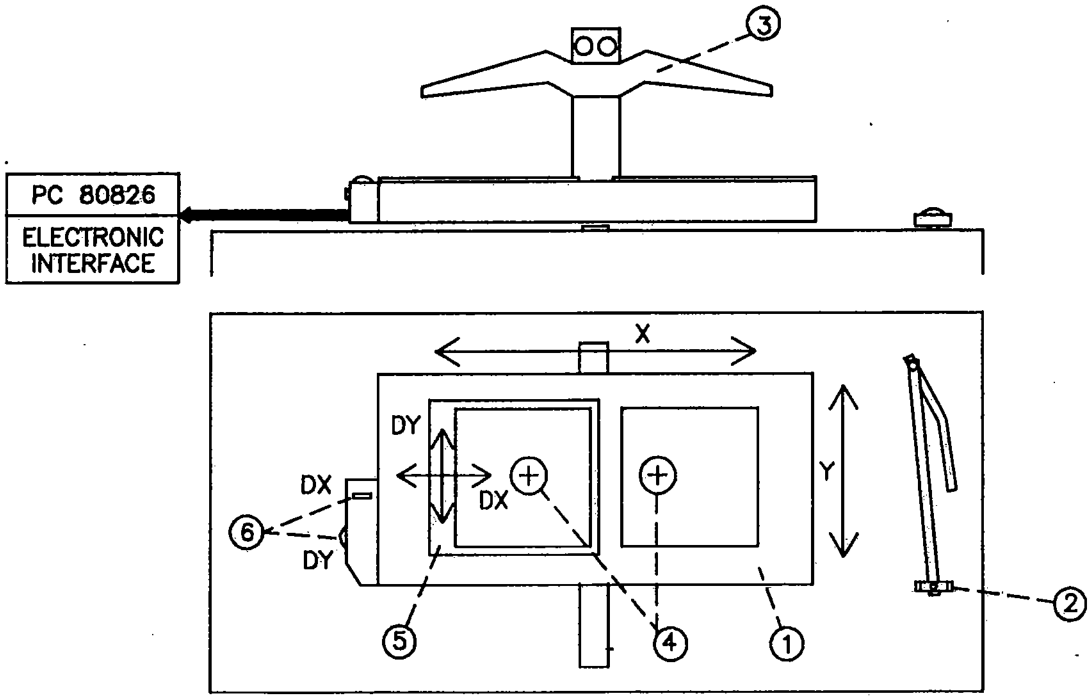

Figure 1 - The STEREOBIT/20

A double illumination device permits the use of both film or paper print photographic material.

The standard magnification of the optics is 5.5x. The resolution of the four encoders (X, Y, DX, DY) is 0.01 mm.

The standard computer is the well known IBM 80286 PC-DOS computer (or compatible), with 80287 co-processor, 640 Kbytes of RAM and a 30 Mb hard-disk. A mouse (or tablet) is suitable for managing menus and programs.

The operating system must be at least MS-DOS v.3.3.

Programs are written in BASIC or FORTRAN languages.

2.1 Analytical bases

One supposes that a preliminary phase of exterior orientation has already given the orientation parameters of the two photographs, i.e.:

- XC1, YC1, ZC1 ground coordinates of the XC2, YC2, ZC2 projection centers.
- $B(\omega 1, \varphi 1, k1)$ orientation matrices of $C(\omega 2, \varphi 2, k2)$ the two cameras.

Let Bx, By, Bz and Cx, Cy, Cz be the 3 columns of these matrices.

The restitution is based on the following procedures.

a) Single point restitution

This consists of the y-parallaxe elimination, i.e. on the control of the DY stepping motor.

The elementary problem is: given the image coordinates x2, y2 of a point in the right plate and x1 being that of the corresponding point in the left plate, calculate y1 and correct the y-parallaxe by means of the DY motor.

For the solution, in the real time cycle, the computer determines:

- the internal direction tangents tx1, tx2, ty2
- the external, transformed direction tangents of the right image, obtained by rotating the internal direction tangents:

$$TX2 = \frac{|\,tx2\ ty2\ 1\,|\ Cx}{|\,tx2\ ty2\ 1\,|\ Cz}$$

$$TY2 = \frac{|\,tx2\ ty2\ 1\,|\ Cy}{|\,tx2\ ty2\ 1\,|\ Cz}$$

- the ty1 direction tangent, using the parallaxe equation
- and finally $y1 = -p * ty1$.

Comparing the so computed y1 with the y1* read on the left plate at the moment, the difference $dy = y1 - y1^*$ can be evaluated and corrected by the DY stepping motor.

b) Contours

During the restitution of the contour lines, the computer must control both the DX and DY movements.

Given x2, y2 and having prefixed the height Qc of the contour, one needs to calculate x1, y1 and determine the DX, DY movements.

The solution is achieved by computing:

- the direction tangents tx2, ty2, Tx2, TY2 as in the single point mode
- the actual height ZC2 of the collimated point P and the difference $DZ2 = Qc - ZC2$
- the ground coordinates of:

$$XP = XC2 + TX2 * DZ2$$
$$YP = YC2 + TY2 * DZ2$$

- this ground point can be "projected" to the left plate:

$$TX1 = \frac{XP - XC1}{QP - ZC1}$$

$$TY1 = \frac{YP - YC1}{QP - ZC1}$$

- having called $c = C^T$ the transposed orientation matrix and cx, cy, cz its columns, one obtains:

$$x1 = -p\,\frac{|\,TX1\ TY1\ 1\,|\ cx}{|\,TX1\ TY1\ 1\,|\ cz}$$

$$y1 = -p\,\frac{|\,TX1\ TY1\ 1\,|\ cy}{|\,TX1\ TY1\ 1\,|\ cz}$$

- the difference to the read coordinates is then sent to the stepping motors DX,DY.

Both the above computation sequences are carried out in less than 20 milliseconds and therefore the operator can explore the model in an apparently continuous stereoscopic way.

There is no problem, therefore, for plotting edge lines or contours: the real time cycle and the computer control of the motors guarantee a correct continuous solution.

The ground coordinates of the points are computed and can be recorded for an efficient data collection.

3. OVERVIEW OF THE SOFTWARE

A large amount of photogrammetric software is available on the STEREOBIT/20, derived from the wide software library of the Galileo analytical plotter"DIGICART".

Five packages are of special interest in particular for most architectural applications as shown in fig. 2:

1 - Metric images ("RESTI")
2 - Semi-metric images ("RESEAU/ROLLEI")
3 - Quasi-metric images ("RESEAU/PENTAX")
4 - Aerial triangulation
5 - Off-line graphic editing

An efficient triangulation procedure (point 4) has been developed for data collection and block adjustment up to 100 models.

In addition to the above routines, many other programs are avalaible for a wide series of applications.

For example:

- a self-explaining program has been developed by GALILEO for teaching and training purposes.
- a simple but efficient package is also available for collecting and editing data for the information systems.

In particular, the produced files are in DXF format (compatible to Auto-Cad) or in a simpler Galileo format for further data-base management system programs (for instance: GART, especially designed for architectural applications).

In every case, all the selections of the wanted program or procedure are obtained by the user-friendly "pop-up menus" technique.

The operator will be able to select the choosen option by using the UP-DOWN cursor key, or by pushing the left key of the mouse; some options, when selected, display further sub-menus for a more precise choice.

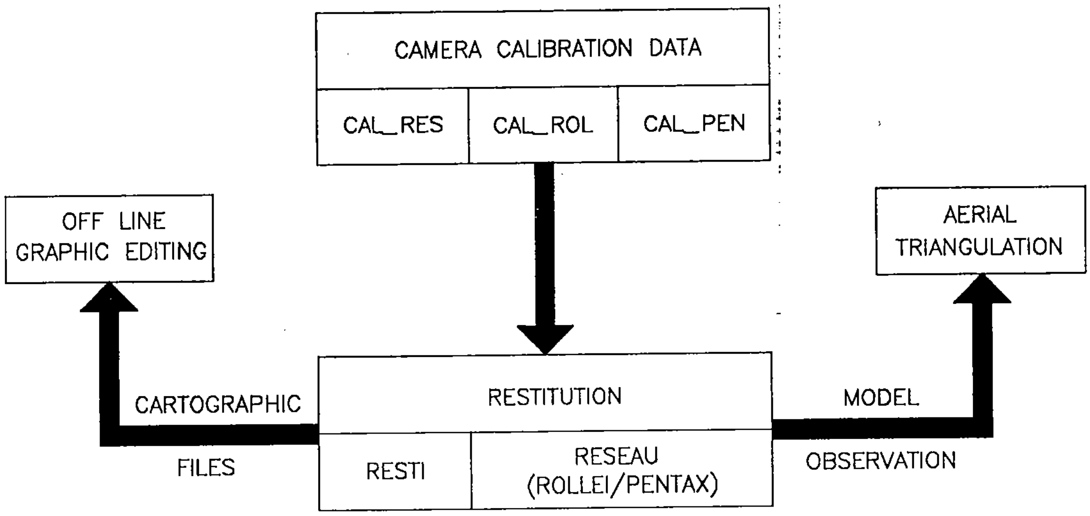

Figure 2 - STEREOBIT/20: available restitutiton procedures

A procedure for "self-calibration" of non metric cameras will be available within a few months.

For example, each of the options 1, 2 or 3 (see above) opens a sub-menu that offers two possibilities: CAMERA CALIBRATION DATA or

RESTITUTION.

By selecting the CAMERA CALIBRATION DATA option, the operator is allowed to load the data of the camera, as described in the calibration certificate: principal distance, principal point position, fiducial point coordinates, lens distorsion table and (in case the camera is semi-metric) the coordinates of the calibrated reseau.

The option "RESTITUTION" permits the choice of the wanted procedure: metric (RESTI), semi-metric (ROLLEI) or quasi-metric (PENTAX) image restitution.

Flow-charts in figures 3 and 4 show how the different restitution phases are carried out. The restitution package for quasi-metric images is, in particular, described in chapter 5.

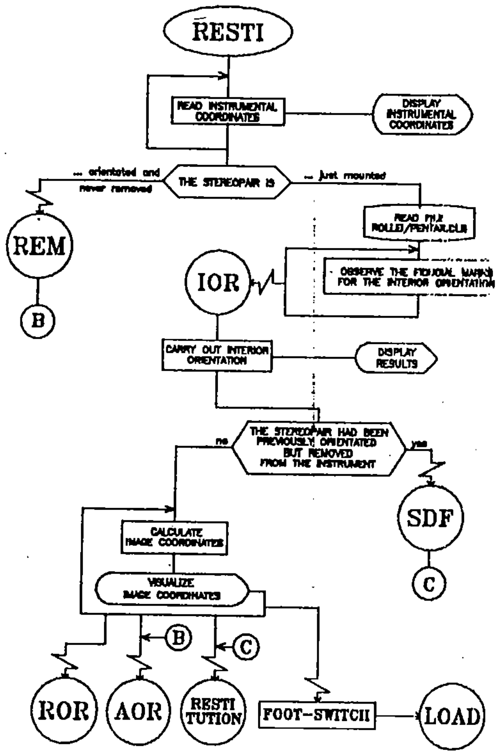

Figure 3 - The RESTI package flow-chart

Pop-up menus, divided into omogeneous functions (EDIT, ORIENTATION, OUTPUT, RESUME, END OF JOB, AERIAL TRIANGULATION, etc.) gives the operator an easy guide through the successive restitution phases.

A help menu allows one to display all the commands and gives a short comment for each.

Each selected command causes the interruption of the stand-by cycle of the computer and starts the corresponding procedure.

In the flow-charts such interruptions are graphically represented by a small broken arrow.

4. RESEAU CALIBRATION THEORY AND PROCEDURES

It is known that, among the various elementary plane transformations, a particular affinity, called general affine transformation and a particular projectivity called homography, exist.

If oxy and OXY are two plane reference systems, the general affine transformation allows one to transform exactly three known points of the first system into three corresponding points of the second system.

The homography allows one to transform four points from the first to the second system.

Therefore, the general affine transformation allows one to change any triangle into any other and the homography allows one to transform a quadrilateral into any other.

Analytically, the equations of the general affine transformation are:

$$\text{a)} \qquad X = ax + by + c \qquad Y = dx + ey + f$$

and the homographic transformation equations are:

$$\text{b)} \qquad X = \frac{ax + by + c}{gx + hy + 1} \qquad Y = \frac{dx + ey + f}{gx + hy + 1}$$

When the 6 parameters (a,....,f) of the general affine transformation or the 8 parameters (a,...,h) of the homography are known, the calculation of the transformed coordinates (X,Y), given (x,y), is immediate.

In both cases, the parameters, originally unknown, can be defined by the knowledge of

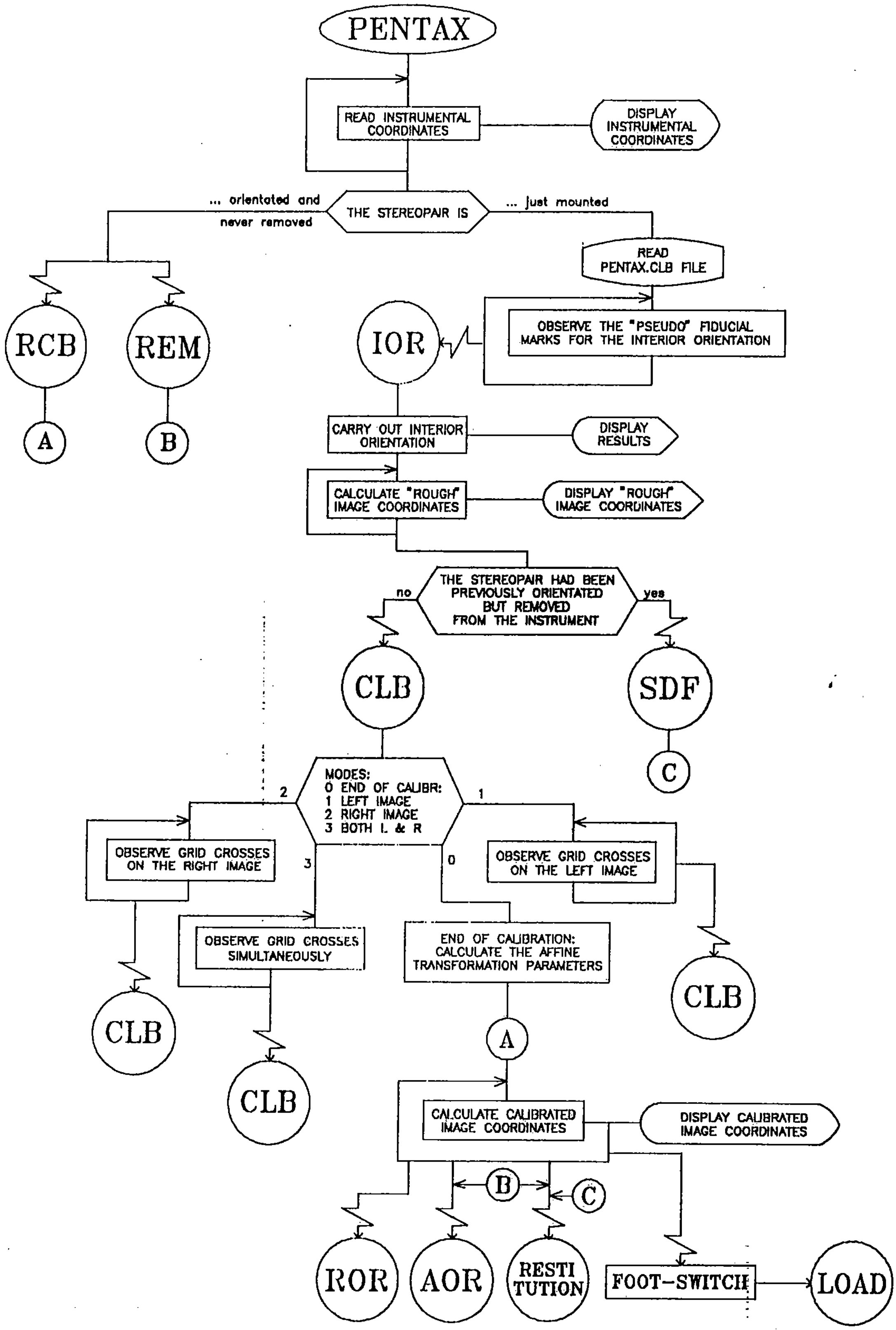

Figure 4 - The PENTAX package flow-chart

the coordinates of some points in the two reference systems.

As a minimum, six equations (2x3 known points) of type a), or eight equations (2x4 known points) of type b) can be written, where the unknowns are the above mentioned parameters.

Equations a) or b) have a particular geometrical meaning: the transformation from the starting configuration (oxy system) to the final configuration (OXY system) can be seen as the combined result of:

- for the general affine transformation: 2 translations, 1 rotation, x- and y-scale change and 1 tilt as shown in fig. 5;

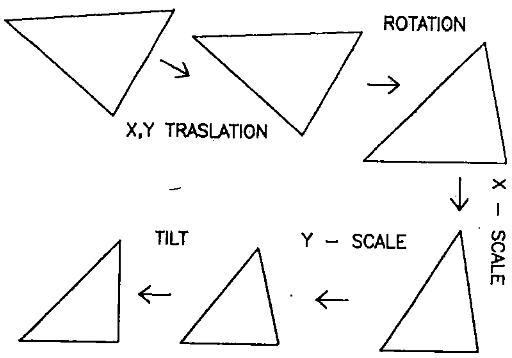

Figure 5 - Parameters of the general affine transformation

- for the homography: 2 traslations, 1 rotation, x- and y-scale change, 1 tilt and 2 angular convergences as shown in fig. 6.

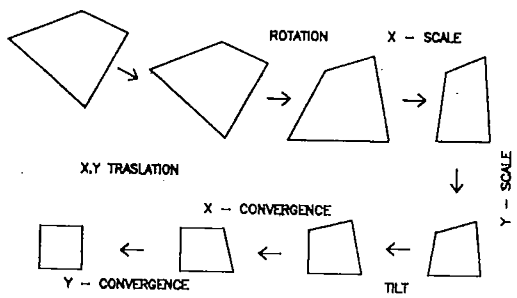

Figure 6 - Parameters of the homographic transformation

In both cases it is simple to express the numerical values of these entities in function of the mathematical parameters which define the above mentionned transformations (a,..,f or a,...,h).

What has all this to do with our problem?

Let us consider a mesh of the calibration grid that appears on the photogram and which we can see as being very deformed.

If we used a Pentax camera with a 9 cross grid, the image area can be subdivided into 8 triangular meshes, as shown in fig. 7).

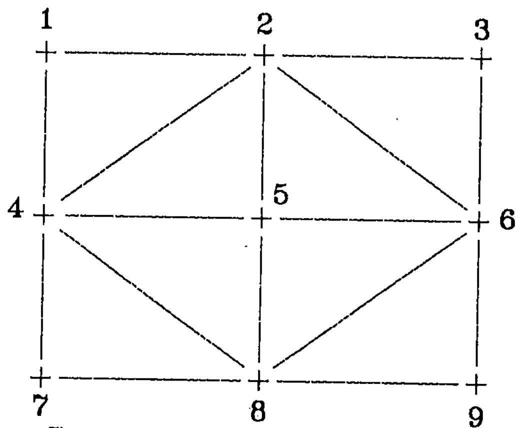

Figure 7 - PENTAX grid and triangular subdvision

If the camera is a Rollei camera with a 121 cross reseau, the photogram is subdivided into quadrilaterals, as shown in fig. 8).

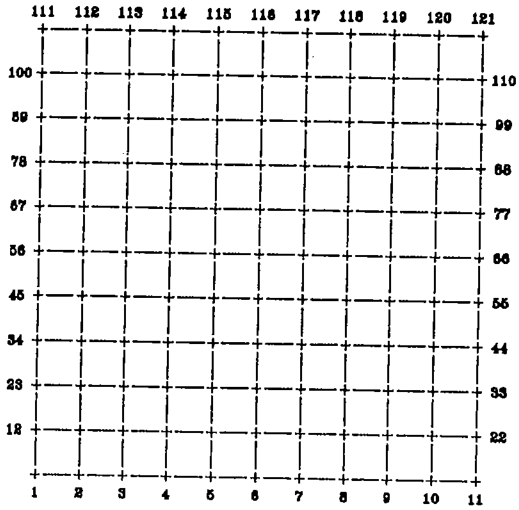

Figure 8 - ROLLEI grid and quadrangular subdivision

It is possible to calculate the parameters of the affine general transformation or of the homography that transform the vertices of each triangular or quadrangular mesh from system (x,y) to (X,Y) and apply the same transformation to all the internal points of the considered mesh.

It can seem arbitrary to model the complex deformations of the photogram by a simple affine or homographic transformation: the small size of the mesh (5x5 mm for the Rollei, 23x17 mm for the Pentax camera) and some properties of the considered transformations, lead us to think that the phoenomenon has been well described and corrected.

This approach seems to be sufficiently rigorous: many of the commonly used correction systems are limited to a linear interpolation or to attribute the simple translation of the nearest cross to each point.

5. THE SOFTWARE PACKAGE FOR QUASI-METRIC CAMERAS

We have already pointed out that:

- there exist a new type of camera, that we ca have called "quasi-metric", (ref. also to COMOGLIO [1991]), produced by PENTAX and equipped with a flattening device and a reseau of only 9 crosses.
- a package for the restitution of such images has been developed, based on the affine transformation and a triangular subdivision of the image area, as shown in fig. 7.

We now want to give a short description of this package, called PENTAX (see flow-chart fig.4).

When starting the procedure, the operator is required to input some general information and the calibration data file of the camera, previously edited and recorded on the disk.

Then, the program asks the operator if he is going to work on a stereopair already positioned on the instrument and never previouosly moved (as in the case where the job has been interrupted and then restarted) or if it has just been mounted at that moment.

In the first case, after the collimation of the start-points, the operator must select the MODEL RESUME command of the RESUME menu; in this way he can restart his job from the previous interruption point, by-passing all the preliminary calibration and orientation phases.

Otherwise, the procedure starts with the collimations necessary for the internal orientation. By using four crosses of the reseau as fiducial marks, a preliminary "rough" interior orientation is carried out.

The grid calibration procedure is then activated: the operator collimates all the reseau crosses that he sees in the 2 photograms. During this acquisition phase, a scheme of the two reseaus apears on the screen, allowing the operator to follow his work and avoiding any collimations being forgotten.

When all the collimations are carried out, the program calculates and stores in memory the parameters of the 8 (left image) + 8 (right image) general affine transformations.

The instrument is then ready to start restitution: the image coordinates of the observed points will be measured and then continuously corrected, by means of the affine general transformation. The logical sequence of the real time operations is:

- the encoders give the 4 "instrument coordinates" of the 2 collimated points;
- the program finds (separately for the left and for the right photogram) the meshes in which the collimated points are located;
- the 6 parameters of the affine transformation corresponding to the particular meshes are retrieved from memory and the instrument coordinates transformed into the corrected coordinates;
- after this correction, the instrument will operate as if metric images were used.

Therefore, after the grid calibration phase, the PENTAX program is exactly the same as the standard RESTI program: the operator goes on with the usual relative and absolute orientation phases etc., following the classical procedures of the restitution programs.

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"STEREOBIT /20" AND "RESEAU". A NEW PHOTOGRAMMETRIC ANALYTICAL SYSTEM FOR SEMIMETRIC IMAGES: IMAGE ACQUISITION AND PRACTICAL EXAMPLES.

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ABSTRACT

GALILEO SISCAM, the main Italian producer of photogrammetric instruments, in cooperation with the Politecnico of Turin, has recently introduced a new complete system for the use of semimetric images.

Image acquisition is based on the well known ROLLEI 6006, the reseau camera with 11x11 calibration crosses or the more recent PENTAX PAMS 645P, a "quasi-metric" camera with a mechanical flattening device and a special reseau with only 9 crosses. Both cameras are of a low cost, easy to use, and equipped with a full set of lenses and optionals.

Photogrammetric plotting is performed by means of the new motorized STEREOBIT/20 a rigorous analytical plotter with only two parallaxe controls.

In order to verify, in practice, the advantages attainable with the calibration of semimetric images by means of the RESEAU software, a series of simulations and experimental tests have been carried out; results and some comparisons between different semimetric images are presented and discussed.

1. INTRODUCTION

In recent few years we have witnessed a growing interest in photogrammetric techniques, also by those operators in the survey sector who, by tradition, have always paid particular interest to the description of the shape but were oblidged to neglect the metric aspect because the available instruments were inadequate.

The main reasons for this growing interest in photogrammetric techiques are:

- the low cost of the photographic equipment (semimetric cameras) compared with the cost of current terrestrial metric cameras;
- the low cost and easy handling of the systems designed for semimetric images in comparison to the traditional photogrammetric analytical plotter;
- non-experienced operators need to know only a few practical rules which permit the restitution of the objects by means of monoscopic (ROLLEI MR2, WILD ELCOVISION) or stereoscopic collimation (STEREOBIT): the highly advanced software with its transparency enables the operator to solve all the problems connected to orientation and plotting.

The appearance of some types of semimetric cameras made it necessary to furnish users with an analytical plotter that combines the accuracy of the classic photogrammetric plotting (in the sterescopic collimation of points and in the survey of continuous lines) with the economy and facility of use, bothof which are necessary to render the whole survey system competitive with other simplified methods.

A fruitful collaboration has existed for many years between the Politecnico of Turin and the GALILEO SISCAM in Florence in order to study and create hardware and software instruments for photogrammetric surveys.

During the planning phase for these systems, it was found necessary to take both scientific needs and the facility of use by those operators who have only a minimum of practical experience, into consideration. The work carried out during the last two years with STEREOBIT and the RESEAU software has been undertaken for this purpose. This system makes it possible to utilize the images taken with the semimetric ROLLEI 6006 camera with an accuracy higher than that of other systems which have been available until now.(CAMBURSANO, 1990)

In the following sections, and after a brief description of the semimetric cameras, the results obtained by the latest version of the RESEAU program from various semimetric images elaborated in our Department, are presented.[1]

For a description of the new STEREOBIT/20 please refer to the paper presented by CAMBURSANO, DEQUAL and ZONCA in this same session.

2. THE SEMIMETRIC CAMERAS

It might be convenient to recall briefly the basic idea behind semimetric cameras. They aim to combine easy handling, flexibility and the space saving advantages of the amatorial camera with the metrical characteristics of the traditional photogrammetric cameras.

The semimetric cameras differ from the common camera as follows:

- they are equipped with a grid ("reseau"): the coordinates of all the reseau crosses are known with a high degree of accuracy. This grid is superimposed by contact on the image when the picture is taken and allows the reconstruction of the internal orientation and the correction of some deformations of the film;
- they are equipped with a certificate of calibration which contains all the information about the coordinates of the principal point within the reseau reference system as well as the principal distance and the value of the geometric distorsion of the lens system. Every combination of camera body, reseau and lens has its own particular certificate. Much of the calibration data is obtained by photographic calibration of the camera. The coordinates of the reseau crosses come from a direct measuring operation with a resolution of at least 1 µm.

The function of the reseau is to show what the effects of the flatness errors of the film and of the deformation of the photografic support are upon the geometry of the taken image at a certain number of points.

It is possible to correct such deformations and rebuilt the exact geometrical shape by determining the differences in position between the observed crosses and the calibration values.

This approach allows one to use enlarged paper prints and measuring systems for non-calibrated coordinates.

It was found convenient to use 4X enlarged images of the original negative film: when measuring with the instrument resolution of +/- 10 µm the results are the same as if an image had been used in its original format with a coordinate measuring system of a resolution of +/- 2.5 µm.

The calibration carried out by observing the reseau crosses also permits the correction of all the systematic instrument errors (eg. orthogonality, linearity of the guiders, encoders, etc.): the read coordinates in correspondence to the reseau crosses are affected by those errors which, however, are completely eliminated during calibration.

Obviously, the corrections are interpolated inside the meshes.

The greater the number of reseau crosses, the more precise the reconstruction of the internal geometry of the taken image becomes.

On the other hand, a dense reseau overlaid on the image creates considerable disadvantages for the operator because important features of the object might be covered and cause considerable disturbances during the stereoscopic observation.

It will be necessary, therefore, to find the right balance between the density of the grid and the necessity to reconstruct the internal geometry of the image in order to achieve sufficient precision at every point of the photographic image.

The cameras used in the tests represent, in a certain way, two solutions which could be called extreme: the dense grid (121 crosses) of the ROLLEI 6006 camera and the new PENTAX PAMS 645P, with a grid of only 9 crosses.

2.1 THE ROLLEI 6006 CAMERA

This well known semimetric camera derives from the similar amatorial camera and is provided with a grid of 11x11 = 121 crosses at a regular distance of $5x5mm^2$ that cover an area of $50x50\ mm^2$, centered on the original format $60x60\ mm^2$ of the film. This camera can be used

1) The team directed by Prof. S. DEQUAL, has been financially supported by the Italian Ministry for University and Research (MURST 40%)

with all the standard available accessories (filters, extension tubes, lenses of different focal lengths, etc.), and can use normal negative or positive films.

The calibration certificate gives the coordinates of the principal point, the principal distance and the radial distorsion curve of the lens. This curve represents the mean of the radial distorsion along the four semidiagonals, and is defined by the formula:

$$DR = K_1 \cdot r^3 + K_2 \cdot r^5 \qquad (1)$$

where:

r indicates the distance from the principal point

K_1,K_2 are the coefficients of the interpolating polynomial

Calibration data has been established for focusing objects at hyperfocal distance. For shorter distances a table indicates the principal distance variations, while nothing is given about the stability of the principal point or about the variations of the distorsion curve.

2.2 THE PENTAX PAMS 645P CAMERA

This derives from the amatorial model PAMS 645.

It is a multi mode TTL automatic exposure reflex camera equipped with a PENTAX lens with a focal length of 45 mm in the standard version. Other lenses are available with focal lengths ranging from 40mm to 305 mm.

Shutter speeds vary from 1/1000 to 15 s and B. The film (220,120 or 70 mm roll film) is moved by motor drive to give single exposure or continuous operation at a rate of one frame per 0.7s.

All major functions from exposure control to display panel are microprocessor controlled.

External information (exposure factor, film sensitivity, exposure count, etc) useful for the operator is provided by means of a LCD digital display.

A standard model is equipped with a reticule of 5 crosses of which 4 are positioned on the centers of the edges and one in the centre of the photogram.

The extreme scarsity of crosses in the image used for controlling and correcting the negative effects of flatness errors of the film, is compensated by the presence of a mechanical flattening device which presses the film against the reseau glass plate in the moment when the shutter is activated. Thus, the effect of the flatness errors of the film on the geometry of the image is minimized. This error is by far the most insidious and can be eliminated only with great difficulties because of the considerable error variability from point to point on the image. It is

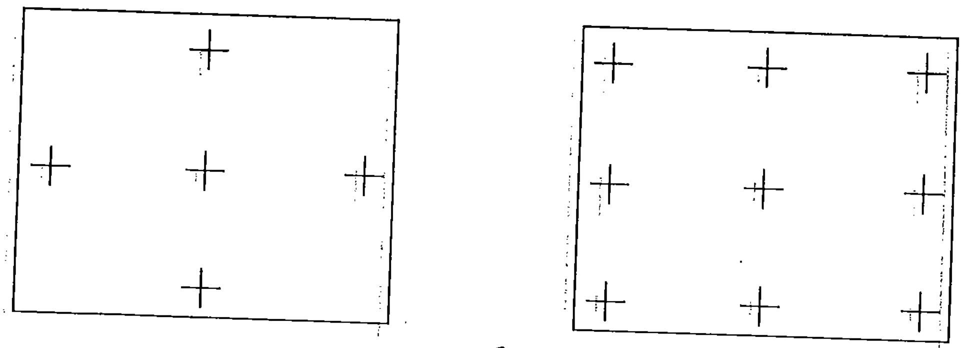

Figure 1 - Reseaus of 5 and 9 crosses of the PENTAX camera

therefore not easy to establish continuous models across the format of the photograph.

On the other hand, the film shrinkage effect can be considered, as a variation of the X and Y-scales, homogeneous over the whole of the image. According to this hypothesis, only a few points are needed in order to correct this kind of deformation.

Using a grid of low density drastically eliminates the inconviencies brought about by having many inner crosses on the image during the stereoscopic observation of the model and will, obviously, speed up the calibration process.

A grid of 9 crosses has been used in the experiments with the PENTAX PAMS 645P; this grid is derived from the 5 cross standard reseau by adding another four crosses at the vertices of the image. This solution is more consistent with the method and techniques in treating semimetric images, since in this case every point of the photogram is contained within three reseau crosses. The need to extrapolate information, a process which is always dangerous, is thus avoided.

The usable surface of the image is 49.4x39.6 mm^2, and normal negative or positive films can be used.

The calibration certificate provides the coordinates of the reseau crosses, the coordinates of the principal point, the principal distance and the distorsion of the lens system.

According to ISPRS indications, the Gaussian radial distorsion is:

$$DR = K_1 \cdot r^3 + K_2 \cdot r^5 + K_3 \cdot r^7 \qquad (2)$$

where:

r is the distance from the principal point

K1,K2,K3 are the coefficients of the interpolating polynomial.

The decentering distorsion effects have also been calculated according to the indications of ISPRS. Finally, there is another important particularity: the lens of the camera is focussed fixed.

3. DESCRIPTION OF THE TESTS.

The experimental tests and their results presented here have been planned in order to verify the correct functioning of the new procedures of the RESEAU package in the handling of the images taken with different metric and semimetric cameras and the comparing of the accuracy of the results obtained with these images.

Measurements have been carried out with the STEREOBIT/20 analytical plotter, installed in the analytical photogrammetry Laboratory of the Department.

A three dimensional test area was created, formed by 30 points, located within a space of approx. 10 m of length, depth and height.

The coordinates of these points have been measured applying the traditional geodetical methods, which gave all standard deviations not exceeding +/- 1 mm in all directions.

Figure 2 shows the three-dimensional distribution of the signals within the test area and the shape of the signals. Establishing the internal points with equal distances in all three directions permits one to simulate critical conditions which are precisely those which turn up when the object develops considerably in depth.

The cameras used for taking the pictures were:

- the ZEISS JENA UMK 1318 metric camera
- the ROLLEI 6006 semimetric camera
- the PENTAX PAMS 645P quasi-metric camera.

Table 1 gives the scale of the photograms and the base/distance ratio of the stereo-pairs.

The absolute orientation of all the stereoscopic pairs were carried out using twelve points of the test area. The remaining points were used as check points.

Table 2 shows the results of these orientations: mean, minimum and maximum discrepancies calculated on the points used for the absolute orientation.

The following figures show the histograms of the discrepancies (absolute values) on all points of the test area.

4. ANALISYS OF THE RESULTS AND FINAL CONSIDERATIONS

One can see that when referring to the results obtained from the orientation and plotting tests performed with different combinations of instruments and type of images, summed up in table 2 and figure 3:

- the results of the test executed using metric images and the DIGICART/40 analytical plotter confirms the inner metric quality of the test area. The mean value of the discrepancies over all the control points is about 1 mm and maximum discrepancies do not exceed 4 mm;
- the same experiment using the STEREOBIT/20 points out discrepancies 3 times larger than those obtained in the previous test. This fact proves once again that the smaller measuring resolution of the STEREOBIT/20 (+/-10 µm) compared to the DIGICART/40 (+/-1 µm)does not affect the results of orientations and restitution to the same degree;
- the tests performed with semimetric images from PENTAX and ROLLEI cameras gave

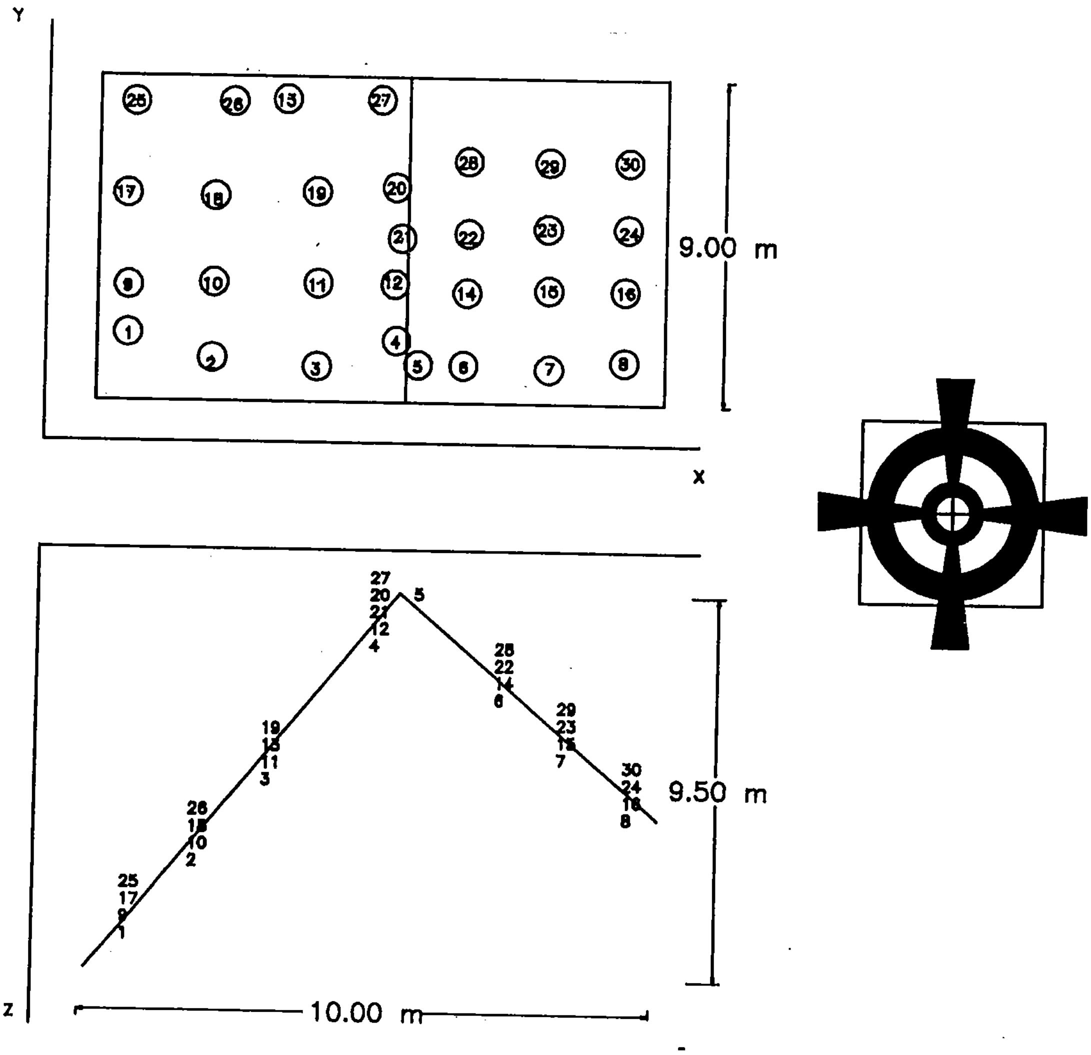

Figure 2 - Test area for terrestrial cameras and signal used

CAMERA	Focal lenght (mm)	Camera-signals distance (m)		Photogr. scale		Taking stereosc base (m)	base/dist.	
		min.	max.	min.	max.		min.	max.
UMK	100	11.00	21.00	1:210	1:110	4.00	1/5.25	1/2.75
ROLLEI	40	11.00	21.00	1:525	1:275	4.00	1/5.25	1/2.75
PENTAX	45	11.00	21.00	1:467	1:244	4.00	1/5.25	1/2.75

Table 1

CAMERA / ANALYTICAL PLOTTER	DXm (mm)	DYm (mm)	DZm (mm)	DXmax (mm)	DYmax (mm)	DZmax (mm)
UMK / DIGICART40	1	1	2	2	4	4
UMK / STEREOBIT20	3	3	6	6	7	11
ROLLEI / STEREOBIT20	4	3	6	9	7	15
PENTAX / STEREOBIT20	5	6	7	13	10	15

Table 2

discrepancies which are quite similar (about+/- 5 mm in the three coordinates) with a maximum value of 10 mm (see table 2). The same considerations can be made as far as the results obtained on the check points are concerned (figure 3). This fact shows the effectiveness of the PENTAX camera concept: the presence of a flattening device counterbalances the low number of reseau crosses with the considerable time saving advantage during the calibration phase. The presence of only one cross inside the PENTAX image also drastically reduces the disturbance caused by the presence of non stereoscopic points inside a stereoscopic model and the risk of hiding important features of the photographed object. At the same time it is necessary to pay attention to what is going on during the taking of the images: with a 9 cross grid the possibility that even only one of the crosses will not be visible can endanger the exact determination of the calibration parameters in a huge part of a photogram;

- by comparing the results on the check points obtained with semimetric and metric photograms it appears that the lack of precision between semimetric and metric images is in a ratio of 2 to 1. The mean discrepancies observed with metric images on the test area are about +/-4 mm with a

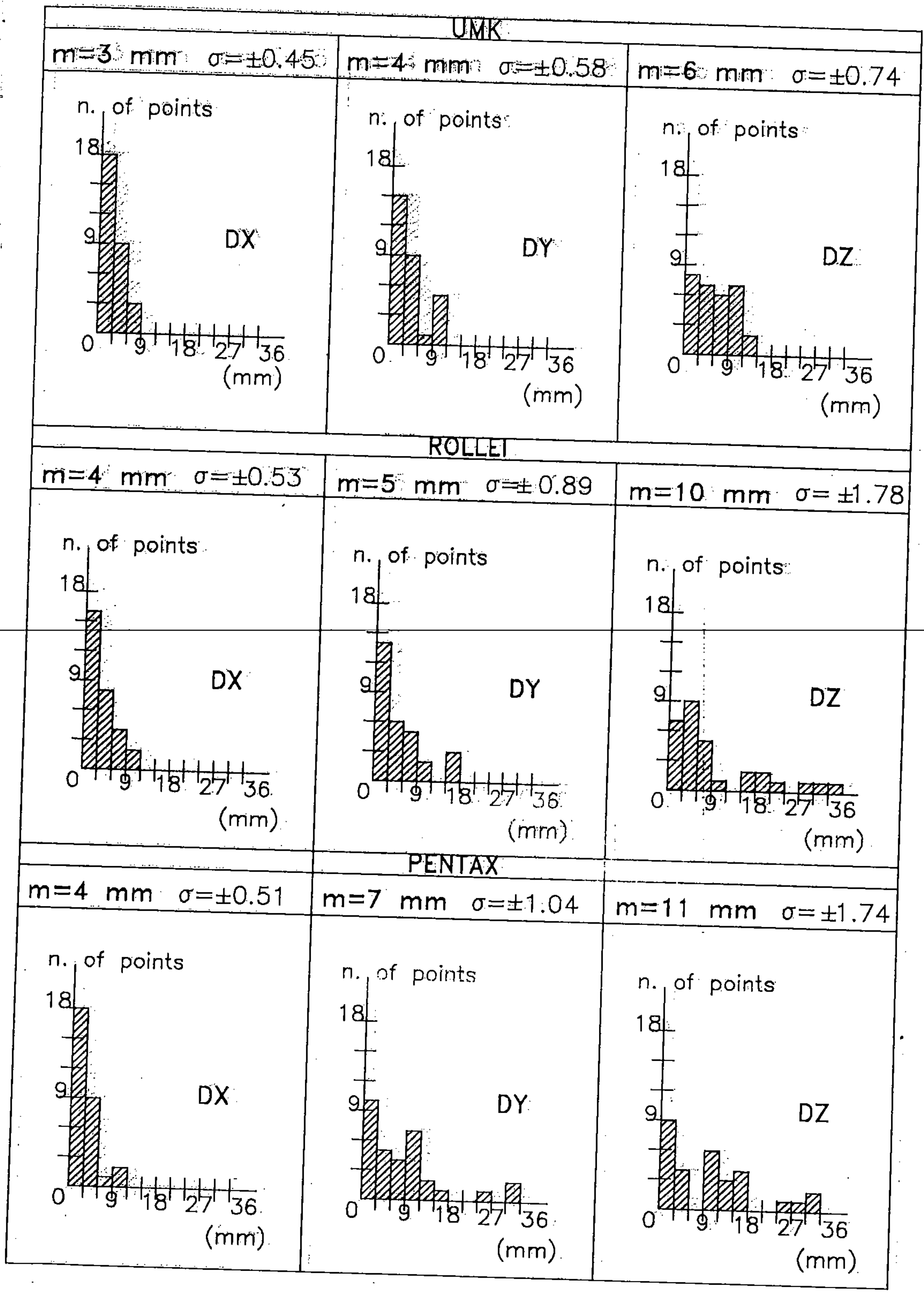

Figure 3 - Histograms of the discrepancies

standard deviation of +/- 0.5 mm. On the other hand the mean of the discrepancies rises to +/-7 mm with a standard deviation of +/- 1 mm when using semimetric images.

As far as the aim of this work is concerned, it is possible to say that the new PENTAX PAMS 645P camera with a 9 cross reseau and a mechanical flattening device, gives the same metric quality as the widespread ROLLEI 6006 semimetric camera with its own 121 cross grid.

The solution proposed by PENTAX is between the classical photogrammetric terrestrial cameras and the ROLLEI semimetric camera. Therefore the authors propose to underline this aspect by using a different name for this type of camera and call it, for instance, a "quasi-metric"camera.

The authors also want to point out that the results obtained with the STEREOBIT/20 are of very good quality and give the user a photogrammetric full system with an optimal cost/performances ratio.

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CIPA

XIV INTERNATIONAL SYMPOSIUM
Delphi 2 - 5 October 1991

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TWO EXAMPLES OF NON-CONVENTIONAL PHOTOGRAMMETRIC TECHNIQUES: THE NATIVITY'S INTERIOR FACADE AND THE SPIRE OF S.BARNABA'S BELL TOWER IN THE SAGRADA FAMILIA - BARCELONE

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TWO EXAMPLES OF NON-CONVENTIONAL PHOTOGRAMMETRIC TECHNIQUES: THE NATIVITY'S INTERIOR FACADE AND THE SPIRE OF S.BARNABA'S BELL TOWER IN THE SAGRADA FAMILIA - BARCELONE

ABSTRACT -
An experimental survey of some parts of the Sagrada Familia in Barcelone was carried out: the interior side of the Nativity's Facade and the San Barnaba's Spire. The interior Nativity's facade was surveyed with mono-rail camera making use of the lens off-set; this feature enabling the operator to enlarge the optical stereo-base and to select the most suitable place for the positioning of the camera stations. The photogrammetric measurements were carried out partly in stereoscopy with a stereocomparator and partly in monoscopy in a digitizer table. The final plotting was carried out with AutoCAD 10 (TM). The San Barnaba's bell tower was the only one finished by Gaudi. The spire was surveyed from the road level with 35 mm camera equipped with lenses 300 mm and 1000 mm focal length. The plotting was made in monoscopic mode with a digitizer table, in Autocad 10 (TM).

1. INTRODUCTION

An experimental survey of some parts of the Sagrada Familia in Barcelone was carried out: the interior side of the Nativity's Facade and the San Barnaba's spire. The survey of the whole temple would be too heavy in terms of time and costs. The employed photogrammetric technique was unconventional and the aim of the experiment was to establish whether or not these methods, characterized by low costs and efficiency, are suitable also for rather difficult projects, was to judge whether or not the results are satisfactory in quality.

2. NON-METRIC CAMERAS

Paradoxally today in architectural photogrammetry there is a seemingly contradictory trend: the demand for photogrammetric architectural surveys continuously increases just when the traditional manufacturers stop the production of their terrestrial metric cameras, already obsolete and too expensive. In the same time the market and therefore the production of non-metric cameras, i.e.amateur touristic cameras, and large format professional cameras, are quite lively, offering new models, more and more sophisticated, mainly because of the massive employ of the electronics. The many requests of Architectural Photogrammetry could be probably satisfied also by means of these types of cameras.

3. THE SELF-CALIBRATION FOR NON-METRIC CAMERAS

With these ideas, a strategy was designed for a quality control of an unconventional, low cost, efficient photogrammetric technique. Metric cameras are supplied with a calibration certificate made by the manufacturer. For non-metric cameras this lack of a-priori information must be replaced by equivalent metric information obtained a-posteriori by extra measurements made directly in the field. Not only that, but also the lens distortion, in practice null for metric cameras, for non-metric cameras is significantly different from zero and it must be estimated and corrected. The required additional information can be supplied by three-dimensional coordinates of the Control Points (Abdel-Aziz, Karara, 1). In the classical photogrammetry the control points are used as well but their quantity can be considerably reduced in comparison with non-metric cameras. Nevertheless in Close-Range Photogrammetry the cost per unit for Control Points is rather low and almost independent from their quantity, the cost for the set-up of the control net being prevailing. A computer program capable of dealing with non-metric cameras was therefore written, based on a self-calibration procedure (Fangi, Presta 2). Its main features are: - suitable for non-metric cameras - employ of graphical tablets as measuring devices of enlarged paper prints of the photos - multi-image restitution - interactive graphical editing with any CAD (Computer Aided Design). The program not only computes some coefficients for lens distortion correction, testing their consistency, but also calibrates the digitizer table taking into account for non-perpendicularity and for scale difference of the X and Y axes.

4. THE PHOTOGRAMMETRIC PROGRAM AS RESIDENT PROGRAM INSIDE INDEPENDENT CAD PROGRAMS

After the orientation of the photograms, (the computation of those parameters for the transformation from the photo-coordinates to the ground coordinates), the operator can switch to the plotting phase. The plotting can be carried out directly inside an external CAD. That means that the photogrammetric program is quitted, and the CAD is activated. For the plotting of primitives the 3-D coordinates of the points are furnished by the photogrammetric program, recalled just by pressing a key, in the same way as they would be typed in the keyboard (Fangi, Presta 2). The advantages are as follows:

- interactive graphical editing,
- little training period, because the operator usually knows already the CAD, employed also for different purposes
- high quality CAD, continuously up-dated
- modularity of the system

- large transportability of the plotting files.

5. MONO-RAIL CAMERAS AND LENS OFF-SET

They are large-format professional cameras, where the lens plane and the negative plane can be moved and rotated with respect to each other in any direction (see fig. 1). They are obviously non-metric cameras.
The above mentioned capabilities can be useful in architectural photogrammetry:
1) rectified images are taken directly from the field,
2) it is possible to increase the base/distance ratio of a stereo-pair getting a better accuracy in direction of the depth and mainly improving the flexibility and the efficiency of the survey. They enable for large taking bases, keeping the parallel lines in the main object plane (i.e a facade) again parallel in the image plane. In practice the operator can choose in a easier way and with less limits the positions of the shooting stations. Mono-rail cameras add the advantages in flexibility of monoscopic takings to the advantages of the stereoscopy (Fangi, 4).

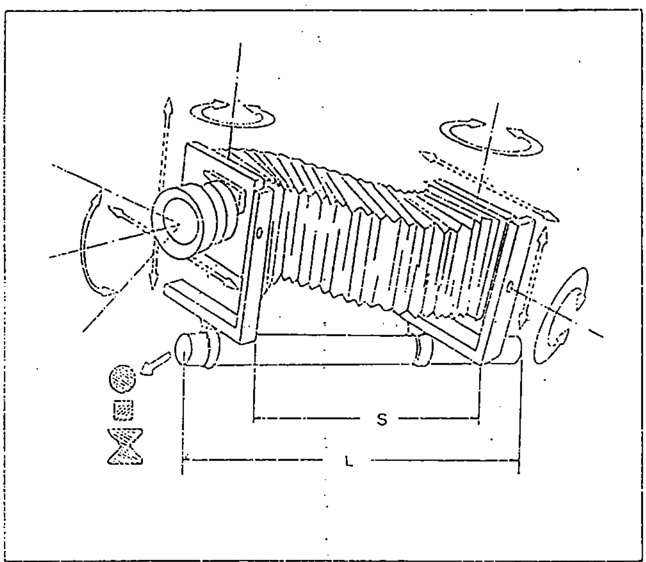

Fig. 1 - Scheme of mono-rail camera

6. THE PHOTOGRAMMETRIC SURVEY OF THE INTERIOR SIDE OF THE NATIVITY'S FACADE

Making use of this type of camera the photogrammetric survey of the interior Nativity's facade was carried out. Three stereo couples were shot, one for the upper part, with horizontal axes, and two couples from the ground, one with horizontal axes for the lower part, and one with inclined axes for the middle part (see fig.2). The camera was a Fatif 9x12 cm with 150 mm lens. Let's take into consideration

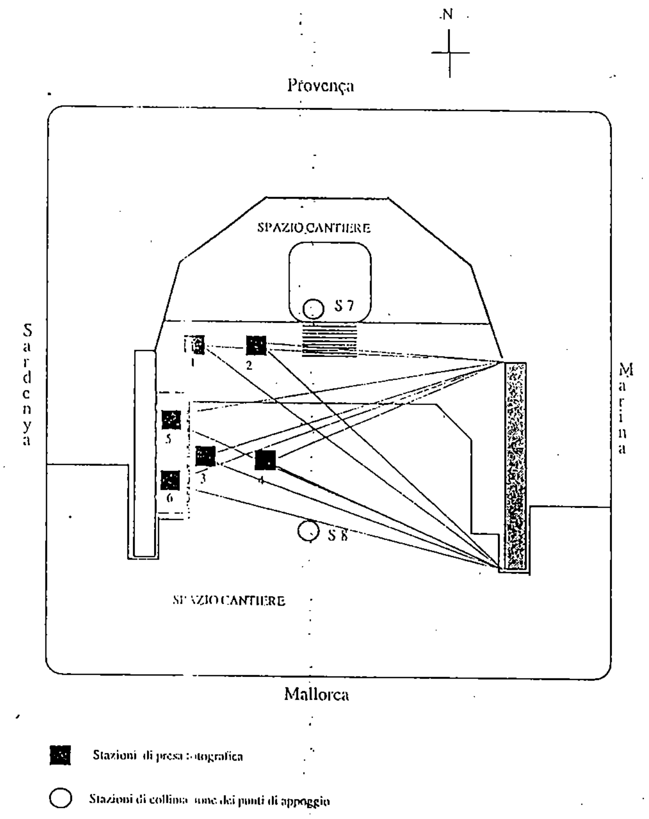

Fig. 2 - Interior Nativity's Facade. Lay-out of the photographic stereo-pairs

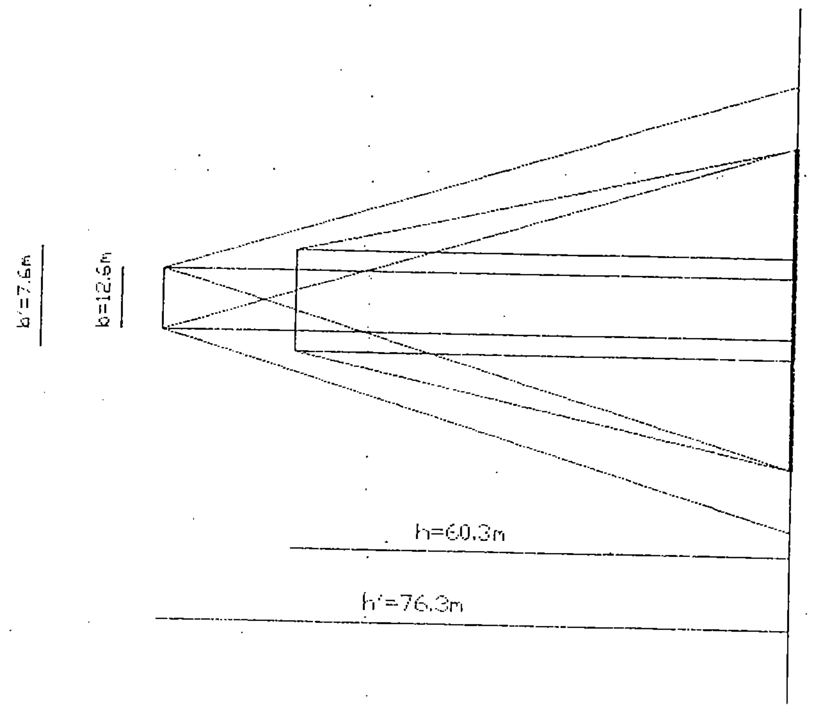

Fig. 3 - Stereo pair made with off-set lens camera versus the equivalent stereo-pair made with centered otpical axis

for instance the stereo-pair 5-6 in fig. 2. With a centered axis camera equipped with the same lens, the negative side should be increased from 9 to 11 cm for the same overlap; alternatively with the same format, the same lens and the same overlap, the distance from the base to the object should be increased from 60 to 76 m, while the base should be reduced in the same time from 12.5 to 7.6 m (the base/distance ratio would change from 1/5 to 1/10). That would be just not possible. 19 control points were surveyed by intersection from a two theodolites base. The duration of the geodetic works was about two hours. With the classical photogrammetry for the three stereo models, partly overlapping, a least of 9 points would be needed. The saving in time would be around half an hour only.

7. LONG FOCAL LENSES

Lenses with large coverage angles are generally used in photogrammetry, (wide-angle). In the case that a suitable photo-scale is needed for objects hardly reachable or very far from the accessible places, long focal lenses are used (narrow-angle). The coverage angle is narrow and the focal lens is large in comparison with the negative format. Even in this case the equipment of metric cameras is rather limited, while the normal photo-market offers a wide choice of any focal lenses at rather low prices. It was demonstrated (Fangi, 3) that in order to use long focal lenses and non-metric cameras, the camera station positions must be known.

8. THE PHOTOGRAMMETRIC SURVEY OF THE SAN BARNABA'S SPIRE

The San Barnaba's spire is located about 100 m above the ground level. The survey was carried out for economy reasons from the ground and therefore long focal lenses were required. The photos were shot from the four directions corresponding to the four vertices of the polygon surrounding the temple (fig.4). A 35 mm reflex camera, Olympus OM4, equipped with a 300 mm and a 1000mm lenses was used. Eleven photos were shot with 300 mm lens. The taking distances from the spire were ranging from a minimum of 150 m to a maximum of 180 m about.

9. THE CONTROL NETWORK

For the survey of the control points a traverse was established all around the temple. The traverse was composed by five stations. An open arm connected in the same reference system the interior side of the church (fig. 5). From the traverse by intersection 31 control points for the spire were determinate. From the interior side 19 control points were surveyed. From the traverse vertices, the photogrammetric stations were surveyed also. Their coordinates were needed because of the long focal lenses used. The adjustment for the control points was carried out in a least squares procedure. All the control points were coinciding with natural details in the object (fig. 7).

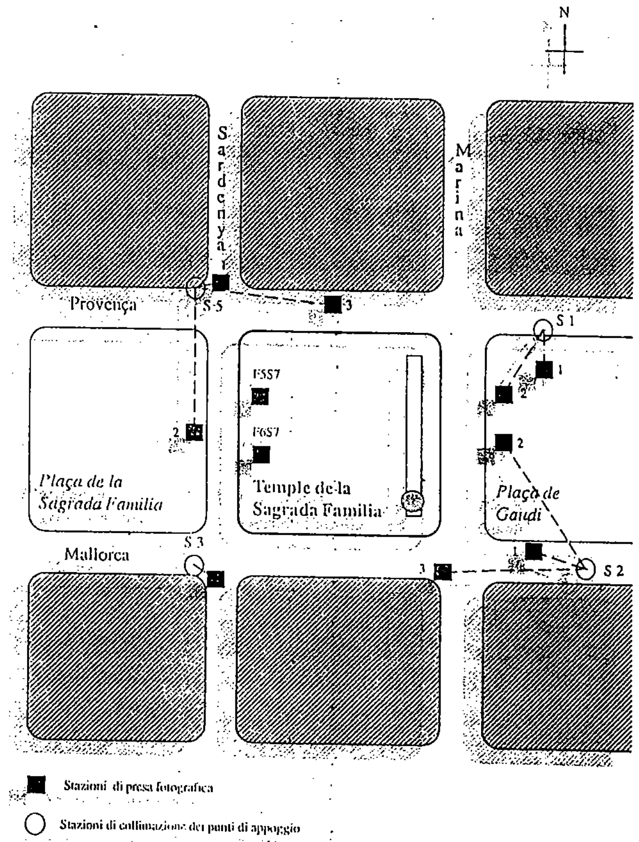

Fig. 4 - Plan of the photographic takings of the s.Barnaba's spire

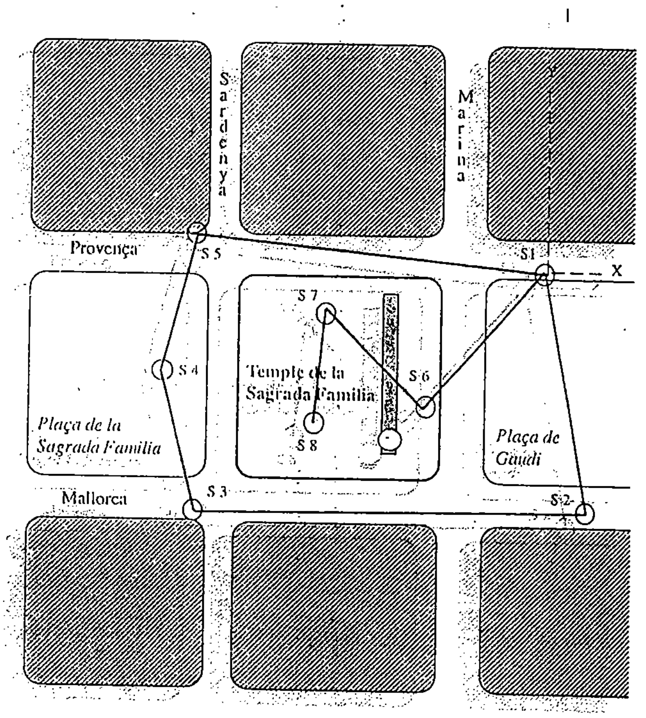

Fig. 5 - The Control Network

10. THE COMPUTER AIDED DESIGN AND THE GRAPHICAL ELABORATION

The plotting was carried-out on-line in Autocad (wire-frame and spatial model) and in Autoshade for the final elaboration (solid model, color treatment and shading). The plotting was carried out partly in a stereocomparator and partly in a graphic tablet with 2.5x enlarged paper prints (20x30 cm). The reason for that, was the limited training of the operators. It should be noted that for the facade the restitution was edited, correcting and rectifing non-aligned lines, when it was evident that they were not corresponding to an ideal architectural geometry. This is mainly due to a point-by-point restitution. The plotted points were the ending points of straigth lines or better lines supposed to be straigth lines. This procedure made difficult to point-out geometrical "anomalies", such as curved lines, off-set of planes, etc. Therefore the graphical editing was more demanding in comparison with traditional continous plotting. From one side the operator could be rather inexpert in photogrammetry but from the other side he should have a deeper knowledge in architecture. The average of the absolute values for the residuals in the three dimensions of the control points was 1.3 cm. The plotting accuracy is expected to be around 2-4 cm. The plotting was carried out inside AutoCAD 10 as CAD program, with the 3-D coordinates passed directly by the photogrammetric program working as resident program in the RAM memory of the Personal Computer. The operator was fully inexpert in photogrammetry, but already trained in CAD. The final drawings were two-dimensional (see fig.6).

11. THE S.BARNABA'S SPIRE

Because of its complexity, it could not be fully represented and understood by the traditional representation (front and side views, cross-sections, plan). The only exhaustive approach seemed to be the fully three-dimensional representation and therefore the Computed Aided Design was probably the most suitable mean to define, represent, understand the spire in all its shapes, patterns and geometry. This plotting was carried out therefore in four different phases:

1) build-up of the wire-frame by photogrammetric measurements (fig.8). The plotting was carried out in monoscopy in a graphic table A2 format with 10x enlarged paper prints. Three phogrammetric models, each made by four photos, were formed. Two other models were set-up for minor parts. 31 control points were used. The upper part only of the spire, 15 m long, was plotted. In these photogrammetric models the orientation of the photograms were particularly difficult because of

- the great distance,
- the prevailing linear shape of the object,
- the little depth of field
- and the incompleteness of the models (the bigger part of the photograms being occupied by the sky). The average of the absolute values for the residuals on the

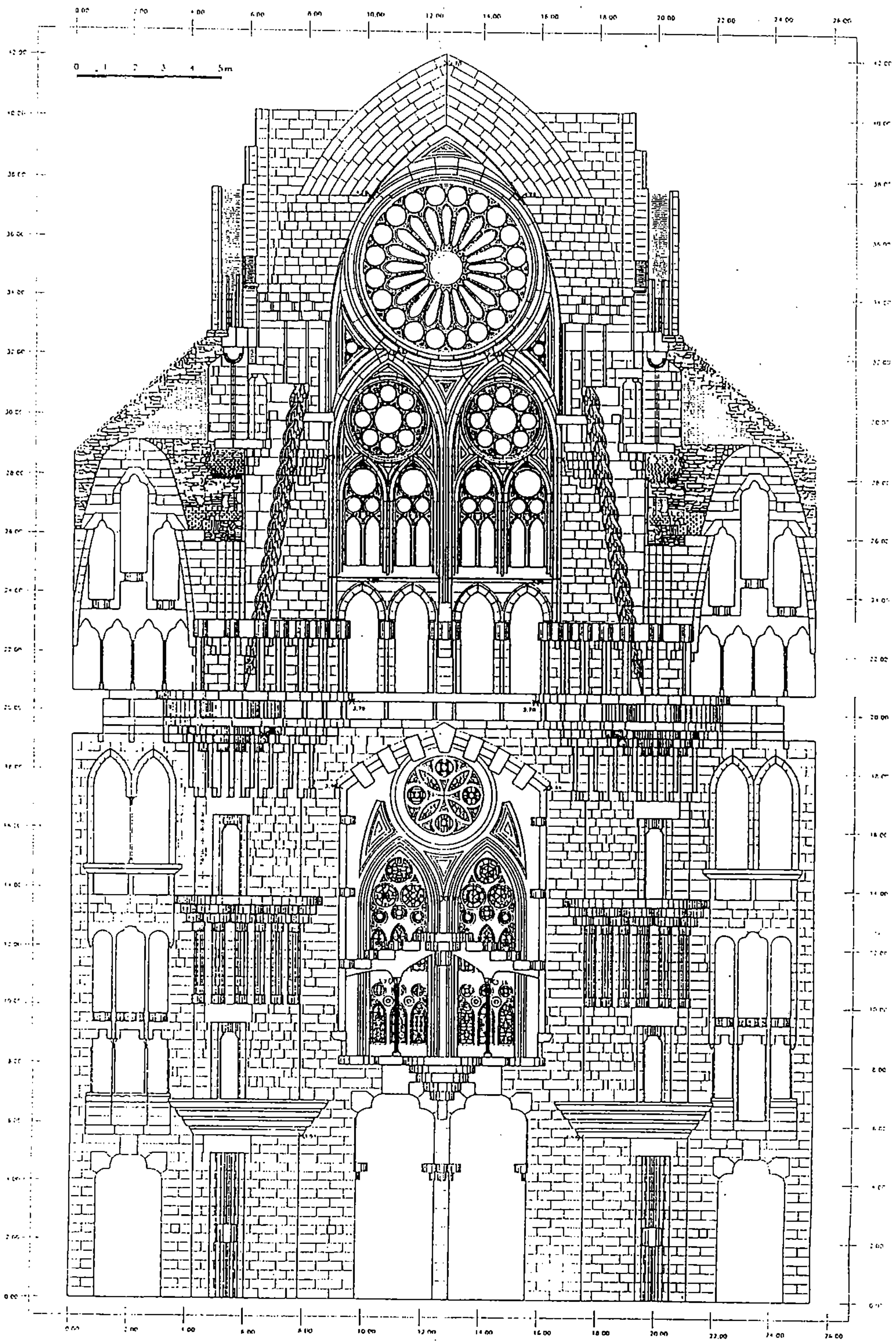

Fig. 6 - The interior side of the Nativity's Facade

control points was 2.7 cm, while the plotting accuracy is supposed to be around 3-5 cm.

2) Off-line build-up of some particular parts The point capture was monoscopic: therefore some continuous parts could not be plotted directly by photogrammetry. Based on the dimensions taken from the wire-frame, working as skeleton, four parts were selected: the upper part, formed by two opposite plates holding on their perimeter 8 spheres each, a central part with shield shape, the base and the connection between the upper part and the central one. The probable law of their generation in space was established, with the help of pictures made with 1000 mm lens.

3) Composition in space of the isolated parts and their jonction with the wire-frame; the wire-frame was then transformed in a solid model, by the identification of the planes and the surfaces passing through the lines. (fig. 9).

4) Removing of hidden lines, shading and color painting.

12. CHARACTERISTICS OF THE PHOTOGRAMMETRIC SURVEYS

Nativity's Façade, interior side

- Photogrammetric System PhOX
- Graphical editing: AutoCAD 10
- Mono-rail camera Fatif 4"x5", lens 150 mm/5.6, color reversal film Ektachrome 64 asa Kodak, B.W Ilford 125 ASA
- average taking distance 60 m
- average photo scale 1:400
- plotting accuracy 2-4 cm
- duration of the geodetic and photogrammetric works: one working day for a three men crew
- n. of photograms : 6 in three stereo-couples

San Barnaba's spire

- Photogrammetric System PhOX
- Graphical editing: AutoCAD 10
- Camera reflex 35 mm Olympus OM4, 300mm lens, 1000 mm
- color reversal film Fujicrome 100 ASA
- taking distances 150/180 m
- average photo-scale 1:500/ 1:650
- plotting accuracy 3/5 cm
- duration of the geodetic and photogrammetric works: three working day for a three men crew
- n. of photograms: 11

13. CONCLUSIONS

The point-by-point plotting of lines doesn't express the full potentiality of the photogrammetry because of non continuity; in addition the monoscopic data capturing

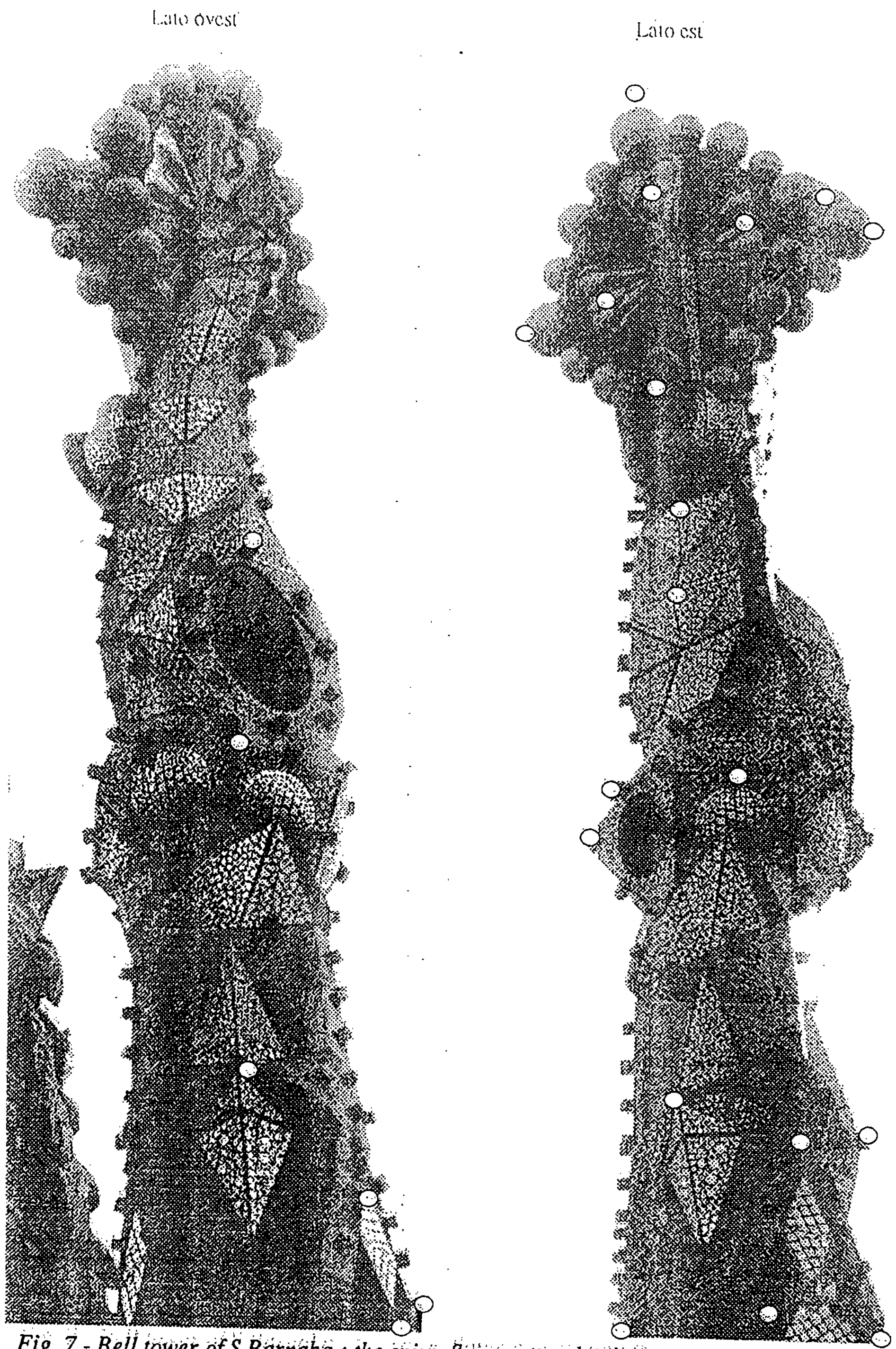

Fig. 7 - Bell tower of S.Barnaba : the spire. Some control points

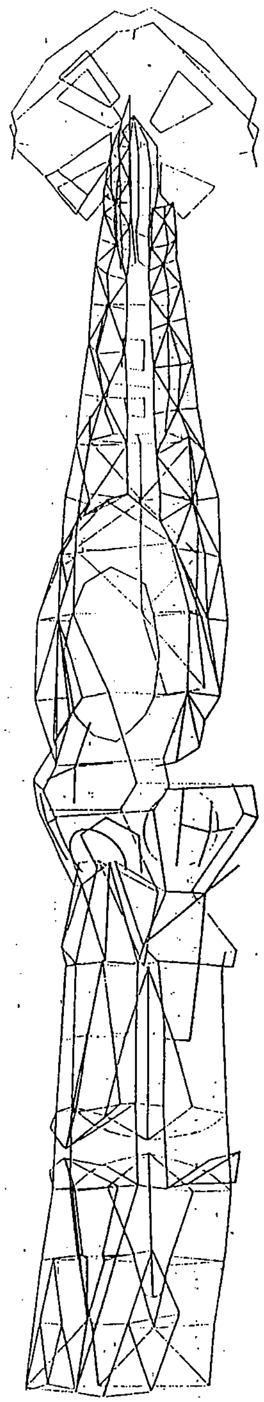

Fig. 8 - S.Barnaba's Spire : the wire frame

reduces even more the information contents of the photogrammetric surveys. The emploied P.C. CAD program, not expressely designed for photogrammetry, had limitations in memory and speed. Nevertheless the efficiency and low cost of this photogrammetric techiques were assessed positively with a satisfactory degree of accuracy. The same surveys would be certainly possible by means of the classical photogrammetry as well (metric camera and stereoplotter). Their results would be certainly better, but their employ would be much more difficult, mainly for the spire, and after all at a much higher cost.

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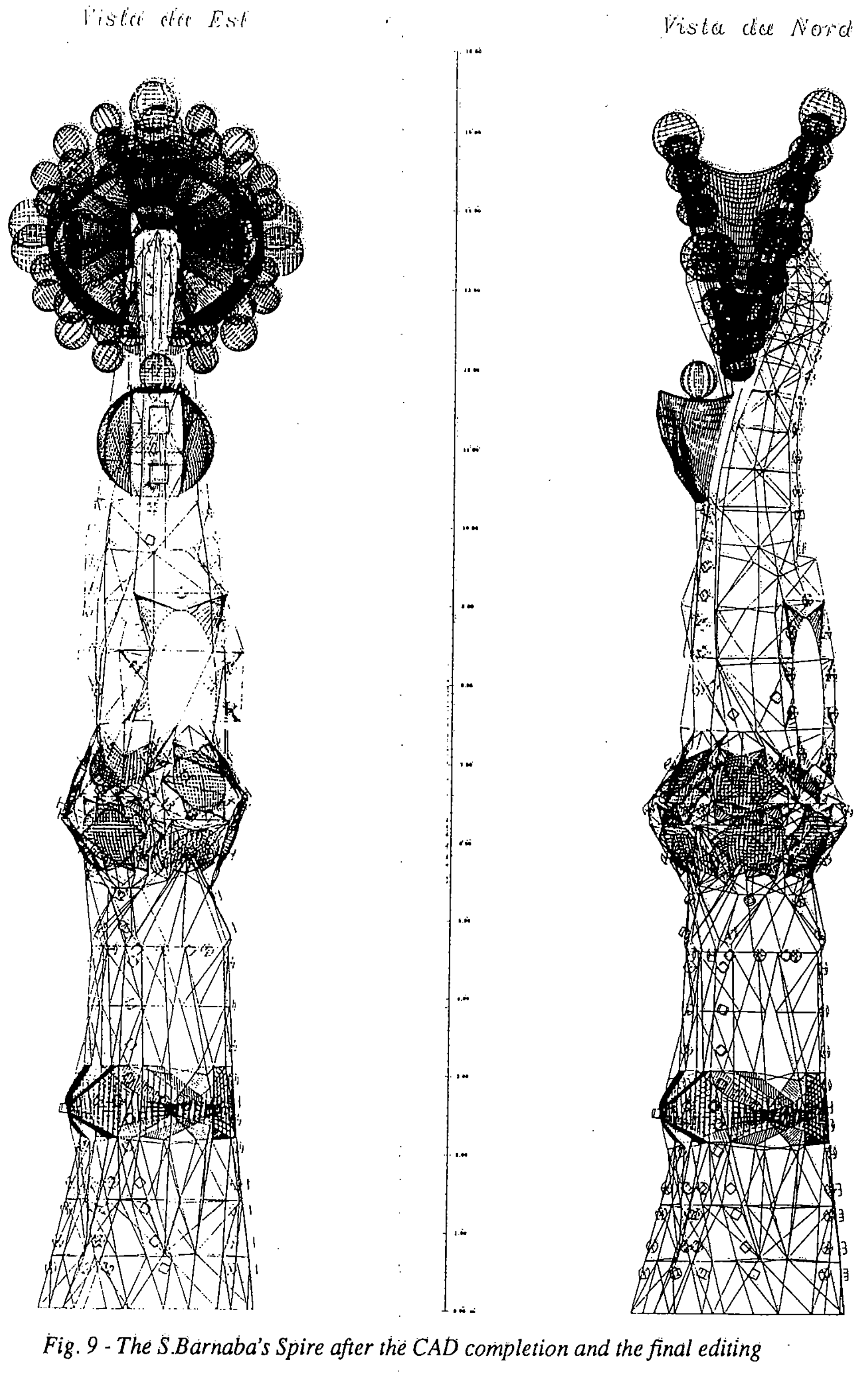

Fig. 9 - The S.Barnaba's Spire after the CAD completion and the final editing

SMALL-FORMAT AERIAL AND CLOSE-RANGE SURVEY OF ARCHAEOLOGICAL AND HISTORIC SITES AND BUILDINGS

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ABSTRACT

Recent research and applications from the author's experience is presented for archaeological and historic sites and buildings, painting, stained-glass and sculpture. Commentary is offered regarding *linearity* and expression; and the contention is made that the operator, and educated viewers and users of line drawings as well, will better appreciate, from these drawings, the difficulties and the merit of the original's execution, as well as its meaning. A programmable procedure for three-dimensional plotting in the drafting room is described, based on the use of utility and micro-light fixed-wing aircraft, specially-prepared or commercial color slides, amateur cameras and in-house rectification on simple proprietary equipment. Observations are made regarding corrections in the drafting room.

KEY WORDS: Small-format, sites and buildings, painting, stained-glass and sculpture, line drawings.

INTRODUCTION

We shall be dealing in this paper with traditional architectural surveys: elevations mostly but also painting, stained-glass, and sculpture. Artists have often (discreetly) used the camera oscura and photography, its legitimate heir, for support; we document here, from personal experience, the equivalent use of non-metric 35mm equipment and specially-prepared or commercial, aerial or terrestrial color slides, to produce on short notice, at reasonable cost, good drawings to reasonable tolerances.

Theory

The following question arises immediately for painting -, and for stained-glass as a derivation: is it useful to render as a line drawing, such a non-linear presentation; and for sculpture, is it useful to render as a line drawing, bodies, the folds of garments, and the expression in faces? Regarding painting, we quickly resolved, in a difficult moment, an encouraging test-case from a commercial slide. Villard's marvelous plates are encouragement also for sculpture - herewith our testimonial. So it appears already at this point in our discusssion, that some certain combination of traditional free-hand drawing with modern methods, including photography and photogrammetry, is recommended.

There remains the thorny question of accuracy; or, more to the point, of a reasonable relationship between price, time of execution, and accuracy. It appears to us, that the *a priori* demands of the scientific method; or the eventual neeed for precise reconstruction of works that might be lost, must be compared to the benefits of a less cumbersome procedure more useful perhaps, in actual practice, to conservators. Dare we present here, from personal observation, this connecting inquiry: how much of a concern is a controllable error, duly announced by the operator, if no one can see it? We speak in this connection of certain drawings deliberately prepared in our office with a distortion of 4%, that specialist viewers were unable to distinguish, face to face, from the original. How much time and money and effort is one willing or able to expend on a particular project? We therefore suggest that in certain situations, larger tolerances be allowed in the trade, to favor expediency.

Applications

In sketching-out this combination of traditional and contemporary procedures, we write for ordinary talent in actual drafting-room practice; and especially for rapid execution and exact proportion. We are thinking also of the young, and of a healthy balance between craft and machine. When using stereoplotters, Corinthian capitals have been rendered ocasionally in the form of artichokes! Adequate training in the survey by hand of historic buildings is the only way, in our experience, of preventing such unexpected results, including for stereoplotter operators, whose usefulness (and astounding accuracy) is not in question.

From surveys done by hand, the draftsperson as well as the alert user obtain important results: a more direct reading of the work owing to *the line's integrity* (Ingres); an appreciation of the difficulties involved in the execution of the original; the perception of intimate reality - troubling at times and hidden ordinarily by the medium and by convention. Psychological connotations less readable in the original owing at times to placement and lighting also become clear. In summary, our feeling is that a photo shows all, while a line drawing shows more! Well yes, a line drawing is already an interpretation; and a teachable one at that, in actual drafting-room practice (please see below).

A few practical applications of this procedure are obvious: restoration and conservation projects, inventories, publication (line drawings are much easier to reproduces than continuous or even half-tones). Others must be explored in connection with conservation groups and the young. To be sure, our method depends on a large pool of readily-available, semi-skilled draftspersons, which is the case in Mexico; and sufficient numbers (well, one-third . . .) of new applicants, from recent experience, can master the few simple rules involved, in one short trainig session.

Corrections

Herewith our observations which will serve to calculate percentage errors (∂, Table I, Fig. 1) with regard to 2R (diameter of an advancing object) for three different telephoto lenses (R=1, d=1):

. . .

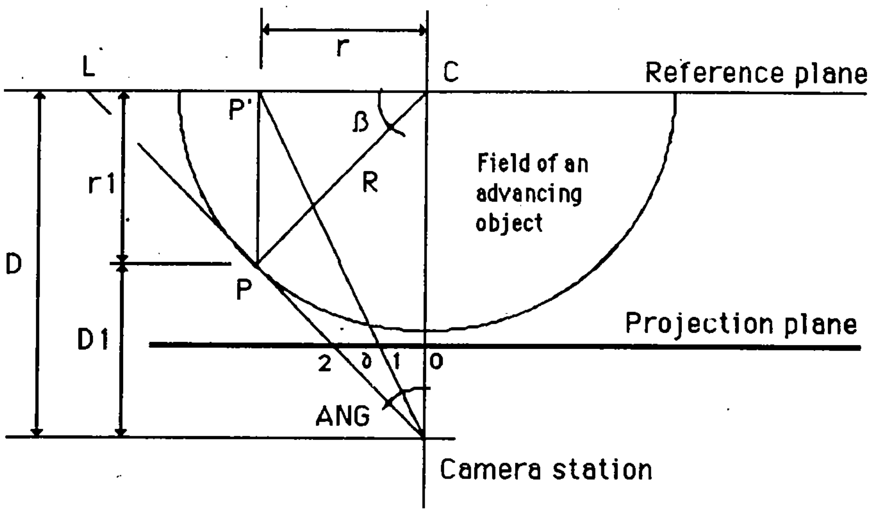

Fig. 1: Deformation in cylindrical or spherical objects.

cosß=R/CL; CL=R/cosß; tanANG=CL/D; D=CL/tanANG (ANG being one-half the lens' horizontal field of view); D1=D-r1; cosß=r/R; R=1; ß=ANG; r=cosANG; sinß=r1/R; r1=RsinANG=sinANG; by similar triangles: 01=r/D, 02=r/(D-r1); deformation for the whole figure is ∂=(02-01)/02*100/2

Now, tabulating the above:

f=200mm, ANG=6°, D=9.56R

ß	r	r1	D1	01	02	∂, %
0	1	0	9.56	0.105	0.105	0
15	0.965	0.258	9.309	0.101	0.104	1.34
30	0.866	0.5	9.067	0.091	0.096	2.39
45	0.707	0.707	8.86	0.074	0.08	2.82
60	0.5	0.866	8.701	0.052	0.058	2.49
75	0.258	0.965	8.602	0.027	0.03	1.45
90	0	1	8.567	0	0	0

	f=400mm, ANG=3°, D=19.1R	f=800mm ANG=1.5°, D=38.46R
ß	∂, %	∂, %
15	0.66	0.33
30	1.16	0.57
45	1.36	0.67
60	1.19	0.58
75	0.69	0.33

Table I

In practice, D is a multiplier for camera-object distance as a function of the object's diameter. Regarding depth (or 3-D), it is obviously the basis of present-day formal photogrammetry; but in our situation, where a rectifier is not available (and, frankly, not an immediate aspiration), we have written an original program in Basic, based on our observation of parallax in our stereoscopic pairs, which allows its calculation. We call this procedure, *in-house stereometrics* (Fig. 2; but the plain truth is that for most situations dealt with in this paper, it is easier to measure depth directly on the object):

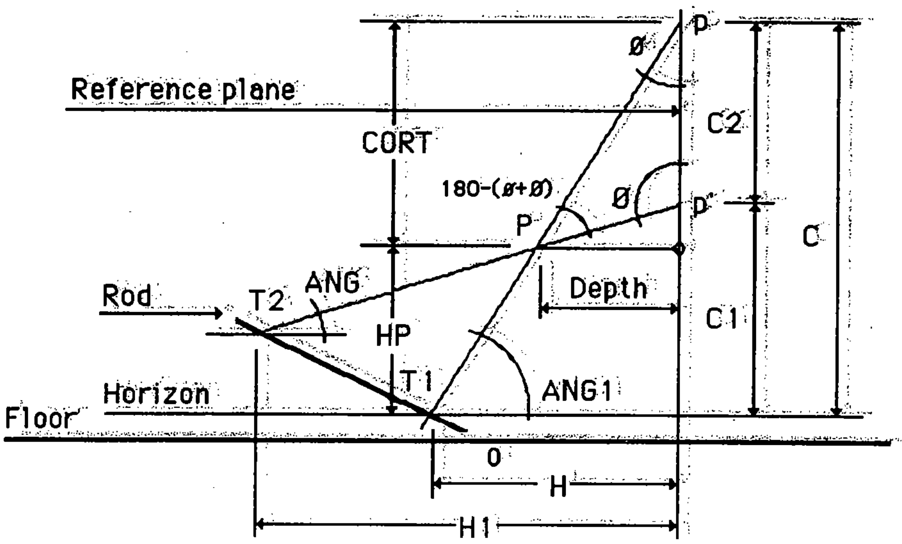

Fig. 2: Stereoscopic exposure with the camera tilted on one plane, perpendicular on the other.

$C2=C-C1$; $H1=H+T1T2\cos(90-INC)$; $ø=90-ANG1$; $Ø=90+ANG$

$Pp=C2\sin ø/\sin(180-(ø+Ø))$; $CORT=Pp\cos ø$; $Depth=CORT\tan ø$

Empirically, we find the following configuration for a simple rectifier that corrects for an exposure with a 135mm telephoto lens and $\beta=20^{\circ}$ approximately :

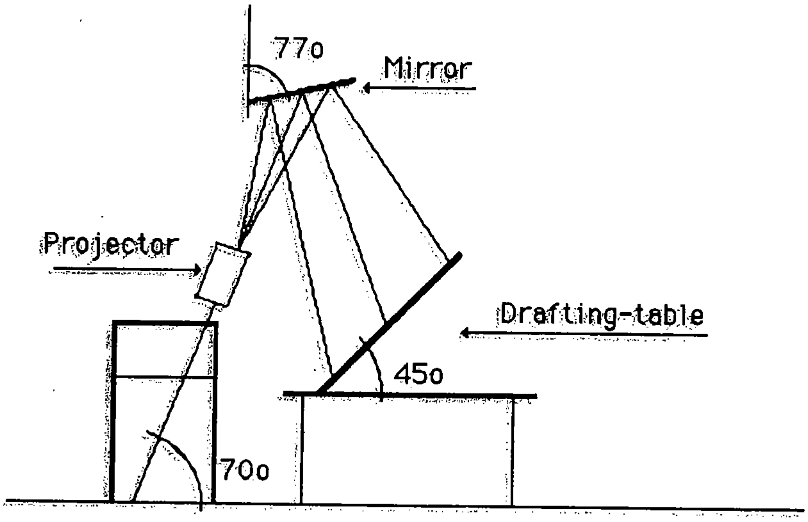

Fig. 3: A simple rectifier.

Operation

Regarding execution, rectification, and reprographics: we usually do large drawings, 90cm wide, freehand in ink with an ordinary fountain pen or fine-tip marker, or with instruments in pencil, tracing directly from slides projected unto bond paper (a zoom projecting lens, or the projector's distance from the drafting surface serving to set the scale of the drawing; the xerographic copier can also be used for the purpose). Corrections can easily be made with white correction fluid; one can even do collages, especially for faces, which are difficult, prior to copying or reducing xerographically on a better-grade paper, such as Canson. Lines become finer on reduction, giving a pleasing effect.

CONCLUSION

Architectural offices and agencies dealing with heritage conservation, as well as individual researchers and groups dedicated to its protection, will benefit from the use of commonly-available resources for the timely, practical and modestly-priced execution of useful surveys with an accuracy acceptable for numerous applications: projects, inventories, publication, research. For these applications, the price-time- accuracy relationship seems to favor simple procedures as outlined herein.

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THE OTRANTO MOSAIC FLOOR: TEN YEARS OF PHOTOGRAMMETRIC SURVEYS

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ABSTRACT

This paper described the photogrammetric analyses of the ancient mosaic floor in the Otranto Cathedral carried out in ten years from 1981 until 1991. Given the development of instrumental methodologies in this decade it seems opportune to illustrate the different experiences with cameras, platforms and stereoplotters. Camera performances in architectural and archeological applications are also documented.

1. INTRODUCTION

In the last ten years, the Laboratory of Photogrammetry (Department of Architecture and Urban Planning, Bari, Italy) has been actively involved in the restoration project for the mosaic floor of Otranto Cathedral (near Lecce in the south of Italy). During the long time required initially for the difficult decisions involving the restoration plans and then for disassembling and reassembling the mosaic tesserae some interesting changes in instrumental and operative methodologies come about. Otranto Cathedral, built in the XI Century, has a wide mosaic on the floor of the nave (10 x 30 m2). This work was executed by a monk from the East between 1163 and 1166.It represents the "life tree" with Biblical scenes, and others illustrating northern tales from classical and Breton cycles as well as figures and signs of the zodiac related to working activities for each of the twelve months. The cited representations probably inspired Dante Alighieri while writing some parts of his major work "La Divina Commedia". In the 80's, since the floor's progressive degradation, it was decided to plan the overall consolidation of the base which showed unhomogeneous static stability. The plan proposed lifting the 300 m2 mosaic all at one time using a technique never tried before. Given the risks for the mosaic, our Laboratory set up the first stage of a metric documentation of the mosaic floor entailing an analysis integrating photogrammetry, micro-geodesy and CAD (M.Minchilli, 1982). Since the Ministry of Cultural Assets was to only partially finance the plan it was impossible to undertake the restoration of the entire mosaic. Thus it was decided to begin work in the fore part of the nave, near the presbytery, using traditional techniques consisting in pulling up the mosaic divided into parts. During this operation and the subsequent archeological excavations, many column foundations, graves, ancient findings and part of another wide mosaic floor were found. From the portion of this mosaic

Fig. 1 - The floor in the original situation.

uncovered, probably dated V-VI century, it seems likely that it was as large as the nave itself! At the end of excavations we executed another photogrammetric covering and control survey (2nd stage, 1986) tightly connected to the first as regards the homogeneity of the coordinate system. It was strictly necessary to keep the reference system unchanged in order to obtain a superimposed graphical representation of the two mosaics. At the beginning of 1989, thanks to other funds assigned to the work, the whole upper mosaic was deassembled so that the lower one was entirely visible. Then the 3rd stage of the photogrammetric records was extended to the 300 m2 of the nave in order to document the earlier mosaic and the archeological excavations. After this operation the archeologists continued their work documenting it solely by traditional methodology. The fact that techniques like archeology, wich destroy existing situations as they progress, are not always documented by photogrammetry is open to severe criticism. Before reassembling the upper mosaic we completed the 4th stage of the survey taking vertical and low-oblique photographs of the bottom of the excavations. The oblique records were necessary to document the archeological stratigraphy and the lateral views of the nave. During the first months of 1991 the medieval mosaic was completely reassembled and we have planned the 5th and last stage of the survey finalizing it to the comparison with the existing situation before the restoration. The long time interval between the first stage up to today has made it possible to experiment with different camera performances, different height platforms and changed stereorestitution methodologies. We started in 1981 using a small-format stereometric camera and a plotting instrument that provided analogical solutions to reach the present using medium and large format cameras, Total-Stations, analyitical stereoplotters and numerical on-line data-collection. Besides instrumental progress, that radically changed the close-range photogrammetry during the last years, we incurred typical difficulties always present in this kind of application. Among these I should mention how the continually modified situation in a

Fig.2 - Part of the mosaic restored in the '50.

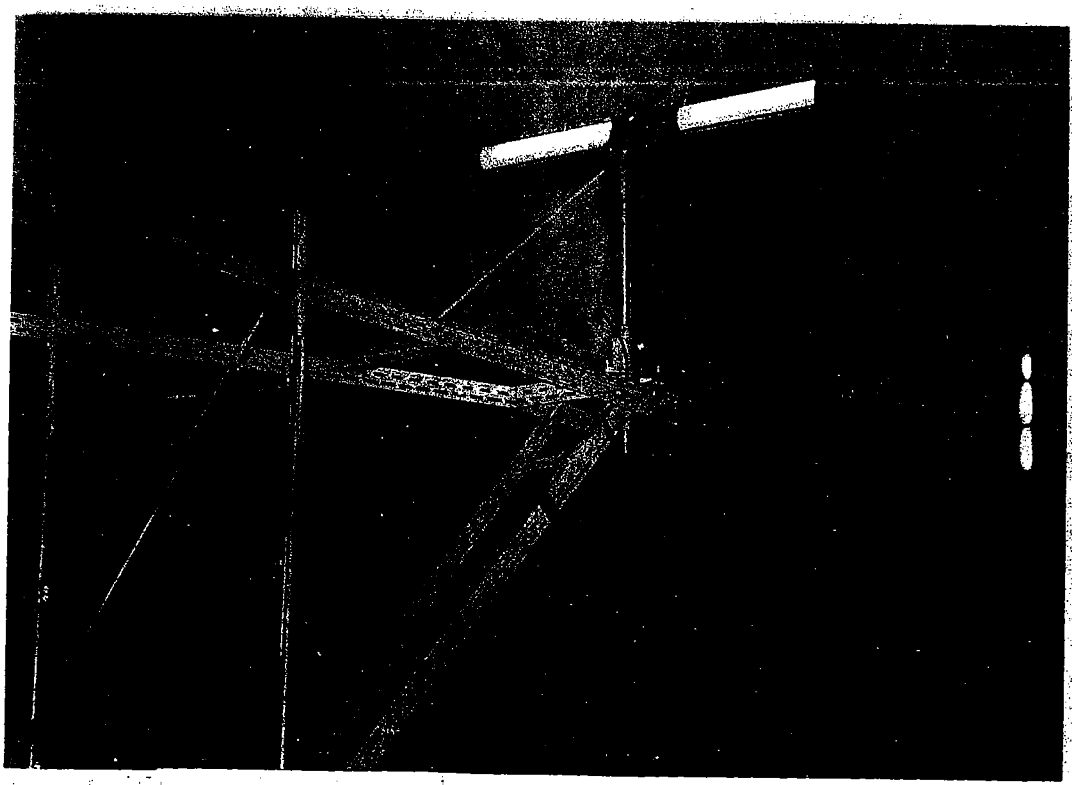


Fig.3 - Special stereocamera bracket used in the 1st stage.

restoration working area frequently involves different taking heights, focal lengths of the camera, scale ratio and, as in our case, changes concerning the control points survey. In the conclusion of this paper I draw some conclusions as to the optimum of terrestrial camera performances and stereoplotting compilation resulting from this field experience.

2. FIRST STAGE (1981)

In this paper I briefly describe the starting stage of the survey, referring to: M.Minchilli, 1982 for more detailed descriptions. The initial request, in 1981, was for a complete metric analysis of the whole mosaic floor with special regard to the height variations of the surface. Both graphical and numerical data were to constitute a basis for the operative restoration design and the permanent documentation of the existing planimetry and altimetry of the ancient mosaic. At that time the state of the floor was still practicable, but great care was needed because of its seriously damaged mosaic, so we planned to take 30 vertical stereometric pairs using a camera with a special bracket mounted on wheels. The light weight of this platform allowed us to perform our work without damaging or detaching the tesserae of the mosaic. The values obtained for scale factor (about 1:60) and base-height ratio (about 1:3.5) resulted in a data collection, by analogical stereoplotting, of less than 5 mm mean accuracy . This upper limit was intentionally fixed because the deep cracks on the surface and a large number of slanting tesserae made a higher degree of accuracy useless, both from the technical and the economical point of view. The restitution of the stereopairs was carried out by a mechanical-projection terrestrial stereoplotter and by assembling a wide photo-mosaic at the scale of 1:20. The 30 rectified photographs had only a slight image displacement because the floor height variations were only a small percentage of the taking distance (less then 2%). The geodetic control included about 350 points, arranged on a regular grid of 1x1 m, materialized by numbered targets on the mosaic surface. The spatial coordinates survey was carried out by classical solution: a network of distances for planimetry and a levelling for altimetry. The global digitizing of the graphic restitution was carried out off-line by a Digital PDP-11 based CAD system; the computed D.T.M. became the base for some graphic processing and automatic contour compiling.

Fig.4 - Restitution of the original situation.

3. SECOND STAGE (1986)

As already mentioned, in 1986 at the beginning of the excavation, only 60 m2 of the mosaic were deassembled. A classic technique was used consisting in gluing small parts of the mosaic surface, about 3 m2, and then pulling them up. The backs of the tesserae were completely cleaned and then they were put together on a light-weight concrete layer. Under the floor the archeologists carried on excavations bringing to light many interesting findings: among them the fore part of another very well preserved mosaic. The photogrammetric coverage was executed in very good conditions because it was economically possible to build a light metallic scaffolding on the excavated area. Using a platform, assembled above c.a. 5 m on the ground, we took photographs with a metric medium-format terrestrial camera with a principal distance of 100 mm suitable for 1:50 photo scale. The control survey was

Fig.5 - Excavations during the 2nd stage.

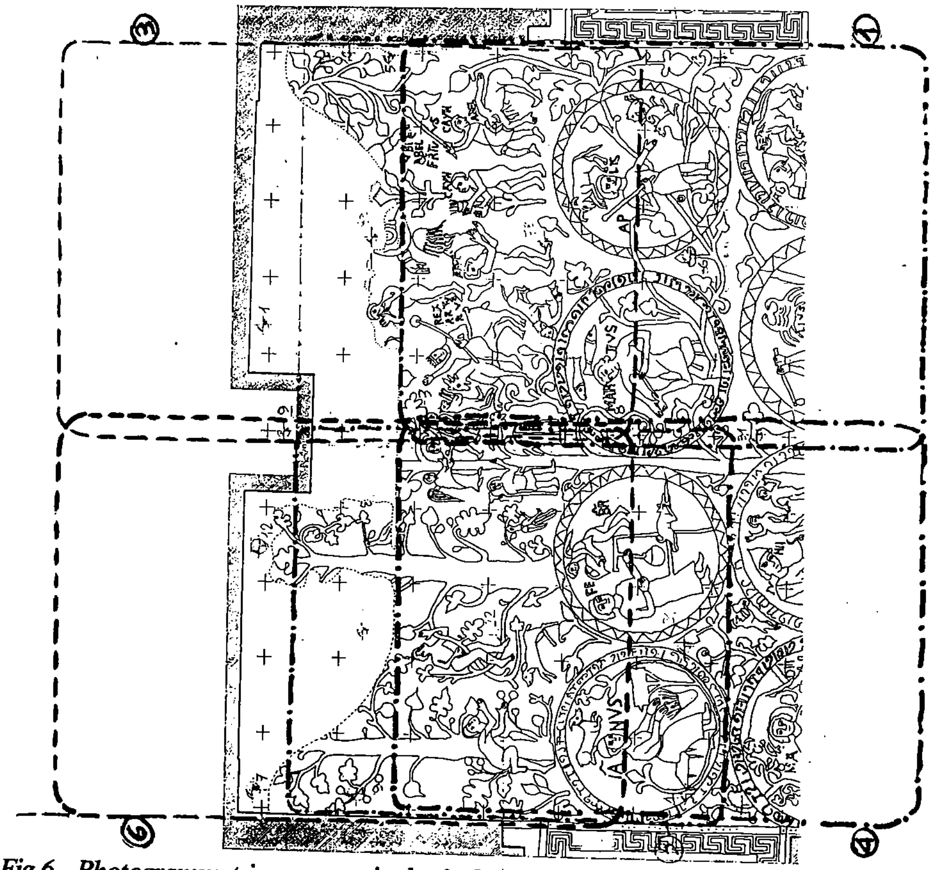
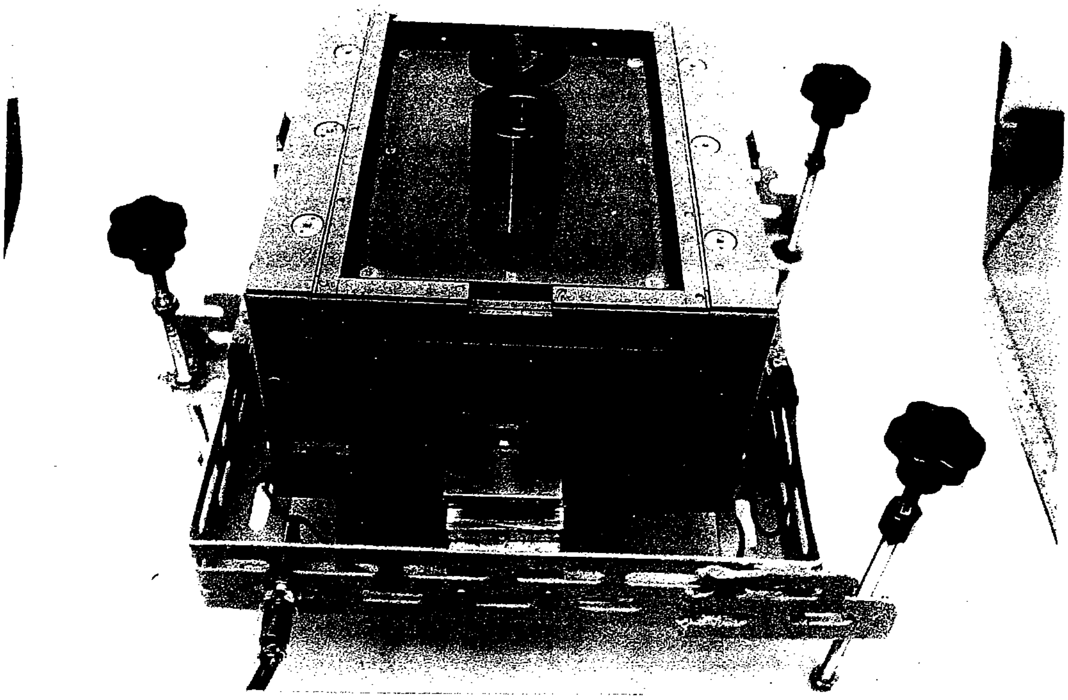


Fig.6 - Photogrammetric coverage in the 2nd stage.



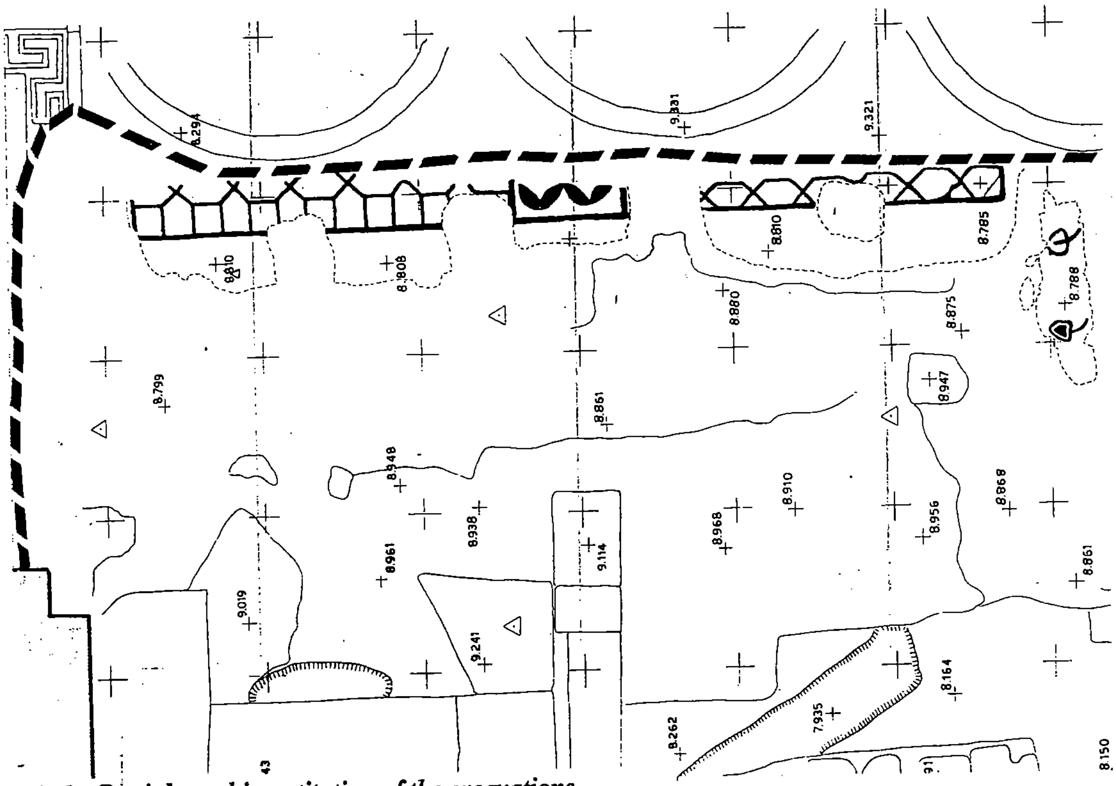


Fig.8 - Partial graphic restitution of the excavations.

executed with direct space resection using an electronic Total-Station interfaced to a data recorder. The target points were materialized by the conical head of milled steel nails. The heights were referred to the same datum mark of the previous control by a short trigonometric levelling. During the restitution, for the first time performed with an analytical stereoplotter compiling on-line, we noticed how the accuracy obtained by the chosen operative scheme exceeded the planned precision. I am fully persuaded that it is really useless to push the accuracy of an archeological photogrammetric survey up to 1 mm because of the texture and shape characteristics of the findings.

4. THIRD AND FOURTH STAGES (1989, 1990)

During the subsequent third and fourth stages we made a photogrammetric analysis of the whole nave after the complete deassembling of the two mosaics. To overcome the expansive cost of a scaffolding, built so that it would be possible to take photographs very close to the object as in the previous stages, we decided to operate from the roof truss of the nave. Having deassembled some decorative elements of the wood ceiling we were able to locate 6 positions for a normal angle camera on a specially built vertical mount. The one strip obtained from the taking distance of 16 m had a photo scale of about 1:100, and the same 1:2.5 base/high ratio of the previous stages. This operative scheme allowed us to work quickly and at low cost but the large area covered by each photograph involved some difficulties in setting up uniform artificial lighting. The photographs, taken in B/W and invertible color films, were restituted both by direct plotting and by numerical data collection in an analytical stereoplotter. At the same time we also took color photographs of the internal lateral elevations of the entire nave in order to analyze the colonnade and the stratigraphy of archeological excavations. In this case we obtained a coverage of the entire surface in only 3 stereoscopic models with a super-wide-angle camera.

5. CONCLUSIONS

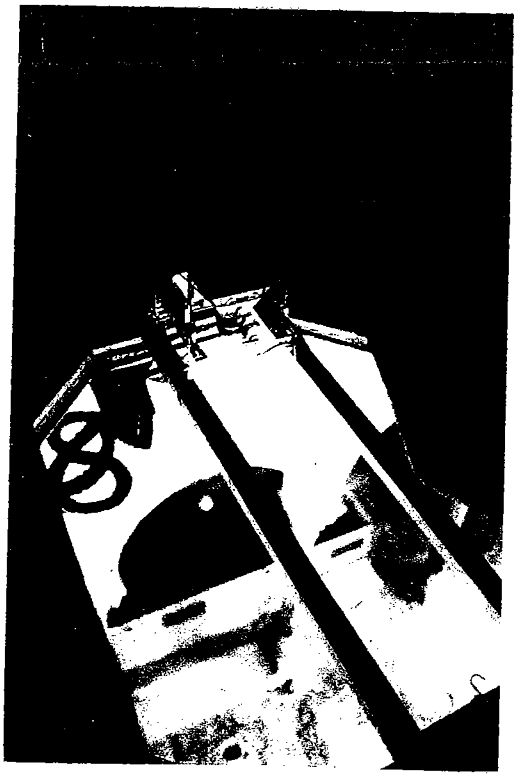


Fig.9 - Vertical mount in the wood ceiling.

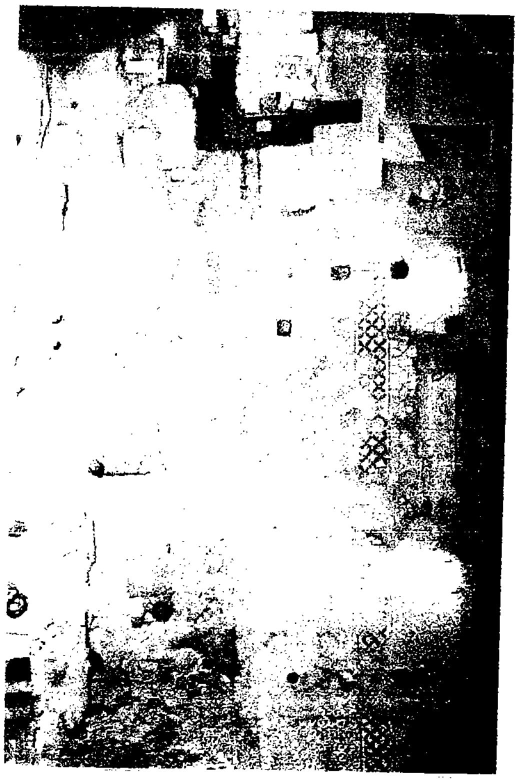


Fig.10 - Excavations in 1989.

Work on the Otranto project come just during the years of a change from the classic analogical to the analytical restitution. At present all the difficulties and the costs related to the off-line map digitizing are largely overcome working exclusively by on-line data collection during stereoplotting. It must be borne in mind that a digital graphic model can be processed very easily and it is a valid base for updating, checking, planning and also for interactions with termographic and ultrasonic analyses. This

TABLE OF PROCEDURES

PH. SURVEY										RESTITUTION			
St.	Date	Ster.mod. n.	Area m²/mod	Base m.	Dist. m.	B/H	Emuls.	Ph.scale	Op.axis	Type	Scale	Numer.	Object
1st	10/81	30	16	1.20	4.2	1/3.5	B/W	1:65	vert.	analog.	1:20	Y(off-l.)	mosaic
2nd	10/86	4	54	2.00	5.2	1/2,6	B/W	1:52	vert.	analit.	"	N	excav.
3th	2/89	4	125	6.50	16.5	1/2.5	B/W	1:107	vert.	analit.	"	N	excav.
3th'	2/89	3+3	260	7.50	11.0	1/1.5	B/W	1:170	hor.	analit.	"	N	elevat.
4th	3/90	4	125	6.50	16.5	1/2.5	B/W color	1:107	vert.	analit.	"	Y(on-l.)	excav.
4th'	3/90	3+3	260	7.50	11.0	1/1.5	B/W color	1:170	-15	analit.	"	N	elevat.
5th	?	7	72	4.30	6.0	1/1.4	B/W	1:60	vert.	analit.	"	Y(on-l.)	mosaic

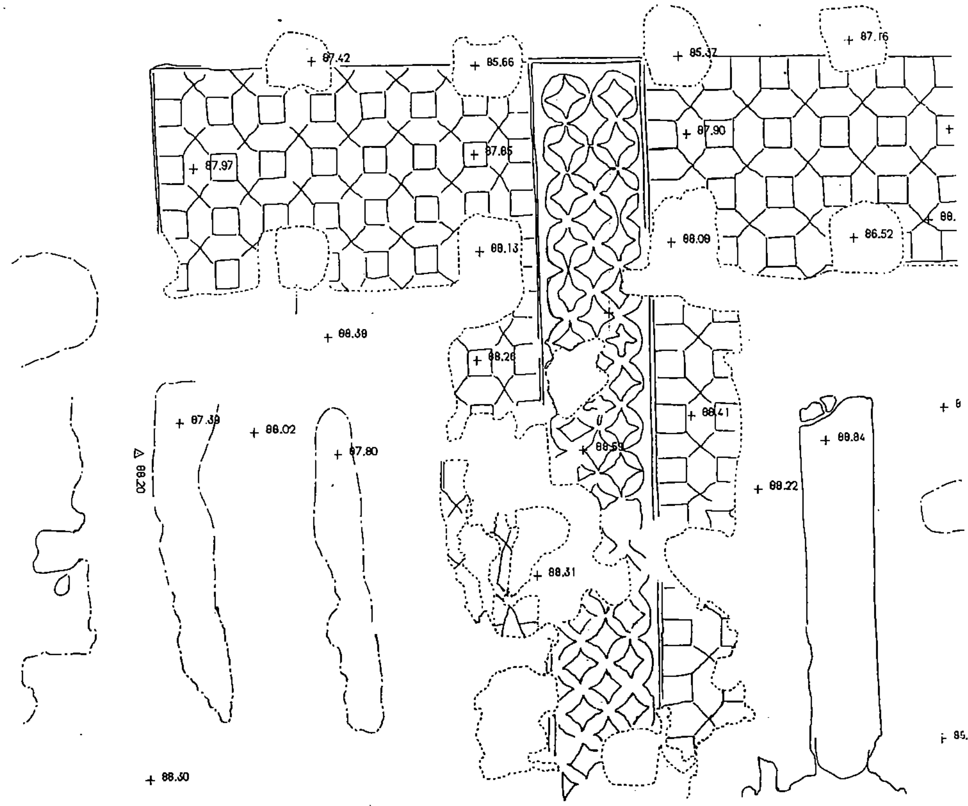


Fig.11 - Partial graphic restitution of the earlier mosaic.

TABLE OF INSTRUMENTS									
PH. SURVEY						CONTROL			RESTITUTION
St.	Camera	Im.for. mm	F.L. mm	Focus m	Ang.field deg	Equipm.	Methods	Control pts.	Equipm.
1st	Wild C120	60x 80	65	fix	17+32x 64	Wild T2+ Distomat	distanc.+. trig.level.	glued targets	photo-rectif. + Wild A40
2nd	Jena UMK 10	120x166	100	6.0	62x 80	Nikon DTM-1	space resection	nails + "	Galileo Digicart
3rd	Galileo Veroplast	112x160	154	14.2	40x 55	"	"	targets	Galileo DS 302
3rd'	Jena UMK 6.5	120x166	65	fix	85x105	"	"	glued targets	"
4th	Galileo Veroplast	112x160	154	14.2	40x 55	"	"	targets	"
4th'	Jena UMK 6.5	120x166	65	fix	85x105	"	"	glued targets	"
5th	Jena UMK 10	120x166	100	6.0	62x 80	" DTM A5 Wild NA2	" sp.resec. dif.level.	" " " "	" Digicart 40

can be held true for aerial mapping but it is not completely right for architectural photogrammetry. I am sure that many research laboratories, and also private companies, today still operate with on-line drawing outputs particularly when highly detailed plans or elevations are required in architectural and archeological applications. This methodology comes from our habits when "reading" architecture and also from the difficulty in schematizing some decorative details. This way of planning and producing the final output of a survey will certainly be put aside when new faster and cheaper computers are able to compute models with a very high number of graphical entities much more quickly than today. So I think that in the near future we will not have to produce simplified drawings, as in aerial mapping, in order to save in managing internal and external computer memory. My last remark concerns current terrestrial metric camera performances. We see an increasing drop in the industrial production of these instruments; at the same time some companies are commercializing semi-metric small-format cameras at a very convenient prices offering good optic performances and light in weight. Is this a real improvement? In the last century Meydenbauer too designed and built "small" format cameras for use on his long travels in Europe and Asia, but only from his very-large format cameras could he obtain that wealth of detail that all of us know and appreciate (G.Weimann, 1988). Except for the industrial applications of photogrammetry, the best arrangement is probably a light weight 4" x 5" camera equipped with a lens wich having a high correction of optical aberrations, will inevitably have residual radial distortion.

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Optimization of Survey Projects

Friday, October 4th, 1991, 9:00 - 11:00

PHOTO-PAIR DESIGN OPTIMIZATION IN ARCHITECTURAL PHOTOGRAMMETRIC SURVEYS

P. A. Dimanidis

ABSTRACT

Photogrammetry is well recognized as the main tool in capturing and recording sites and monuments of architectural interest. Recent trends in photogrammetric research are targeted towards the optimization of the design of the photogrammetric network. Criteria used include not only the photo-pair overlap, but also the dedired optimum accuracy of the final product.

The object of this research is the optimization of a two-photo configuration for the recording of the near flat facade of an architectural monument. It is finally shown that the geometric characteristics of the optimum photo-pair configuration can be computed from relative simple "optimization polynomials", the coefficients of which depend only on the camera charavteristics and the object dimensions, thus by- passing the time consuming Non-Linear Programming computations.

INTRODUCTION

In recent years it is well known that many countries are seriously interested in systematic knowledge and maintainance of their architectural tradition. A basic tool is the registration and survey of architectural monuments, as it is often emphasized in related meetings, symposia etc. *(e.g. ICOMOS, 1981)*.

This survey must include:

- Knowledge of the geometrical characteristics of the monument at a specific time
- Uniform accuracy
- The most possible metric and quality information
- Easy to approach Monument Intergrated Systems

All the above characteristics lead to the method of architectural photogrammetry *(Dallas, 1980)* which can fully satisfy all user needs, economically and quickly.

The method is devided in three main parts:

- Photo-coverage of the monument
- Measurements and observations on these photos
- Production of the final product (plan, section, thematic map, archive, orthophotography etc.)

The first two parts materialize the <u>photogrammetric network</u> as it is usually called in photogrammetry. The accuracy of the final product depends on the design of this net *(Zinndorf, 1986)*.

In this paper the optimization of the design of a two-photo photogrammetric network will be examined. This kind of the network, known also as stereo-pair, is often used in architectural surveys *(ICOMOS, 1981)*. The photos are assumed <u>metric</u>.

THE THEORETICAL ACCURACY OF THE STEREO-PAIR

Mathematic Model

The parameters of the mathematic model of the stereo-pair can be devided in two categories:

a. Those that define the geometric model, i.e.
- The elements of photo exterior orientation. These consist of the camera station coordinates and cameras orientation angles.
- The coordinates of the check points on the object

b. Those that define the stohastic model, i.e.
- Random observation errors
- Systematic errors caused by the degree of reliability of the mathematical model used to adjust the observations.

All the above information must be known in advance, in order to compute the accuracy of the survey. The difference between (theoretic) accuracy which depends on the observations' analysis and precision (or reliability) which depends on the closeness of observation to relity, must be reminded here *(see also Hottier, 1976)*.

The mathematic model which is often used in photogrammetric networks is the collinearity equations *(Manual of Photogrammetry, 1984, p.88)*. Every check point gives 4 such equations and the linearized system of observation equations can be written as

$$\begin{bmatrix} \dot{A} & \ddot{A} \end{bmatrix} \begin{bmatrix} \dot{x} \\ \ddot{x} \end{bmatrix} + v = b \qquad A\,x + v = b \tag{1}$$

where "$\dot{}$" denotes parameters of exterior orientation and "$\ddot{}$" the check points coordinates and

x : vector of parameters
v : vector of photo coordinates corrections
b : vector of differences between observed and approximate photo-coordinates

The solution is given by $N\hat{x} = A^T P b$ (2)

where **N** is the normal equations matrix

$$N = \begin{bmatrix} \dot{A}^T \\ \ddot{A}^T \end{bmatrix} P \begin{bmatrix} \dot{A} & \ddot{A} \end{bmatrix} = \left[\begin{array}{c|c} \dot{A}^T P \dot{A} & \dot{A}^T P \ddot{A} \\ \hline \ddot{A}^T P \dot{A} & \ddot{A}^T P \ddot{A} \end{array}\right] \tag{3}$$

and **P** is the weight matrix of the observatios. For check points accuracy analysis, the covariance matrix N^{-1} or $C_{\hat{x}}$ must be computed.

Partial inner constraints

The matrix **N** has a rank defect d=m-r=7 *(Meissl, 1969)*, where m is the number of parameters and r is the rank of **N**, because the observations on the photos give no information for the reference ground coordinate system. So, the matrix N^{-1} cannot be computed unless 7 parameters are held constant, i.e.

$$Cx = z \tag{4}$$

where C is a known $d_{\times}m$ full rank (d) matrix and z a known vector. These constraints are also called minimum, because they are 7. It can be proved *(Meissl, 1965)* that the best choise of matrix C is not by choosing 7 parameters constant bat by establishing 7 relations between parameters, so that

$$Ex = 0 \tag{5}$$

where E is the $d_{\times}m$ matrix of these relations. The method is known as "inner constraints" and has two basic properties: It minimizes the trace of $C_{\hat{X}}$ and the corrections of parameters, i.e.

$$tr(C_{\hat{X}}) = \sum_{i=1}^{n} \sigma^2_{x_i} = min \quad \& \quad tr\left\{\begin{bmatrix}\hat{x}^T & \hat{\ddot{x}}^T\end{bmatrix}\begin{bmatrix}\hat{x}\\ \hat{\ddot{x}}\end{bmatrix}\right\} = min \tag{6}$$

In our case matrix E is *(Dermanis, 1991)*

$E =$

	$\delta\kappa_i$	$\delta\phi_i$	$\delta\omega_i$	δX_{oi}	δY_{oi}	δZ_{oi}	J	δX_j	δY_j	δZ_j	
..	0	0	0	1	0	0	...	1	0	0	..
..	0	0	0	0	1	0	...	0	1	0	..
..	0	0	0	0	0	1	...	0	0	1	..
..	0	0	-1	0	$-Z_{oi}$	Y_{oi}	...	0	$-Z_j$	Y_j	..
..	$\frac{\sin\omega_i}{\cos\phi_i}$	$-\cos\omega_i$	$-\sin\omega_i\tan\phi_i$	Z_{oj}	0	$-X_{oi}$	...	Z_j	0	$-X_j$	..
..	$\frac{-\cos\omega_i}{\cos\phi_i}$	$-\sin\omega_i$	$\cos\omega_i\tan\phi_i$	$-Y_{oi}$	X_{oi}	0	...	$-Y_j$	X_j	0	..
..	0	0	0	X_{oi}	Y_{oi}	Z_{oi}	...	X_j	Y_j	Z_j	..

elements of exterior orientation of photo i — check points' ncoords.m.

(7)

Using this matrix, the covariance matrix of the parameters is

$$C_{x_E} = N^+ = (N + E^T E)^{-1} - E^T (EE^T)^{-2} EE \tag{8}$$

where N^+ is the pseudo-inverse of N. An alternative form for (8) which is computationally easier can be obtained by similarity transformation of a minimum constrained solution

$$C_{x_E} = S\, C_{\hat{X}}\, S^T \tag{9}$$

where S is the tranformation matrix

$$S = I - E^T (E E^T)^{-1} E \tag{10}$$

and $C_{\hat{X}}$ the covariance matrix of a minimum constrained solution. When we are interested in a subset of the network's parameters, S can be accordingly adjusted:

$$S_C = I - E^T (C E^T)^{-1} C \tag{11}$$

where $C = [\ 0 \quad E\ ]$ for better check points accuracy, or $C = [\ E \quad 0\ ]$ for better exterior orientation parameters accuracy.

The method of inner constraints can be easily applied in photogrammetric projects, as they are usually not referred to a specific ground coordinate reference system (as is often the case in geodesy), which can be independant.

In the case of monuments facades surveys, adjustment is usually devided in two stages:

- In the first, selecting a few points (e.g. 6) which cover all the facade and which are measured with topographic methods. These are the control points used for the determination of the 12 parameters of exterior orientation, $\mathbf{x}$.
- The measuring of any point of the object and computing its ground coordinates using the already computed 12 ext.orientation parameters.

Mathematically, this means that in the first stage apartial inner constraints adjustmentwhich minimizes the norm $[\mathbf{x}^T\mathbf{x}]$ can be used and then by using the parameters $\mathbf{x}$ and their covariance matrix, the covariance matrix of every measured check point can be computed. The covariance matrix of parameters $\mathbf{x}$ is *(Dimanidis, 1991)*

$$C_{\mathbf{x}C} = (I - E^T (E E^T)^{-1} E)\ C_{\mathbf{x}}\ (I - E^T (E E^T)^{-1} E)^T \tag{12}$$

where $C_{\mathbf{x}}$ is the covariance matrix of $\mathbf{x}$ from a minimum constraints adjustment. The covariance matrix we finally need is

$$C_{\hat{\ddot{x}}} = N^{-1} \bar{N}\ C_{\mathbf{x}C} \bar{N}^T\ N^{-1} + N^{-1} \tag{13}$$

STEREO-PAIR DESIGN OPTIMIZATION

The general case

The optimization problem which will be examined here is to attain the highest possible accuracy for points on a facade by changing the design of the stereo-pair, i.e. the parameters $\mathbf{x}$. The problem is known as first order design optimization *(Schmitt, 1985)*.

The specific criterion based on $C_{\hat{\ddot{x}}}$ which was used, is the sum of the volumes e_j of error ellipsoids of every check point on the facade is minimum:

$$\sum_{j=1}^{n} \left\{ \mathrm{Vol}(e_j) \right\} = \min \tag{14}$$

This criterion is known also in Statistics as D criterion and it is relative to the determinant of $C_{\hat{\ddot{x}}}$ and to the product of its eigenvalues.

Another critical point for the optimization procedure are the limits between which the parameters $\mathbf{x}$ can vary. These limits are defined by the

- Topography of the surroundings

- ▷ Coverage of the object in both photos
- ▷ Swing and scale limits of the photogrammetric analog instument (if used)

All these limitations can form equalities and inequalities *(Dimanidis, 1991)* which also contain the optimization parameters $\mathbf{x}$. These can be generally expressed as

$$\mathbf{h}_i(\mathbf{x}) = 0 \;,\; i=1..m \quad \text{and} \quad \mathbf{g}_i(\mathbf{x}) \geq 0 \;,\; i=m+1..p \qquad (15)$$

The problem of finding $\mathbf{x}$, as defined in (14) & (15), is a well known Non-Linear Programming (NLP) problem and can be solved with numerical methods *(Himmelblau, 1972, Chap.8)*.

The case of near-flat facades covered by symmetrical photo-pair.

In this case assuming that the object of the survey is near flat and in order to increase accuracy and stereoscopic viewing, some symmetries in photo-pair design can be established:

- ▷ Cameras at the same height
- ▷ Cameras at the same distance from the facade
- ▷ Same camera convergence and tilt

Swing round the projection axis (κ) can also be kept 0, as it does not influence object accuracy *(Zinndorf, 1986, p.52)*.

The optimization parameters are finally reduced to five, namely distance between the two cameras, i.e. base B, distance from facade D, camera height Y and camera convergence ϕ and tilt ω. All the above assumptions are valid. Exceptions for the established symmetries are due to surroundings limitations, as it is shown in the example given in the next paragraph.

When these limitations do not exist and the symmetric photo-pair is assumed, it can be proved that if the 5 optimum parameters B,D,Y,ϕ,ω for a specific facade with length L are computed, optimum ratios B/D and D/L will remain the same for every facade with length $L' \neq L$ when ϕ and ω remain the same, but also when the length to height ratio remains the same *(Dimanidis, 1991)*.

$$\frac{B}{D} = \frac{B'}{D'} \qquad \& \qquad \frac{D}{L} = \frac{D'}{L'} \qquad (16)$$

For generalization purposes, the height of the facade can also be assumed variable, and in that case onother two ratio equalities are valid, namely

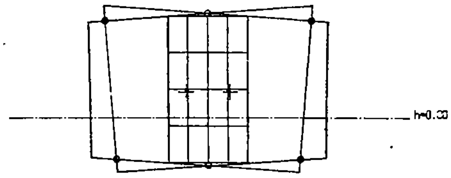
$$\frac{D}{Hup} = \frac{D'}{Hup'}, \qquad \& \qquad \frac{D}{Hdown} = \frac{D'}{Hdown'} \qquad (17)$$

where Hup and Hdown are height differences of up and down limit of simulation facade from camera height.

In order to examine the accuracy of this constant length L and variable height simulation facade for any symmetrical photo-pair design configuration, check points must cover all this overlap "zone" of length L. One usual way of doing this is by assuming a grid over the facade and computing the optimization criterion (14) for every grid node. This technique is shown in

Fig. 1, where the two overlap photos of a stereo-pair and the "zone" of constant length 5m are drawn. The step of the grid must be such, until average value of criterion for all points doesnot significantly change by further increase of the step value.

In Table 1, 10 different symmetrical photo-pair configurations are presented, and the percent of the difference of mean error ellipsoids axis value for every grid density from the same value for max density (100 nodes for this example) to this value of max grid density.



Ø/M : WILD-P30, B = 10m, φ = 15g, ω = 7g, D = 15m, L = 5m, H = 9.4m

Fig.1 Grid on Constant length zone

B	D	φ	ω	number of check poins								
				4	9	16	25	36	49	64	81	100
13	6	42	14	8.9%	4.0%	2.3%	1.5%	0.9%	0.6%	0.3%	0.1%	0.0%
14	6	40	7	8.6%	3.9%	2.2%	1.4%	0.9%	0.6%	0.3%	0.1%	0.0%
19	9	44	21	4.9%	2.2%	1.3%	0.8%	0.5%	0.3%	0.2%	0.1%	0.0%
20	10	43	7	4.7%	2.1%	1.2%	0.8%	0.5%	0.3%	0.2%	0.1%	0.0%
20	12	26	0	4.3%	1.9%	1.1%	0.7%	0.4%	0.3%	0.2%	0.1%	0.0%
29	16	46	14	2.9%	1.3%	0.7%	0.5%	0.3%	0.2%	0.1%	0.0%	0.0%
34	26	24	0	1.9%	0.8%	0.5%	0.3%	0.2%	0.1%	0.1%	0.0%	0.0%
35	20	45	7	2.3%	1.0%	0.6%	0.4%	0.2%	0.1%	0.1%	0.0%	0.0%
36	20	45	21	2.7%	1.2%	0.7%	0.4%	0.3%	0.2%	0.1%	0.0%	0.0%
47	28	44	14	2.1%	0.9%	0.5%	0.3%	0.2%	0.1%	0.1%	0.0%	0.0%
average				4.3%	1.9%	1.1%	0.7%	0.4%	0.3%	0.2%	0.1%	0.0%

Table 1. Grid density dependency on value of accuracy criterion

According to this table, if 25 check points (grid nodes) are chosen, the average ellipsoid axis difference is under 1% of the 100 points average ellipsoid axis, which is a sutisfying value.

Optimum parameters can now be computed for various photo-pair design configurations and same facade length L, and a system of k linear equations be created:

$$\mathbf{Ax} + \mathbf{v} = \mathbf{b} \qquad (18)$$

The equations can be polynomials so $\mathbf{x}=[\, a_1 \; a_2 \ldots a_p]^T$ where (p-1) is the polynomial degree, and

$$\mathbf{A} = \begin{bmatrix} x_1^{p-1} & x_1^{p-2} & \ldots\ldots & x_1 & 1 \\ x_2^{p-1} & x_2^{p-2} & \ldots\ldots & x_2 & 1 \\ . & . & . & . & . \\ . & . & . & . & . \\ x_k^{p-1} & x_k^{p-2} & \ldots\ldots & x_k & 1 \end{bmatrix} \qquad (19)$$

where x is ϕ, D/L, D/Hup, D/Hdown successively and $\mathbf{b} = [\, b_1 \; b_2 \ldots b_k]^T$ where b is B/D, ϕ, ϕ and ϕ correspondingly. Solution is given by

$$\hat{\mathbf{x}} = (\mathbf{A}^T\mathbf{A})^{-1}\mathbf{Ab} \qquad (20)$$

The organization of the computations can be as follows:

1. Choose a camera
2. Choose a facade length
3. Choose a camera height
4. Choose a tilt angle
5. Optimize stereo-pairs for camera distances from facade between an upper and a lower limit (e.g. 50 - 4m).

For different tilt angles repeat steps 4,5. An example of polynomials coefficients polynomials is given in Table 2. Such polynomials can be obtained for any metric camera. To use them, compute first D/L and then from polynomial $f(D/L)=\phi$ with tilt ω, compute ϕ. With ϕ D/Hup and D/Hdown can be computed. If Hup or Hdown is not valid, try another tilt w' and compute parameters with an interpolation method between two polynomials for tilt >ω' and tilt <ω' *(e.g. the Aitken method, see F.Sheid, 1968, pp.54-55).*

D/L ▷ ϕ

ω	0.0	7.0	14.0	21.0
ϕ	19.530 - 24.630	31.936 - 45.600	33.914 - 46.000	35.785 - 46.000
1	2.79414845D+00	-3.60934973D+03	-1.61928250D+03	-9.54172069D+02
2	2.03330040D+00	7.15867087D+03	3.01922978D+03	1.82925881D+03
3	1.55740643D+00	-5.60553310D+03	-2.17761965D+03	-1.32886098D+03
4	-3.20430517D-01	2.19174098D+03	7.80615592D+02	4.79296368D+02
5	1.81782832D-02	-4.27654877D+02	-1.39045646D+02	-8.58265374D+01
6		3.32976245D+01	9.84259098D+00	6.10229678D+00

B/D ▷ ϕ

ω	0.0	7.0	14.0	21.0
ϕ	19.530 - 56.918	31.936 - 56.000	33.914 - 56.604	35.785 - 44.706
1	7.24124670D+01	7.27514326D+01	7.32018676D+01	7.66351417D+01
2	-3.95191068D+01	-3.89289412D+01	-3.90816641D+01	-5.55251885D+01
3	-9.98126841D+00	-6.74695230D+00	-4.64073753D+00	3.15018082D+01
4	4.22261183D+01	3.33042436D+01	3.02368374D+01	-1.01995504D+01
5	-3.71964164D+01	-2.57664549D+01	-2.35908117D+01	1.39203942D+00
6	1.71733424D+01	8.89908594D+00	8.11533594D+00	
7	-4.50860578D+00	-1.19919649D+00	-1.08478582D+00	
8	6.35791019D-01			
9	-3.74064655D-02			

Table 1. Optimum polynomial coefficients for symmetrical photo-pair

Optimization example

The method presented applied in the survey of a NE part of the byzantine church of "Agios Dimitrios" in Thessaloniki, Greece. The specific part is surrounded (see Fig.2) by other parts of the monument so it offers an interesting application of the method.

Two photo pairs were taken: An optimum (**03-04**)and a near-"normal case" one (**01-02**) in order to realize the significance of the optimization

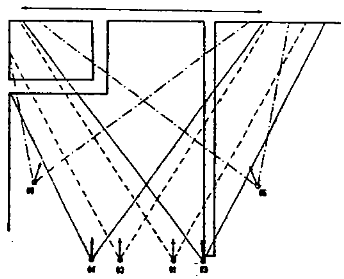


Fig.2 Photo-pairs for "Ag.Dimitrios"

procedure. Photo-pair **05-06** shown in Fig .2 is the optimum with no limitations, taken from polynomials. The facade was covered with 26 points (6 control and 20 check points) which were measured with a high accuracy 3-d topographic network. The parameters of the photo-pairs were:

01-02 : B=3.19m, D=14.32m, $\phi_1=-\phi_2= 1^{grad}, \quad \omega_1=\omega_2=0$

(near normal case)

03-04 : B=6.88m, D=14.32m, $\phi_1=-\phi_2= 4.96^{grad}, \quad \omega_1=\omega_2=0$

(optimum case)

The 26 points were measured on the photots and the adjustment procedure was carried out using a bundle adjustment program. A criterion used to compare the two photo-pairs was the distances' differences between check points computed from the two solutions and those computed from the topographic network, which are shown in Fig.3. It can be easily seen that accuracy of 03-04 is almost twice as better from the 01-02 photo pair.

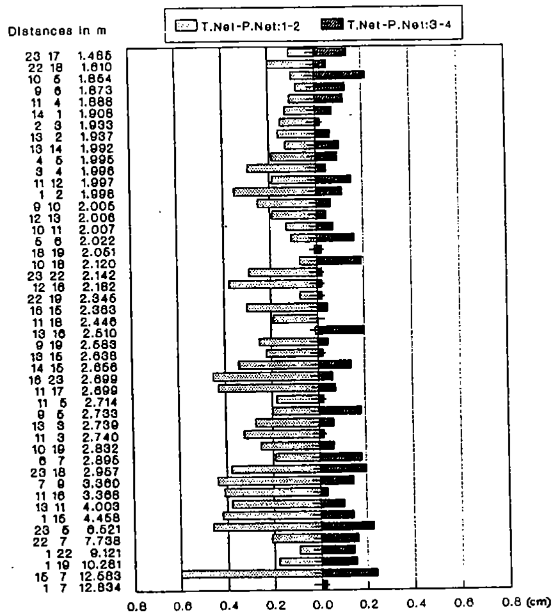


Fig.3 Comparison of two distances series

Conclusions

It has been shown how interesting and useful photo-pair design optimization can be for surveys of architectural monuments. The method presented needs no extra photos, just a better design of the photo-pair. In case of no surrounding limitations, optimization polynomials can be used, which by-pass the time-consuming general optimization method and so the optimization parameters can be computed on site.

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SIMPLIFIED METHODS IN ARCHITECTURAL PHOTOGRAMMETRY

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ABSTRACT

The requirements of cultural resources for their inventory, historical analysis and restoration, do not in the majority of cases demand the high accuracy offered by photogrammetry, hence the continued usage of traditional systems. A simplified methodology must be established for photogrammetric surveys of architecture. In this paper, different methods for simplifying the photogrammetric surveys are described for the use of semi-metric cameras and analytical plotter with special attention to the ADAM MPS2.

For many years the extended use of photogrammetry as a technique in the recording of cultural resources has been principally based on the greater accuracy which it offers in comparison with traditional techniques, excluding topographic ones. There exists a constant rivalry between traditional and instrumental techniques, due to the conflicting accuracy-cost relations, and this has led to a deadlock in the development of photogrammetric applications, on being restricted to applications in which specific accuracy is demanded, subject to the possibility of meeting the high costs.

Photogrammetry in its traditional applications inevitably has elevated costs owing to the high price of the instruments and the operations which have to be performed (photographic shots, measuring of control points, etc) which up till now were compulsorily determined by the work methodology itself. In contrast to this, traditional measuring systems, using a tape measure, plumb line, spirit level, etc, can easily accommodate their costs according to the demands of accuracy needed, and only when maximum accuracy is demanded are there any real problems. The flexibility of traditional systems in their adaptation to the requirements of precision constitutes the most direct cause for photogrammetry not having extended as a method of surveying, due to the fact that the systems used up until now, even if highly accurate, are always costly and do not allow for flexibility between the elements of precision-cost. It should be taken into consideration that the requirements of cultural resources for their inventory, historical analysis and restoration, do not in the majority of cases demand the high accuracy offered by photogrammetry, hence the continued usage of traditional systems which offer greater flexibility and adaptation to the cost-accuracy elements.

The appearance of new photogrammetric instruments, and above all the establishment of analytical systems of surveying, allow us to consider fresh possibilities and adapt the systems of photogrammetric surveying to actual demands. Therefore it is necessary to establish photogrammetric work methods which offer the availability of low-cost surveys combined with the required accuracy, while on the other hand dispensing with highly-skilled personnel. Only in this way could photogrammetry become the main technique and offer maximum advantages for architectural and archaeological recording.

In our opinion, a simplified methodology must be established for photogrammetric surveys of architecture. A simplified method must be one which allows for the cost reduction of surveying, adjusting the precision to existing requirements. The setting of these requirements is essential in this respect, as it must be taken into account that the accuracy-cost relation may be compared with a logarithm-type function[1]. The establishment of accuracy requirements within the actual necessities of surveying therefore constitutes the basis for any work on planimetric recording.

We can analyze the different elements involved in a photogrammetric survey, and we shall take a look at the ways of simplifying the various operations.

Traditional photogrammetric survey.

OPERATION	INSTRUMENTS	PERSONNEL	TIME
Photographic shots	metric cameras	specialized	t
Topographic control	theodolite	specialized	2*t
Orientation	Plotter	specialized	O
Plotting	Plotter	specialized	R
Simplified photogrammetric survey			
Photographic shots	semi-metric	non-specialized	0.3*t
Control	tape,plumb and level	non-specialized	0.1*t
Orientation	analytical plotter	specialized	1.5*O
Plotting	analytical plotter	specialized	R

The question raised by this chart is that data-taking jobs can be reduced by practically 7 times, at the same time using equipment whose cost is about 5 times less.

Ways of cost reduction in surveys:

Use of less costly instruments: semi-metric cameras, reduced format plotters, plotters based on tablet digitizers.
Non-topographic control: a theodolite is unnecessary and measuring time is reduced.
Non-specialized personnel: pre-determined procedures are used.

[1] See related to this the diagram by H. Foramitti. ICOMOS-CIPA, 1983. Hans Foramitti et le développement de la photogrammétrie architecturale. p.12.

Procedures for operating with simplified control

Independent models:

Set orientation of cameras: normal case (bi-cameras)

Left-hand camera as a reference point:

- Levelling of camera. Rotations=0
- Formation of model by relative orientation
- Deduction of base by means of verification of a measurement
- Introduction of base for absolute orientation.

Setting of orientation elements on the object

- Plumb line or orientation marks and measurement of distance between two points.
- Formation of model by relative orientation.
- Deduction of base and of the rotations by measuring on the model with the plotter
- Absolute orientation by means of the data deduced

Overlapping models:

Orientation through an overall model of a lesser scale; based on this the control points of larger scale models are measured.

Setting of orientation elements on the object:
Plumbs, levelling marks and setting line.

Measurement of distance between points.

Orientation of blocks by bundle adjustment. This procedure will be subject to a more detailed analysis at a future date.)

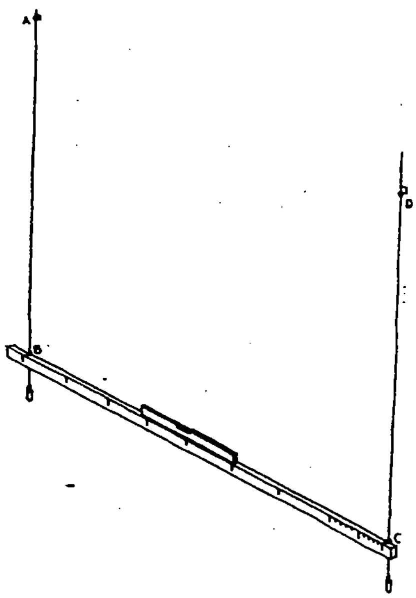

Fig 1, Method for fixing control points without geodetical survey

INSTRUCTIONS FOR PHOTOGRAPHING WITH NON-METRIC CAMERAS

The first point to be considered is the desired scale for the plotting. This should never be greater than ten times the size of the negative. The scale of the negative is determined by the focal length of the lens used, and by the distance from the camera to the object.
We shall consult the obtainable scales in this chart:

40 mm. lens

Distance	Negative scale	Plotting scale recommended	Plotting scale maximum
40	1000	200	100
20	500	100	50
10	250	50	25
4	100	20	10
2	50	10	5

80 mm. lens

Distance	Negative scale	Plotting scale recommended	Plotting scale maximum
80	1000	200	100
40	500	100	50
20	250	50	25
10	125	25	15
8	100	20	10
4	50	10	5

The visual field will depend on the distance and the lens used. The lens to be used must be chosen according to these variables.

The camera may either be operated mounted on a tripod, which will facilitate the approximate orientation and the levelling of the camera, or it may be manually operated. In this case the levelling proves to be more problematical, but if control points are available, then this will present no drawback.

The base (distance between the camera stations of two stereoscopic photographs), must be between a 1/3 and 1/10 relation to the distance to the object. The former value is not advisable if the object has considerable relief, unless difficulties are foreseen later in stereoscopic vision. With a relation of 1/10, appreciation of the depth may be insufficient, and therefore the accuracy of the measurement too. The average value recommended could be 1/5.

Both of a pair of photographs should have approximately the same scale. To achieve this they should be taken at an equal distance from the object and with parallel axes. A slight convergence may be admitted and may even prove beneficial to the accuracy, but if this is too great, there may be differences in scale towards the edges of each photo, which would be incompatible with a correct stereoscopic vision. The maximum admissible convergence is one that is produced with an angle of 15° between the optical axes of the two photographs

The ideal shot is one which has the planes of the negatives parallel to the plane of projection of the plotting. In principle, there is no limit for tilting the axis of the camera upwards or downwards, or even right or left. In such cases one should endeavour to take the two shots with a similar tilt. However, it must be remembered that in the more distant areas the scale is smaller and the base/distance relation will also be smaller, and therefore there will be a lesser degree of accuracy in measuring these parts. In these cases we have to consider that plotting is necessarily more laborious, since the planes of the object and the projection are not parallel

When taking photographs it is essential to take note of the approximate values of the distance to the object, the base and the tilt of the camera. It is equally ESSENTIAL TO TAKE NOTE OF THE LENS AND THE POSITION OF THE FOCUS USED since in non-metric cameras the figure corresponding to the principal distance is not printed on the negative.

PROCEDURES FOR CONTROLLING THE PHOTOGRAPHS

In order to plot a pair of photographs, it is also necessary to have the data of their orientation, or in other words, we must know the position from which the photos were taken with respect to their three coordinates X Y Z and the three rotation angles of the camera in each position Ω Φ K (α Θ K in the case of terrestrial photogrammetry).

These values may be obtained either directly, measuring them simultaneously with taking the shots, or indirectly by ,measuring the control points. This latter procedure is the more frequent of the two and the one which assures greater accuracy in results.

The orientation data can be calculated in the plotter if we know the three coordinates (x y z) of at least four well visible points in each pair of photographs[1]. The coordinates of these points are usually the intersection of lines of sight.

The control points should be chosen in such a way as to incorporate the area to be plotted within the perimeter determined by those points. The control points may be marked and measured previous to obtaining the photos, or they may just be points of the object measured simultaneously or even afterwards. In both cases special care must be taken to ensure their easy identification in both photographs.

A simple way of defining two control points which have been previously marked is by placing two plumb lines or correctly-weighted surveying rods and a string,ruler or horizontal rod which passes through the base of the former (Fig 1). The string, ruler or horizontal rod should be parallel to the plane of projection.

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[1] In fact the minimum requirements consist of knowing the three coordinates of two points and the coordinate in the direction of the optical axis of a third point. Usually the orientation programmes of the plotters (such as ADAM MPS2) demand knowledge of the three coordinates of at least three points. Anyway, it must be taken into consideration that with just this data the programme is unable to check possible errors in the coordinates, as there is no redundancy. Therefore the minimum information essential is the coordinates of at least four points. For a more complete information on minimum control requirements see P.WALDHAÜSL, J.PEIPE, **Control Information in Architectural Photogrammetry** Invited paper. XIIIth International Symposium of CIPA, Cracow, October 1990.

Then we measure the distance between the vertical lines (plumbs or rods) and the height from the horizontal rod to an easily visible point on each vertical rod which can be marked with an adhesive tape or similar. With this information it is easy to calculate the coordinates of four control points. If rods or sights are used, then it is unnecessary to measure anything. In extreme cases, one vertical line may be enough, marked with two points, one at the top, and another half-way.

Another straightforward method, although somewhat less accurate, of determining the orientation data, is with the use of a camera level. In this way we are able to control two of the rotations (Θ, K). The third rotation (α) and the base can be calculated taking the distance between two points which define the plane of projection. This system is only valid in the case of independent stereoscopic pairs, and of photographs with the plane of the negative in a vertical position.

For the plotting of several consecutive pairs we must establish a reference system which is common to all of the pairs, such as a string which is horizontal and parallel to the plane of projection. On this cord we must mark visible points, at least two of which should appear in each pair of photos and if possible at the edges of the area common to both photograms. The distances between the marked points are then measured. (Fig 2)

Although these systems make the orientation of models in the plotter more laborious, they simplify data-taking considerably. At any rate, we must advise that because of the lesser accuracy obtained, the system should be avoided for measuring objects of great depth. Areas to be plotted should be between planes reasonably near to the plane on which horizontal distances have been taken. Complementary measurements, whether vertical or of depth, may be of assistance in controlling the accuracy of the plotting.

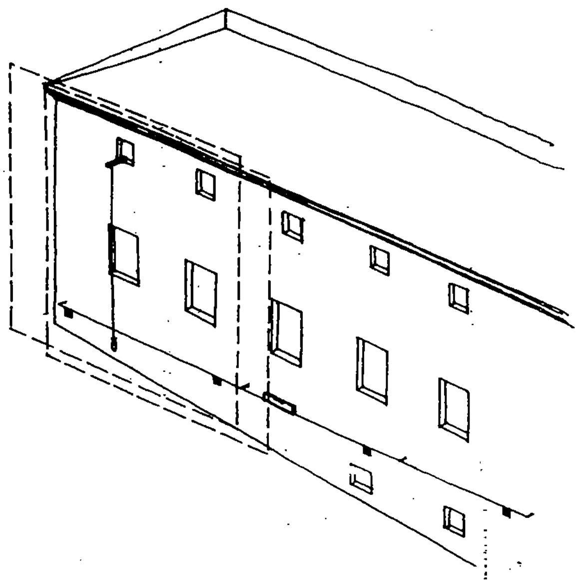

Fig 2, Method for relating consecutive models

WAY TO OPERATE IN SOME SIMPLIFIED CASES OF PHOTOGRAMMETRY

1st case:

Independent model: only one pair of stereoscopic photographs.

Characteristics of the object:
An object for which it is unnecessary to establish a priori a preset system of coordinates or projection plans.

Data-taking: We shall take two photographs of axes which are parallel or almost parallel and perpendicular to the base (as far as is possible).
We shall take accurate measurements of at least one distance between two well-defined points (D).
We shall take note of the approximate distance to the object and the base (may be done by long paces of approx. 1 m.)

Orientation: As there is no obligation to orientate with respect to a predefined reference system, we can use as such the one defined by the left-hand camera, which is the one referred to by a relative orientation in analytical plotters.
As an introduction we shall mention the approximate distance to the object and the base (b). Orientation is by observation of at least six points to be found along the outer edges of the model, whether on the perimeter or at a proximity or at a distance.

Once this former orientation has been obtained, the next step is to measure the coordinates of the two outer points from the control distance taken in the object. The distance obtained will be

$$d = \sqrt{(x_1-x_2)^2+(y_1-y_2)^2+(z_1-z_2)^2} \qquad [1]$$

the scale of the model will be

$$e = \frac{d}{D} \qquad [2]$$

In order for the model scale to be 1/1 and to allow us to measure true coordinates, we should modify the base initially introduced as approximate data. The true base will be equal to

$$B = \frac{1}{e}\, b = \frac{D}{d}\, b \qquad [3]$$

If on taking the photograph the left-hand camera was placed in both the adequate position and direction, then this procedure may prove to be fast and convenient, especially if the plotting is going to be edited in a CAD programme. If the selection is required of one or more specific projections with respect to planes specified in the object itself, the projected forms may be obtained quite simply through the CAD programme.

Operating with ADAM MPS2

Introduce the approximate values of base and distance on to the object, on card nº 1 (option 2 of the main menu). After introducing the photographs, internal orientation is effected (option 3) and relative orientation (option 4) with at least six points. Once this has been carried out, the orientation is accepted and the next step is then digitalization (option 5). Using option 7 (digitalization), we proceed to measure the coordinates of the outer points of the control measurement taken.
Formulas [1] and [3] are used to calculate base B, the value of which is introduced on card 1 with option 2 of the main menu. Next the relative orientation (option 4, option3 and option 4) is re-calculated.
The coordinates are re-measured in digitalization, and the distance between the points is checked. If this is correct, plotting may be begun.

With the 2.30 version it is possible to introduce onto a type-5 card in the main menu the figure of the distance between two points. On effecting the exterior orientation these points are digitalized with the same name as they were given on card 5. After calculating the relative orientation, the programme automatically calculates the new coordinates of the right-hand camera.

2nd case.

Independent model: only one pair of stereoscopic photographs.
Characteristics of the object:
Object for which the plan of projection is a vertical plane, the alignment of which is determined by two points of the object.

Data-taking: We shall take two photographs of axes which are parallel or almost parallel and perpendicular to the base (as far as is possible). The base will be approximately parallel to the plane of projection. The camera will be set up using a level which controls the two rotations nadir and kappa. This level may be the Cullman type fixed to the hot shoe flash attachment. The accuracy of this level may be considered as ±1°.[1] We shall take a precision measurement of at least one distance between two well-defined points (D). If possible, it will be the points which define the alignment of the projection plane.

The distance to the object and the base will be taken down (they may be measured with long paces of approx. 1 m).

Orientation: In this case it will be necessary to calculate the

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[1] The errors occurring as a result of levelling may be overlooked if only one plotting parallel to the negative plane and with little relief is going to be performed. For a 1° nadir error and for a point 20 m. higher than the camera. the planimetric error will be

$$e = 20 \sin^2 (1°) = .006 \text{ m}$$

The error of kappa will produce a general tilt of the plotting which can be controlled by levelling two points with a topographic or water level.

rotation α of the camera with respect to the plane of reference, using the levelling of the camera itself as a reference for the other rotations. By means of the procedure previously described, we can calculate the actual base, and repeat the relative orientation with this value which has been obtained. We can take simultaneous measurements of coordinates x and y of the two points which define the direction of the projection plane. Rotation α will be (Fig 3)

$$\alpha = \text{arc tg} \frac{Y_2 - Y_1}{X_2 - X_1} \qquad [4]$$

This value will be introduced as orientation information of the left-hand camera, and a new relative orientation can be compute. It would be appropriate to re-measure the points and check the angle and the base, and adjust accordingly until adequate results are obtained.

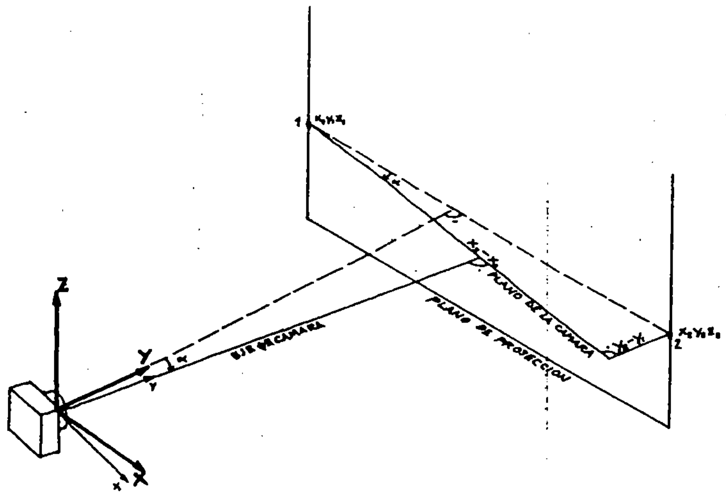

Fig 3, Determination of the α rotation

Operating with ADAM MPS2:

The appropriate values of base and distance are fed onto card nº 1 (option 2 of the main menu). After feeding in the photographs, internal orientation is done (option 3), and relative orientation (option 4) with at least six points. Once this has been completed, the orientation obtained is accepted and option 5 (digitalization) is chosen. With option 7 (digitalization) measurements are taken of the coordinates of the furthest points of the control measurement taken, and those of the two points determining the α direction of the projection plane.

Using formulas [1] and [3] the calculation is made of B base, the value of which is fed onto card nº 1 with option 2 of the main menu. Angle α is calculated with formula [4]. To feed this value in, two nº 6 cards must be filled in with option 2 of the main menu. On these cards there must be the coordinates of the left-hand camera, which may be the original values of coordinates (0,0,0 or

even 100,100,100), and the orientation angles of this camera which are α,90,0 introduced in gggmmss form[4]. *On the other card nº 6 there will be the approximate values of the right-hand camera, 100+b, 100, 100 and α,90,0.*[5]
The relative orientation is then re-calculated (option 4, option 3, option 4). The coordinates are re-measured in digitalization and the distance between the points and angle α is checked. If correct, then restitution may begun. To the contrary, a new adjustment is made.

3rd case:

Independent model: only one pair of stereoscopic photographs.

Characteristics of the object:
Object for which the plane of projection is a vertical plane, the alignment of which is determined by two points of the object and of which we know two level points, or preferably two points on one vertical.

Data-taking: We shall obtain two photographs of axes which are parallel or nearly so, and perpendicular to the base (as far as is possible). The base will be almost parallel to the plane of projection.
Precision measurements will be taken of at least one distance between two well-defined points (D). If possible, these will be the two points which define the alignment of the plane of projection.
The approximate distance to the object and the base will be noted (may be measured with long paces of approx. 1 m.)
The vertical orientation of a plane or the existence of a vertical line will be checked[6]. In the first case it will also be necessary to have two level points. All of these elements must be on a plane which is parallel to the projection plane.

Orientation: In this case we have to calculate the three rotations α, Θ, K of the left-hand camera with regard to the projection plane. This can be done by calculating these same angles from measurements of the reference elements.
By means of the above-mentioned procedure, the actual base may be calculated and we shall re-calculate the relative orientation with this value which has been obtained. At the same time we shall

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[4] When feeding in this information, the initial value of the FI angle originating from the first relative orientation must be taken into consideration, since the α value which was calculated is the correction that must be applied to this angle. The direction of the angle must also be taken into account, remembering that the angle we use should be that of the plane of the negative with respect to that of the projection.

[5] In a relative orientation, and whenever both cards 6 of left and right-hand cameras are completed, the programme accepts the left-hand camera values to be definite, and the right-hand camera ones as approximate, in order to begin calculations of the relative orientation. As values deriving from orientation, for the left-hand camera there will be those introduced on card 6; and for the right-hand camera those which derive from relative orientation, taking as a base the one introduced on card 1.

[6] A plumb line may be used for this.

measure the coordinates x y of the two points which define the direction of the projection plane, the coordinates y z of two points on a vertical of the plane which defines the vertical, and the coordinates x z of the points which are level or to be found on a vertical line.
Rotation α will be (Fig 5)

$$\alpha = \text{arc tg} \frac{y_2 - y_1}{x_2 - x_1} \qquad [4]$$

The value of K in the case of points on a vertical line will be (Fig 4)

$$K = \text{arc tg} \frac{x_4 - x_3}{z_4 - z_3} \qquad [5]$$

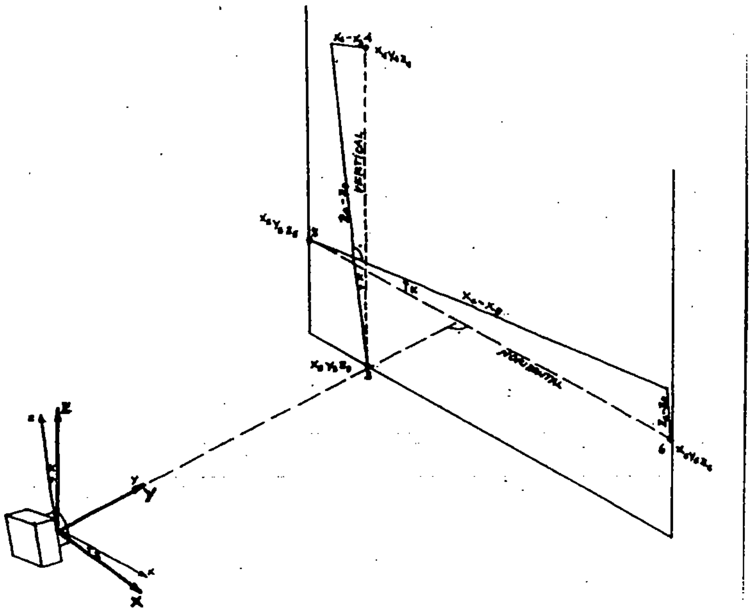

Fig 4, Determination of the K rotation

and for the case of levelled points

$$K = \text{arc tg} \frac{z_6 - z_5}{x_6 - x_5} \qquad [6]$$

The value of Θ will be (Fig 5)

$$\Theta = \text{arc tg} \frac{y_8 - y_7}{z_8 - z_7} \qquad [7]$$

These values will be introduced as orientation data of the left camera, and a new relative orientation computed. It is as well to measure the points once more, as well as to check the angles and the base, and re-adjust until desirable results are achieved.

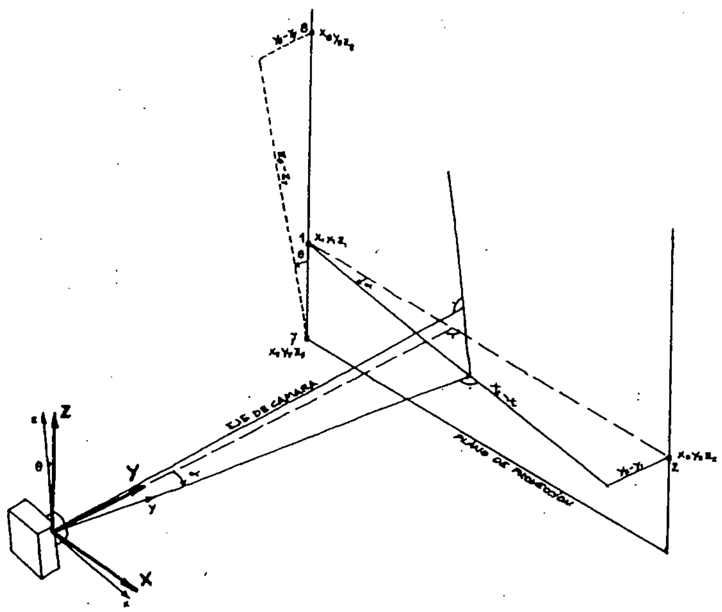

Fig 5, Determination of the α and Θ rotation

Operating with ADAM MPS2:

Introduction of approximate values of the base and distance to the object onto card nº 1 (option 2 of the main menu).
After introducing the photographs the internal orientation is done (option 3) and the relative too (option 4) with at least six points. Once this has been done, the orientation is accepted and the next step is digitalization (option 5). With option 7 (digitalization) we measure the coordinates of the outer points of the control measurement taken, and of the points which determine directions α, Θ, K of the plane of projection.

Using formulas [1] and [3] B base is calculated and the value introduced onto card 1 with option 2 of the main menu. Formulas [4],[5],[6],[7] are the means for calculating angles α, Θ, K. In order to introduce these values we should fill in two type-6 cards with option 2 of the main menu. On these cards we must introduce the coordinates of the left-hand camera, which may be values of origin of coordinates (0,0,0 or even better 100,100,100), and the orientation angles of this camera, which will be α, Θ, K, introduced in the form gggmmss[7]. On the other card 6 we must introduce the approximate values of the right-hand camera, which will be 100+b,100,100 and α, Θ, K.
Immediately afterwards, the relative orientation is calculated (option 4, option 3 and option 4). The coordinates are re-measured in digitalization and the distance between the points and the angles are checked. If they are correct, we can go ahead with plotting. If not, a new adjustment is made.

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[7] Refer back to note 2.

4th case:

Consecutive models: several pairs of stereoscopic photographs with parts in common (for example, partial consecutive model of the same façade).
Characteristics of the object:
Object for which the plane of projection will be a vertical plane, the alignment of which is determined by a level line which figures in all models (a string with specific points set on it).
Data-taking: We shall take the photographs with a properly levelled camera, and with the axes parallel or almost parallel and perpendicular to the base(as far as is possible). The base will be nearly parallel to the plane of projection which should be the one defined by the line of the object (horizontal string)(Fig 2).
We shall take accurate measurements of the distances between the points defined on the string. At least two of these points should appear in each pair of photos, and where possible on the edges of the part which is common to both photos. The approximate distance to the object and the base for each pair of photographs is noted (may be measured by long paces of approx. 1 m.)

Orientation: We shall orientate the first model as in case 2. Once the model is orientated, we shall measure the coordinates of one of the points on the string which appears in the following model. For orientation of the following model we shall proceed just as in case 2, and once orientated, then measurements will be taken of the coordinates of one of the points of the string. With this coordinates, we can easily calculate the coordinates of all the points of the string which have the same value for the z_0 and y_0. The coordinate x_0 of each point will be these of the previous plus the distance between. The differences between coordinates (x_0-x_p), (y_0-y_p), should be subtracted from the coordinates of the left-hand camera, and the relative orientation re-calculated with the new camera coordinates. By doing this, we shall have performed a general transcription of the second model, adjusting it to the coordinates of the first. We shall continue with the remaining models using the same procedure.

Operating with ADAM MPS2:

Introduction of the new coordinates, once calculated, for the left-hand camera of the second model, is done through card 6 of the left camera. The three coordinates X, Y and Z should be introduced on it. Approximate values, which may initially be X+b, Y, Z, should be introduced into the right-hand camera. Operations are performed in the same way in successive models.

A PRACTICAL CASE STUDY. FAÇADE OF "THE HOSPITAL OF THE FIVE SCOURGES", IN SEVILLE. ANALYSIS OF THE RESULTS

In February 1991, during a course on photogrammetry for postgraduate students of the Higher Technical College of Architecture in Seville, we performed an experiment on the façade of a historical building, "The Hospital of the Five Scourges", at that time in the process of being restored and refurbished as the official seat of the Andalusian Parliament.

In order to carry out a more complete study, a somewhat modified lay-out drawing by Hernán Ruíz (Fig 6), the original architect, was made available to us, together with the survey done by the architect Dr Alfonso Jiménez Martín, who used manual means to draw up the plan for restoration (Fig 7).

For the analysis we took two photographs with axes which were almost parallel and perpendicular to the base, using a ROLLEI 6006 METRIC camera with a lens of 40 mm. The camera was mounted on a tripod and a Cullman level fixed to the hot-shoe attachment was used to level it properly. Setting of the camera stations and α orientation of each camera was done visually. The distance to the façade and the base was measured approximately, and found to be 20 m and 40 m respectively. The time taken to do this was about ten minutes. Afterwards the measurement was taken of ten control points by intersection of the lines of sight using a theodolite, from the two theodolite stations, with a required time of one hour for the operation.

We made an orientation with an ADAM MPS2 plotter, using 8 control points plus one pass point on the higher part of the façade. The RMS obtained for each coordinate were .003, .005, .001. From this orientation we were able to draw a simple plotting on general lines.(fig 8, thin line)

Then we took a second orientation of the model using as our only data the horizontal distance between two control points on the lower part of the façade and on one same plane. Taking as reference the system described in case 2, we took an orientation calculating the base and the α rotation from the measurements taken in the plotter. Rotations Θ and K were adjusted according to the camera level.

An outline and the eight control points were plotted using this new orientation. With the help of an AutoCad, the second plotted drawing was transcribed, adjusting it with the first drawing on the lower left control point. (Fig 8, wide line) In this way the two drawings were superimposed and the errors could be checked.

If we consider the exactitude of the plotting from this orientation with the control points, we may say that the orientation without control points is correct with regard to scale, and we can observe as an error a general rotation, due to the inaccuracy of the levelling of rotation K. If we take advantage of this rotation, the maximum errors which occur are 2 to 3 cms. In the higher part, there is a slight over-elevation caused by the error in the Θ rotation and a slight excess of base. The sum of all these errors can be considered as <5 cm.

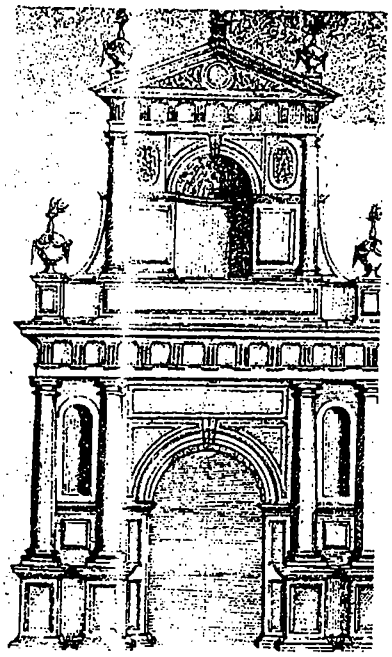

Fig 6, Original disign of the façade

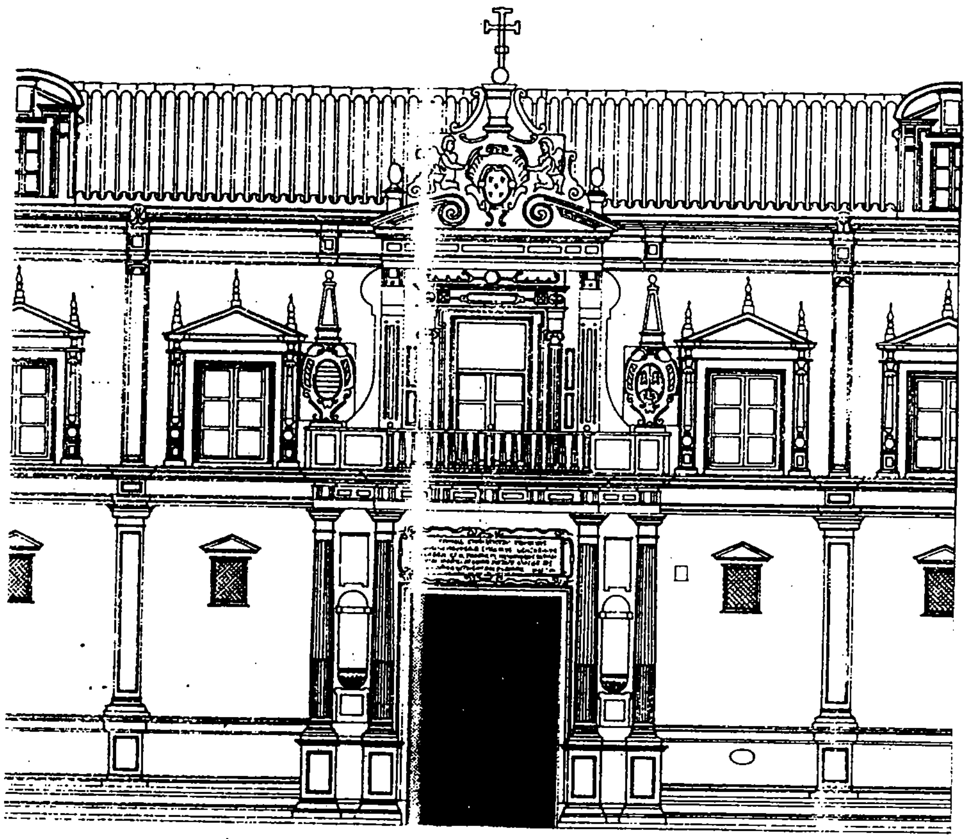

Fig 7, Survey by manual method

When we compare the plotting with the survey carried out manually, we can see that in the parts where it has been possible to measure with a tape measure, the drawings coincide. However, quite considerable errors can be observed in inaccessible areas and in the placing of elements which are on different planes and which have not been related on one level. Generally, errors up to 15 cm. have been observed in the projections of cornices and in the upper part of the façade, which no doubt could not be reached for measurement. Although we are lacking in information, from experience we could estimate the time necessary for this manual data-taking to be at least two hours.

To summarize, there are some conclusions to be drawn. In the first place, the errors resulting from manual measurements, no doubt performed with insufficient accuracy, are too great for a scale of 1/100. In spite of this, the time for data-taking was the longest. Data-taking with a semi-metric camera and complete control from a theodolite reduced the time for data-taking (58% of the previous time), but a greater degree of precision was obtained. Lastly, data-taking with limited control achieved considerable time-saving (12% of the time of manual taking and 20% of the time with complete control) without increasing the errors excessively. At any rate, the accuracy is more than sufficient for a 1/100 scale drawing.

The longer time necessary for orientating in the last case is rarely irrelevant with regard to the overall plotting time. Anyway, we can estimate the plotting time between 50 and 70% of the time required for a finished drawing of a manual measurement.

With instruments costing at a rate of 20% of the price of instruments normally used in photogrammetry (metric cameras, theodolite and precision plotters), and with data-taking times 90% less than what is required when working with metric cameras with theodolite survey, these simplified systems of photogrammetry allow the cost of an elevation to adapt to the necessities of accuracy required in the majority of dealings with cultural resources. Photogrammetry is no longer a sophisticated and costly technique, it is within the scope of any institution or professional person responsible for historical resources. Of course, the system cannot be applied in all cases. It will depend on the size of the buildings and the degree of accuracy required, but a considerable number of buildings and objects can be included in the field of application of the methodology explained in this paper.

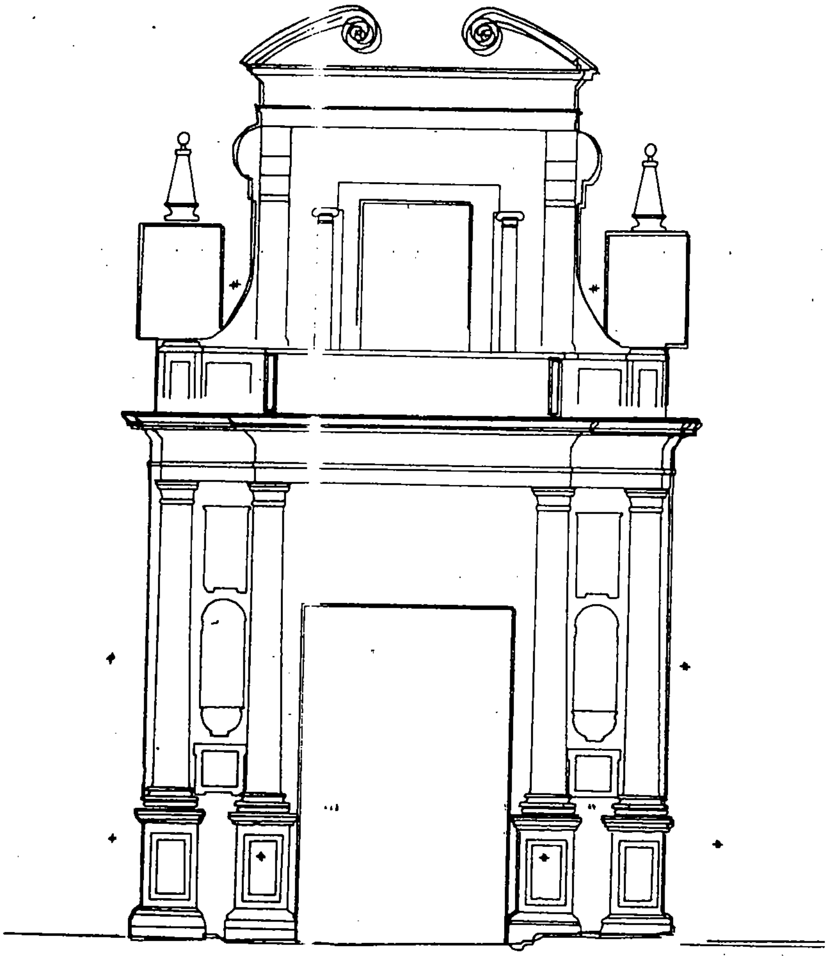

Fig 8, Fotogrammetric survey

ANALYTICAL PHOTOGRAPHIC RECTIFICATION THE WALLED CITY OF CITTADELLA (Padua, Italy).

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Centro Interdipartimentale di Cartografia e Fotogrammetria - IUAV - Venezia - Italy

The need to identify the most efficient methods and instruments for the survey of the walled city of Cittadella prompted us to examine those systems which have the capacity to analyze wall texture. In the first phase photographic rectification emerged as the best solution, although the cost is unbearable when using orthoprojectors for differential rectificators or automatic computer assisted rectificators. Manual photographic rectification, on the other hand, generally does not guarantee a sufficient degree of precision nor a homogeneity of results. Starting with these considerations and a knowledge of applicable developments in computer graphics, we have finalized our analysis of alternative processes to traditional photographic rectification, keeping financial concerns in mind. In the course of this research analytical methods were tested using commercial software and PC hardware.
Within the scope of this survey is an examination of three distinct procedures:
a)methods of furnishing an image of the photographic or raster type;
b)methods which anticipate a large manual intervention in the phase of digitalization;
c)methods of automatic vectorialization;

Introduction

This report outlines the initial findings of an investigation of those survey methods applicable to a study of wall texture by means of automatic rectification.
The study began as part of a project designed to identify the best available survey technique for the city of Cittadella.
Such research is linked to the article of Arch. di Thiene and of Dr. Baratin on the techniques of their experimental photogrammetric survey of Cittadella.
The survey of the walls of Cittadella consists of a field of complete experimentation regarding all those problems encountered when surveying wall texture. The specific results obtained in this particular case can, however, be made generally applicable to the survey of any wall texture.
In order to obtain a final and complete design, any survey of wall texture can not be limited to considerations of aesthetic character alone, but must also include analysis of building techniques. The study of wall texture includes, in fact, a combination of information regarding:
-the disposition and dislocation of holes (doors, windows, support holes, niches...)
-the geometric characteristics of various construction materials (bricks, stone, wood, connecting rods, tie rods, braces, mortar...)
-a few phenomena of decay (stress fractures, humidity, chipping, vegetation...)
Such information is essential to historical, statical, physic, and chemical analyses. The problematic character of a survey of texture can best be resolved by means of the traditional photogrammetric survey. The traditional photogrammetric technique is, however, extremely onerous in terms of time and money on account of the large number of elements which must be considered in this kind of restitution. These difficulties can be resolved if one considers applying the procedure of automatic rectification.
Such an approach is warranted considering that wall texture belonging to a structure has the intrinsic characteristic of appearing in such a way that, though endowed with quite significant features, it is similar to a plane. If the wall structure is such that it is significantly non planar it is always possible to subdivide it into portions ever smaller until finally these become similar to a plane.

Experimentation

For a complete evaluation of the viability of rectification we have taken into account methodological, qualitative, and metric aspects as well as those considerations of cost and time. In order to carry out the evaluation, diverse methodologies of rectification were performed on the same section of wall.
The first step of this process involved the identification of a set of targets on the surface of the restitution subject which are obtained through topographic or photogrammetric means. Such targets must be sufficient in number in order to permit not only a calculation of parameters of rectification but also to test that the segment of wall under

consideration is actually similar to a plane; this is, in fact, the condition necessary to carry out rectification. Whereas by means of the calculation of the eight parameters of rectification four control points are necessary, it is useful, to evaluate how far from a plane is the portion of wall under consideration, that the control points should be at least double (or more) and distributed in a uniform manner on the surface.On the zone of wall singled out for this test the following typologies of rectification were tested which seem to cover almost all the possibilities:

a)methods of furnishing an image of the photographic or raster type;
a1-analogical, manual, photographic rectification by means of a special enlarger;
a2-analytic rectification of the raster matrix obtained by means of a scanner;

b)methods which anticipate a large manual intervention in the phase of digitalization;
b1-manual digitalization on the non-rectified photograph and immediate rectification of vectors across appropriate programs that one interposes between the digitizer and the CAD programs.
b2-rectification in batch from the inside together with the vectors which constitute the design obtained through digitalization of a non-rectified photograph by means of the scanner.

c)methods of automatic vectorialization;
c1-vectorialization aided by a program of a non-rectified raster matrix and a successive rectification in batch;
c2-vectorialization aided by a program of the raster matrix already rectified;

The method a1 (analogic rectification) constitutes above all the simplest and most immediate resolution to the problem but presents few advantages:
-the result is analogical and then not editable through CAD programs
-it is not possible to strictly control either parameters of rectification (in effect it is not possible to carry out any compensation) or the rectification plane reference.
-it is not always possible to make a precise subdivision of the total plane surface in sub-area.
The method a2 (rectification of the raster matrix) has the advantage of following an analytic procedure permitting control of data by means of compensation. In addition, it is possible to combine parts of images obtained with different parameters of rectification and the best possible patchwork.
One obtains from this method of restitution a photographic quality which, however, in contrast to that obtained from the proceeding method a1, can be the foundation for successive vectorialization (see c2). The principal difficulty is connected to the dimension of the raster matrix, and then to the capacity of the computer memory and to times of calculation. The dimension depends on the average scale of the pixel and of the size in bit (the number of tones of grey or colors) of the same pixel, according to table A.
Both b methods use as input for the rectification the digitalization of the non-rectified photograph. The differences between the two methods are not a reflection on the metric precision but solely on the character of the work method: in fact, the same program (PhotoCAD) is used in these two options, interactive and batch.
The advantages consist of the possibility of restituting with precision only the most significant elements of the objects which are selected during the restitution. The elements in addition can have a graphic structure (in blocks, polylines, etc.) in a form which greatly facilitates the general editing phase, always necessary.
There is, however, the necessity of operating with competent and specialized personel and, depending upon the particular digitalization used, the amount of time necessary may be from five to ten times greater than that required for automatic rectification (method c).
The c methods seem, at first analysis, like the optimum procedure and therefore we have concentrated our study on these methods. The procedure, in fact, promises in part a degree of precision intrinsically larger than that of the b methods , in so far as it excludes the introduction of errors due to human intervention, as well as an enormously greater speed of restitution.
From the following test, however, we have learned that it is not possible to obtain the promised results both because programs of vectorialization endowed with algorithims of pattern recognition appropriate for architectural surveys are still not available at a low cost, and because the condition of the photograph greatly affects the final result of scanning.
The graphic results of the following test are presented in the pages which follow. The experiment was carried out using two different portions of masonry in order to test both details and the all result. We have tested diverse resolutions of scanning, diverse scales of photograms, diverse methods of vectorialization and diverse filtering options of image.

Conclusion

From our experiments we have deduced, after obtaining a rectification of wall texture which fulfills those requirements of architecture, design, and having a good metric precision and a minimized time of execution, that it is necessary to adopt a procedure which combines aspects of both methods b and c.
We maintain, in fact, that the construction of part of the restitution partially integrates the process of design of architecture not existing of a biunivocal relationship between this and the photograph. This lack of correspondence is due to the fact that no software can possess (at least it is currently an unpredictable development in the field of expert systems) the knowledge in the field of representation, which permits the association to a symbol of complex and built whole of architectonic elements.

In addition to this structural and practically insurmountable difficulty, exists another difficulty regarding the quality of the images (of the atmospheric condition at the moment of the shot, of the optical instruments used for the shot, the printing and the scanning) which affects the performance of the vectorialization program.
Here, then, it seems necessary to conduct a deeper investigation into the treatment of the image.
Such a study can be finalized upon the achievement of a modified raster matrix in which it will be easier to recognize the outlines of the forms.
In conclusion we maintain that, at the fore of great improvements of the present procedure in the direction as indicated, human intervention will always be necessary and in the editing of the raster, by means of great image area manipulation, and in the editing of vectorialized drawing, with precise and specific interventions.

Reference

Rosenfeld A. - Kak A. C., *Digital Picture Processing*, London, Academic Press, Inc., 1982
Slama C.C., *Manual of Photogrammetry*, Falls Church Va., American Society of Photogrammetry, fourth edition, 1980
Serra J., *Image Analysis and Mahematical Morphology*, London, Academic Press, 1988
Selvini A., *Principi di fotogrammetria*, Milano, Clup, 1988

Hardware used

IBM PS/2 mod 55
Compaq Deskpro 386/20e
Macintosh cx
Scanner ScanJet Plus HP
Printer Apple Laserwriter II NTX
Plotter Calcomp 1041
Digitizer Calcomp 9148
Kern DSR1

Software used

PhotoCAD for manual and batch rectification
AutoCAD for drawings
QTDXF for vectorialization
Adobe Photoshop and Adobe Digital Darkroom for image processing

TABLE A

Photography scale 1:100

DPI	One Pixel is real cm	N. of Pixel per real cm²	KB/cm² photography 2 colors	16 colors	256 colors
300	0,85	1,18	1,744	6,975	13,950
150	1,69	0,59	0,436	1,744	3,488
75	3,39	0,295	0,109	0,436	0,872
40	6,35	0,157	0,031	0,124	0,248

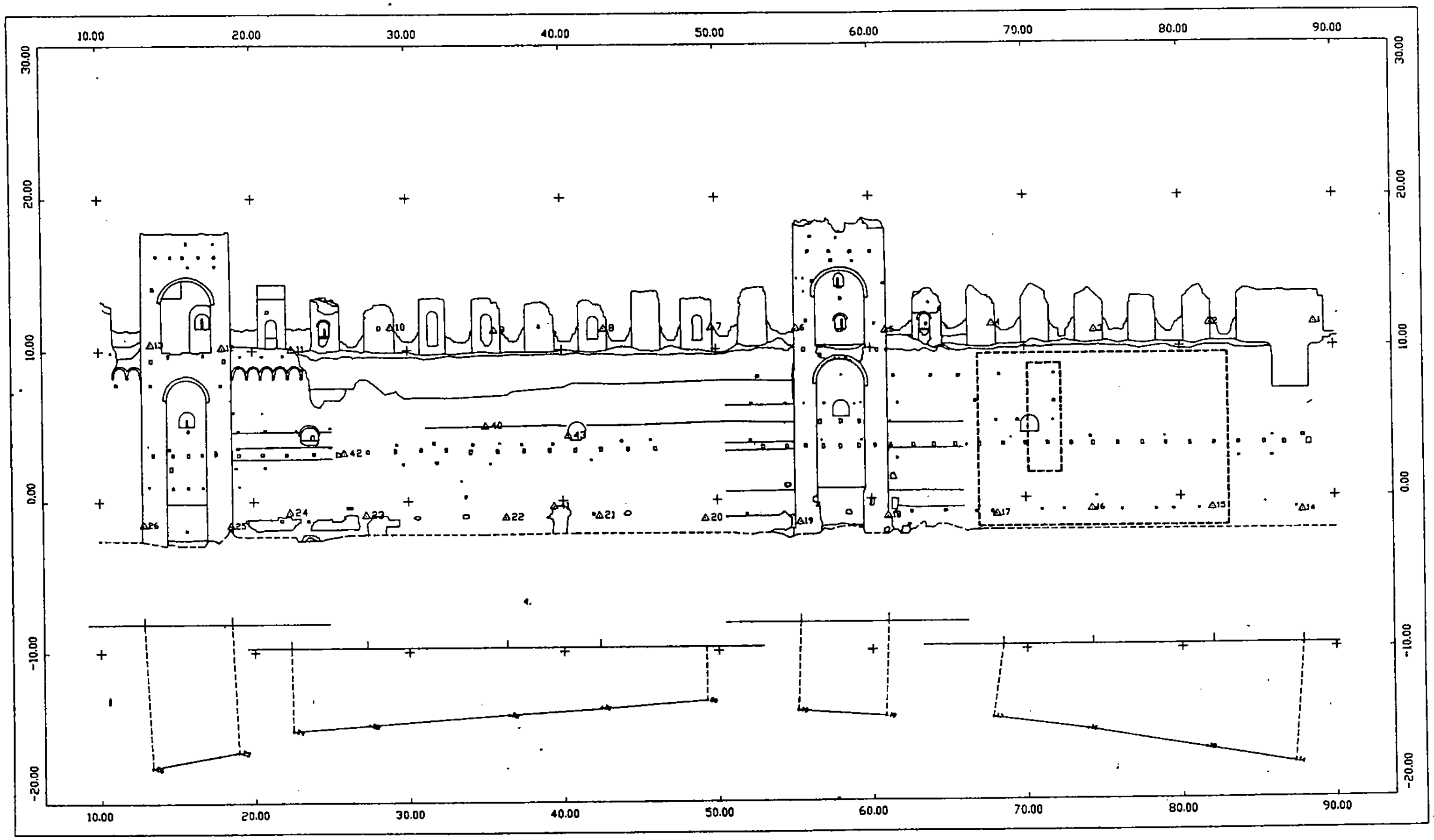
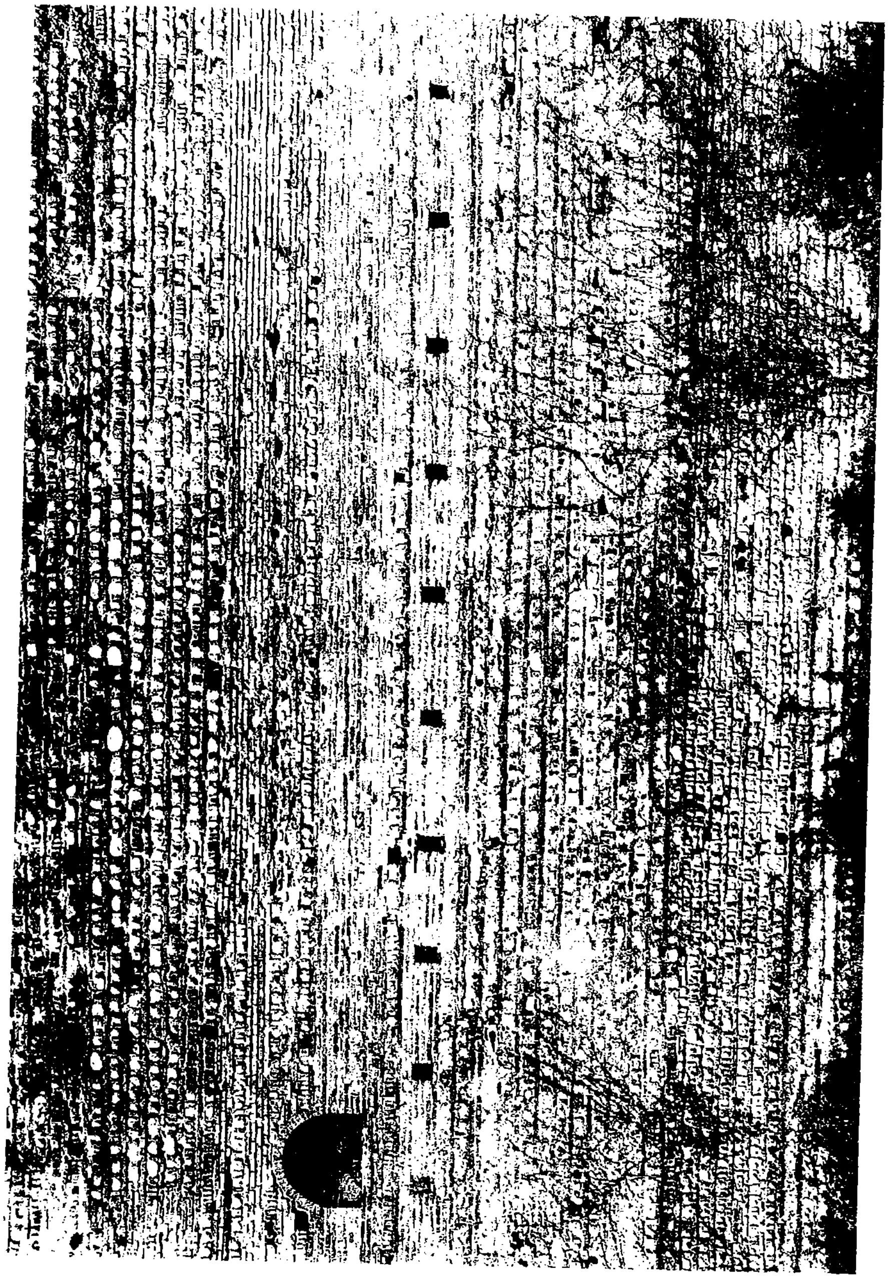


Fig. 1 - Front view of section of wall highlighting the parts under consideration for the experiments.
For the general section we have used four topographic target points and fifteen points obtained through photogrammetric restitution; for the particular section six photogrammetric points.



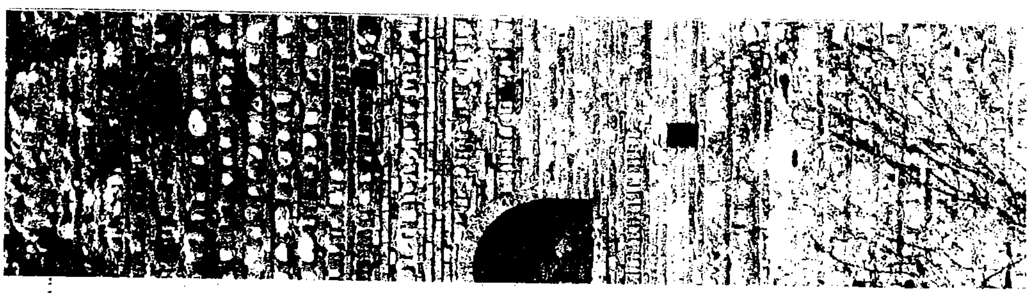
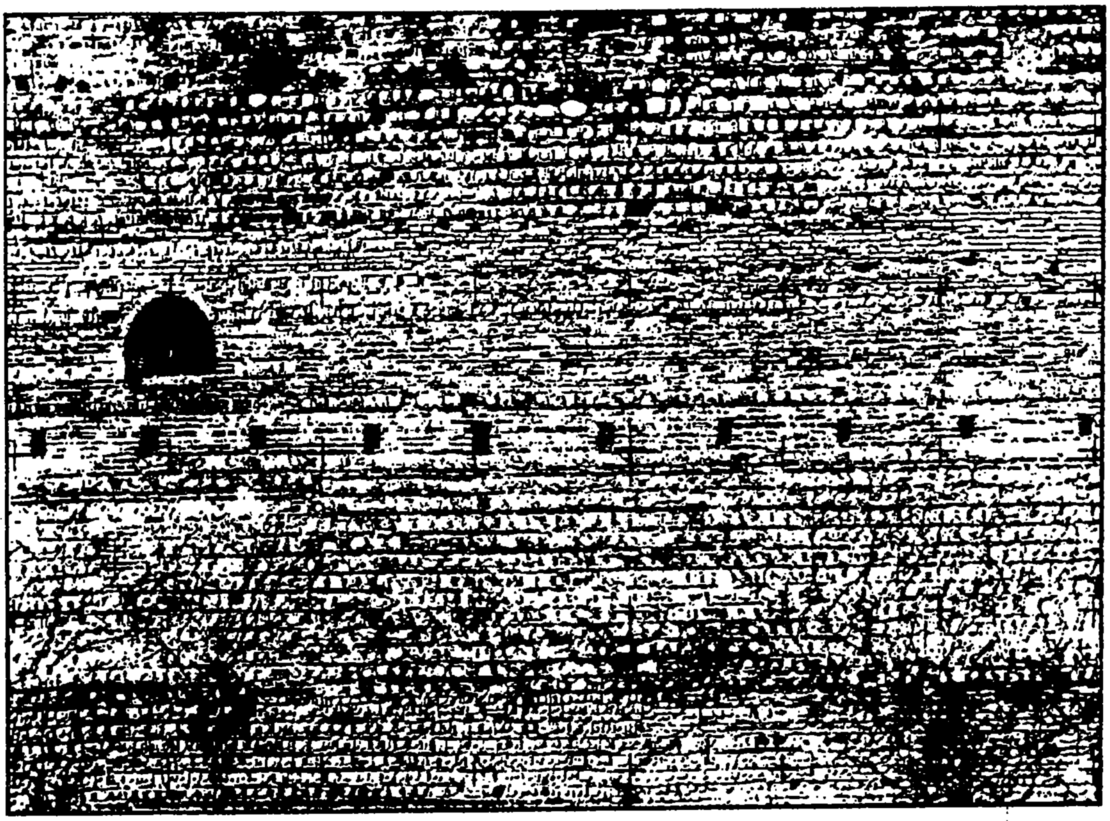


Fig. 2 - Manual photographic rectification of the general section.



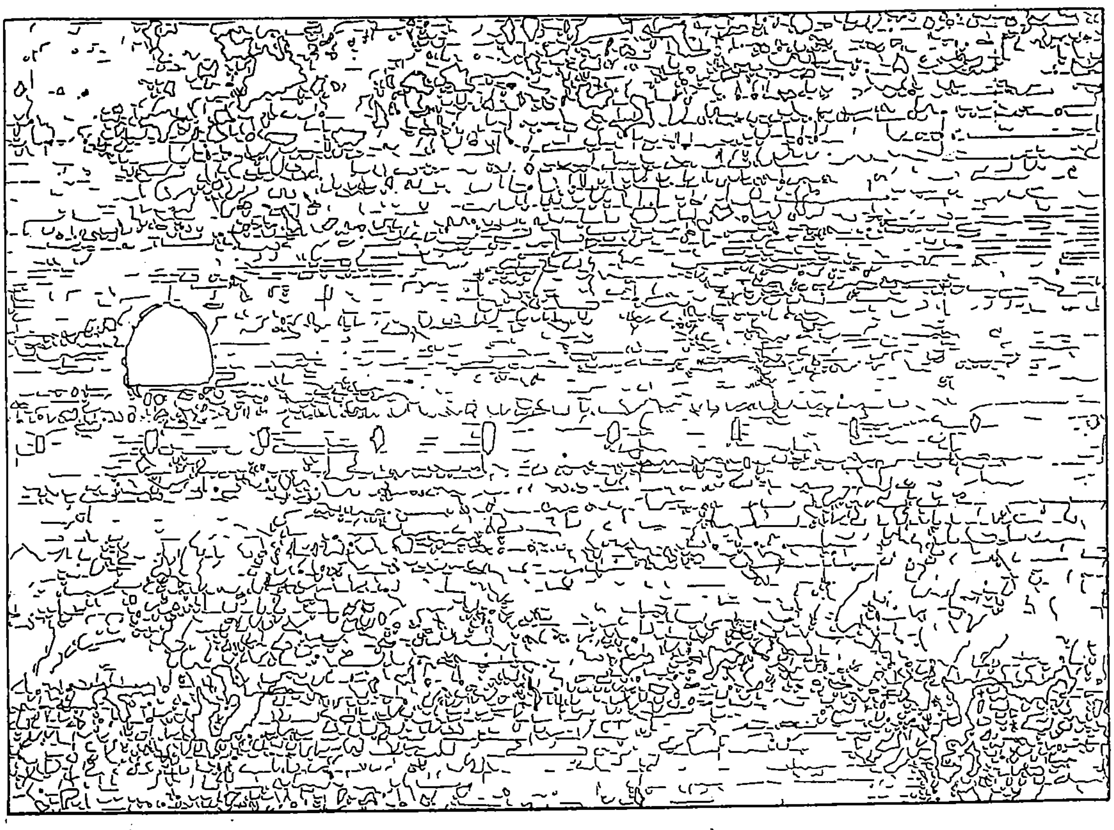


Fig. 3 - Print of one bit raster matrix (two colors) of general section.
Vectorialization of raster matrix at low level of detail.

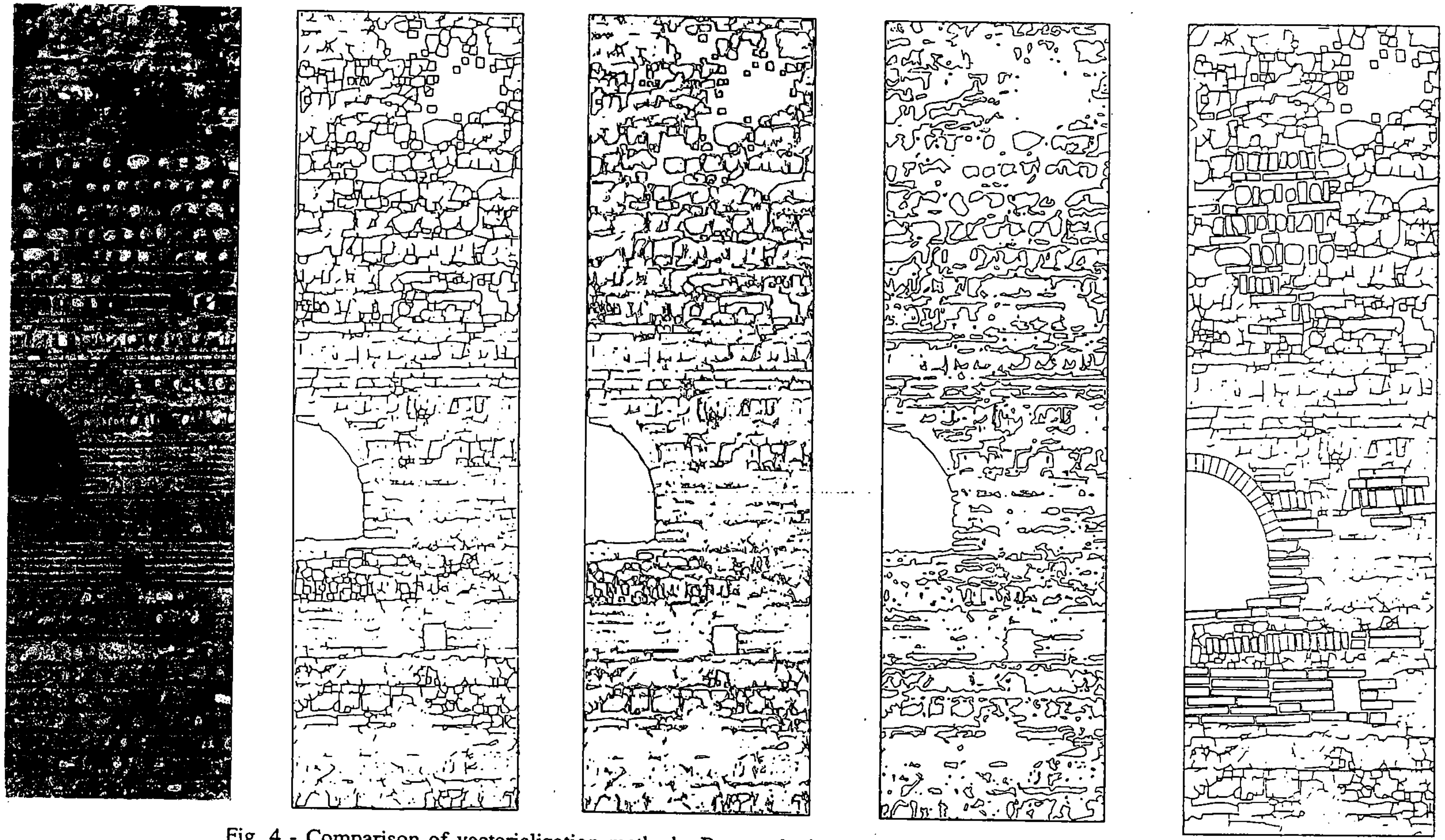


Fig. 4 - Comparison of vectorialization methods. B was obtained through an "outline" procedure (the contour of dark areas) at high resolution (300 DPI) and average accuracy. C was obtained trough "colouring" procedure (highlighting of light-dark areas), with average parameters of accuracy and thinning. D was obtained with "centerline" method, with average parameters. E represents a combination between manual digitalization and automatic rectification.

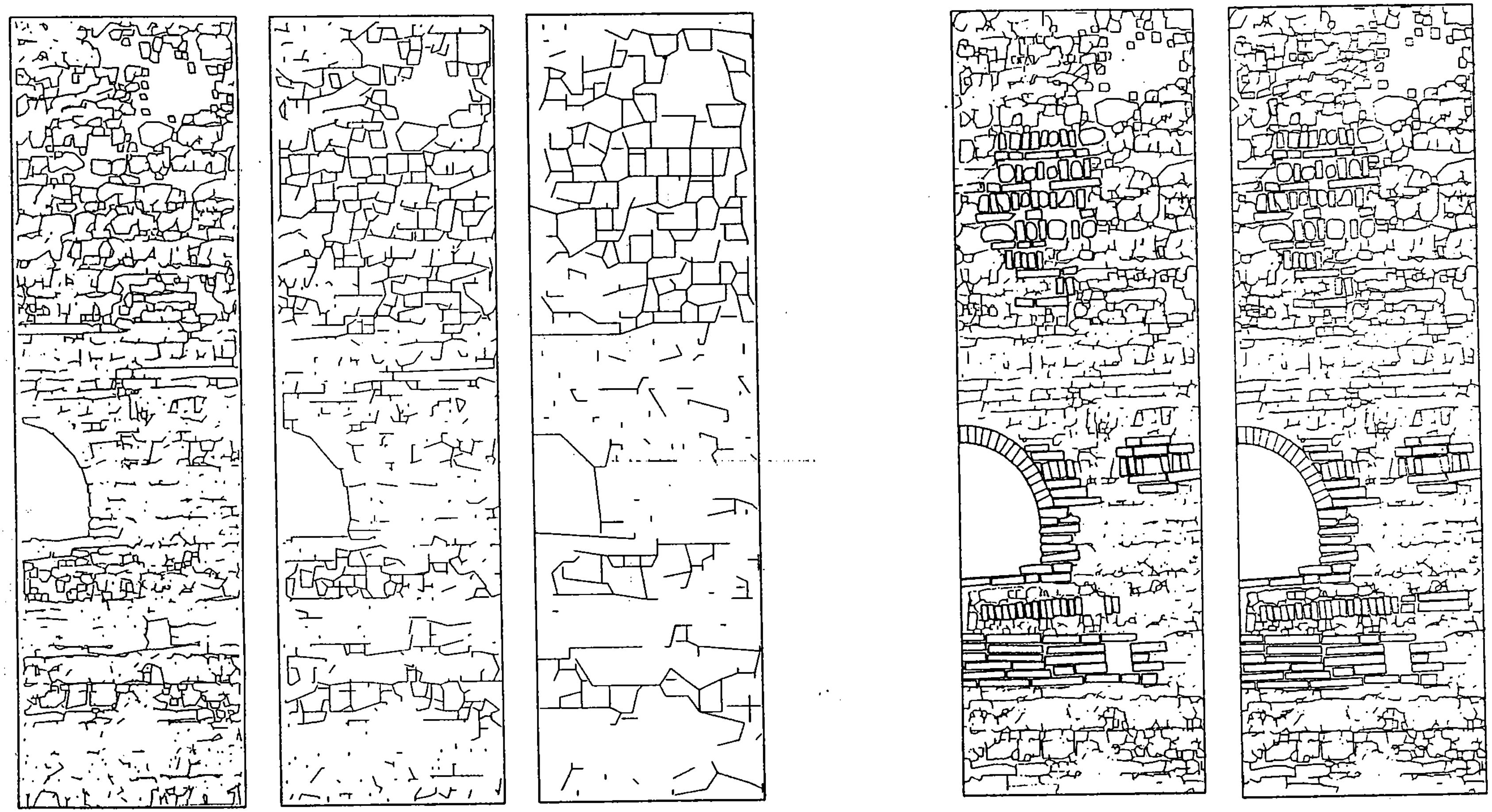


Fig. 5 - Section A. Comparison of various resolutions. A was obtained with outline method, 150 DPI of resolution (quite alike to 300 DPI); B was at 75 DPI and C at 40 DPI.
Section B. Combination between manual digitalization and automatic rectification. In the first figure is highlighted the digitized part.

THE EMPLOYMENT OF PROCESSING IN DIGITAL FORM OF IMAGE IN PHOTOGRAMMETRY FOR READING THE CHURCH ESTATE

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FONDAZIONE ITALIANA FOTOGRAMMETRIA ARCHITETTONICA
c/o CATTEDRA DI FOTOGRAMMETRIA ARCHITETTONICA - POLITECNICO DI BARI - ITALY

In quality of president of the Fondazione Italiana Fotogrammetria Architettonica I address my greeting and best wishes to all the people attending the meeting.
Our Fondation, confirming its own theories developed throught international seminars and meetings (april 1986 - June 1991) has established and verified the following master points (1st enclousure):

1) **Architectonic Photogrammetry** must be intended as a discipline about architectonic representation made of three-dimensional scale pictures;
2) **Direct Photogrammetry** means the tecnique which makes it possible for us to relief the dimension of an object from the three-dimensional picture;
3) **Inverse Photogrammetry** must be intended as the tecnique which enables us to report the pre-fixed dimensions on the three-dimensional picture.

Nowadays, in the italian schools and universities, we are go on using the graphic language in the architecture study.
The depiction of those "undepictable" monuments addressed to our descendants is made of plane graphic representations, which value is less than an identiki.
Photographic language, then, is often requested even if not taught !
Photogrammetry and cartography are still confused in their techniques because the photogrammetric survey can give a graphic elaborate, but that is non identificated with the graphic elaborated one.
For a correct use, we must necessary use some "interpreters" to traslate the informations from the photographic to graphic language.
To understand perfectly a photographic reproduction of architecture, the architect, the history critic and common man use a category of "interpreters".

But reading architecture and particulary the holy one, needs so many competences that a single "interpreter" can't pretend to get: to file the cartographic representation of a building, even if of numeric kind, would be like (this is stated by Professor Antonio Daddabbo: Director of the Cattedra di Fotogrammetria Architettonica - Politecnic of Bari) filing "I Promessi Sposi" by summarizing it or commenting on it.

Unfortunately, during the IV National Photogrammetry Meeting ocurred in 1988 in Bari about the matter: "Holy Architecture: use, documentation, planning", same photogrammeters pretended to survey the holy building without properly knowing its origins.
During the International meeting of last june in Bari, rose that the main characteristic of a new kind of survey and of a Survey Centre will be to supply by a dinamic survey of the building through time and space, useful in real time.
The survey of an holy building can not be limited to the graphic representation but must start from a functional analysis of the monument.
Nowadays technology help us to do this besides explaining and file it: we must, then, to secure for our descendants the indirect use of cultural works which for same reason (natural and artificial elements) are subjected to changes.
As on medical grounds, for the cultural works we need a photogrammetric study not for topographic aims and use.
Among this point of view is developed the collaboration with the Collegio dei Geometri di Roma and the Cattedra di Fotogrammetria Architettonica of the Politencic of Bari.
Infact the Collegio dei Geometri di Roma will be next october 1991, present at a work of photogrammetric survey in Assisi, with particular care to the works in favour to Convent of S.Damiano.
Besides the Fondazione Italiana Fotogrammetria Architettonica, the Collegio dei Geometri della Provincia di Roma and the Cattedra di Fotogrammetria Architettonica of Bari's Politecnic , through the president of the Foundation, they signed in Bucarest on august 9th 1991 co-operation plans with Governement Body of Romania.
This co-operation plans will begin in april 1992 with the start of a photogrammetric documentation's project about church estate placed in the town of Tirgoviste.
This work will develope in the didactic curriculum of professional-training of "Analista Edile" [1] and in the project called to "Fotogrammetria e Tutela del Territorio" [2].
Infact remarking that photogrammetric survey is not only identified with the graphic representation and, as a consequence of this, in order to use the new technologies, is necessary, in our opinion, to acquire a new mentality.
This is the reason because in the programme "Fotogrammetria e Tutela del Territorio", we consider the formation plan, begun in 1985 by the professorship of architectonic photogrammetry at the school of Bari, a very important step.

To verify the programme of teaching already started, we have planned a photogrammetry course to be attended by almost twenty students next year.

The commune of Bari will provide to finance this course and the study will aim to build a town in miniature (like "LEGOLAND" in Denmark), designed on computer and built using "LEGO" forms.

All students will be taught the photographic language, the observation and understanding of territory also by plane views (flights will take place with the co-operation of the local "Aereo Club", Bari-Palese).

We have already created , thanks to the partecipation of some students of the 1985 course now fifteen years old, a special aircraft model section inside our Foundation.

At the end of this year we hope to get to some good results of stereo photographic reconaissances by radio-controlled aircraft models (on this occasion we are fixing a "CANON" camera of 35 mm. with a firm focus and incorporated motor on a "CESSNA 177" model with awing span of 170 cm. and a 10 cc. engine).

Next year, when the training of the very young pilots will get to the end, we inted to fix a telecamera (dimension 79 mm. x 57 mm. x 26 mm., weight 78 gr. and with a 400 mW transmitter with a weight of 160 gr.) on a "R.C. VOYAGER" aircraft with a roler diameter of 160 mm., a fuselage 1300 mm. long and a 4 stroke 200 cc. engine.

At the same time we are going on testing the use of digital image in the survey of cultural works.

Thanks to the co-operation of "Apple Computer" (through the ISIPROG s.r.l. - Apple Center - Bari) that placed a "Macintosh LC" at our disposal, we can show you a programme proof, written in the "Hypercard" language, which is aimed to advance what we intend to show in 1993, when next international architectonic photogrammetry meeting will occur in Bari (Italy).

To all of you interested in this plan, I would like to underline that, in the final report, we will show colour photographic images, related to shootings, even though our only care is for the interactive programme so to talk to the user without tiring him.

The partakers of the last meeting occurred in June know that the pattern we chose among the cultural works was the Convent of S.Damiano in Assisi, the community of which offered to co-operate in writing down the final report form.

Finally, I would like to thank you and I inform you that me and Dario Daddabbo are at your disposal to show you the programme proof as I referred to before.

1st ENCLOUSURE

The Fondazione Italiana Fotogrammetria Architettonica, to acquire scientifc instruments and fix methodologies to employ in its working and researching plannings, establishes the following points:

* **architectonic photogrammetry** must be intended as a discipline about architectonic representation made of three-dimensional scale pictures;
* **three-dimensional picture** must be intended the picture observed by stereoscopic observation of a couple of photograms obtained by an optical-mechanical or electronic way;
* possible **graphic representations obtained by the photogrammetric survey,** direct or automatic, of the three-dimensional photographic picture must be clearly so called "**photogrammetric restitution**";
* **photogrammetric restitution** must be intended the transformation of the two pictures, obtained by the central perspective, in one picture like an orthogonal projection;
* **direct photogrammetry** means the tecnique which makes it possible for us to relief the dimension of an object from the three-dimensional picture;
* **inverse photogrammetry** must be intended as the tecnique which enables us to report the pre-fixed dimensions on the three-dimensional picture.

Footnotes

1) The course of "Analicta Edilc" is a professional training course funded by Regione Puglia - Italy, by regional resolution n° 56 on july 16 th 1992, managed by A.N.C.I.F.A.P. Bari - Italy and with didactic advice of the Fondazione Italiana Fotogrammetria Architettonica and Cattedra di Fotogrammetria Architettonica of the Bari's Politecnic.
2) This project, "Fotogrammetria e Tutela del Territorio", is a research project united to the bilateral agreement between Regione Puglia - Italy and University of Bari - Italy, for the common use of photogrammetric instruments, signed on january 18 th 1985.
The project aims to the use of the architectonic photogrammetry in the architectonic plan and in the town-planning, as diagnostic instrument about the territorial reality and as instrument of preventive representation of the territorial reality before to change it.
The project has been shown during the III National Congress of Architectonic Photogrammetry, in Italy, and it is subdivided in four sections:
Photogrammetry and Didactics - Photogrammetry and Documentation - Photogrammetry and Project - Photogrammetry and Global Civil Protection.

COMBINING A THEODOLITE - BASED MEASUREMENT SYSTEM AND STEREOPHOTOGRAMMETRY FOR THE RECORDING OF HERRENCHIEMSEE PALACE

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ABSTRACT

The measurement system CASOB consisting of electronic theodolites with electronic distance meter, a personal computer, some additional hardware tools and sophisticated software is applied to the recording of the palace *Herrenchiemsee* in Bavaria. CASOB yields 3-D coordinates of discrete object points and interfaces directly with common CAD systems. The measurement results can be displayed on site on the PC monitor and further processed in the CAD system.

Photogrammetrically determined information can be combined with the CASOB data. As an example, the upper part of the southern facade of *Herrenchiemsee* was recorded from a lifting platform with photogrammetric cameras.

In this paper, special attention is focused on the use of CAD in order to produce quickly, precisely and economically the entire 3-D model of a building and some follow-up products such as ground and elevation plans, and sections.

1. INTRODUCTION

The royal palace of *Herrenchiemsee* was built by the famous and fabulous Bavarian King Ludwig II. It is situated on an island called *Herreninsel* in the *Chiemsee* lake. Modelled after the palace of *Versailles* in France, its construction was largely completed around the year 1880. Today the *Chiemgau* region, the picturesque area around the lake, is an important centre of tourism in Bavaria. *Herrenchiemsee Palace* considerably contributes to the prosperity of the region, because all the castles and palaces of Ludwig II attract millions of visitors.

The King's architects, *von Dollmann* and *Hofmann*, built the palace of such an extraordinary quality that even over a 100 years later, it is still in an unusually good condition. Nevertheless, nowadays there is the necessity to do some preservation work in order to avert serious damages and to maintain the good general condition of the building substance.

Available plans date from the planning stage of the last century. As a result of many alterations during construction and the fact that the palace was never completed in total, drastic deviations from the original plans exist. Therefore, a survey was necessary for the purpose of preservation and, in general, for a complete documentation of the monument.

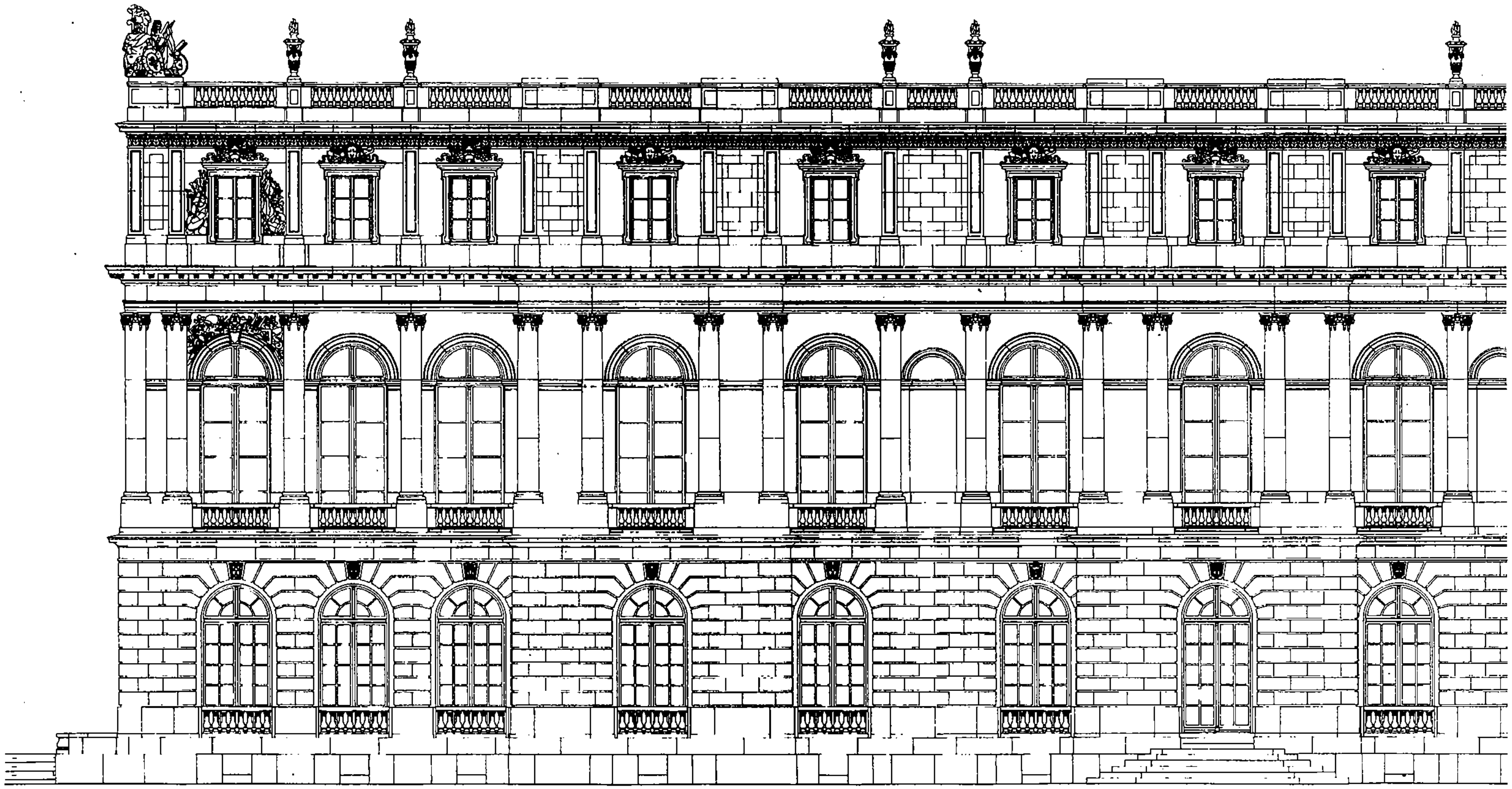


Fig. 1 Part of the southern facade of *Herrenchiemsee Palace.* The plan reduced from the original plotting scale of 1 : 50 was derived from the CAD model. The entire facade is approximately 100 m in length and 23 m in height.

A digital data base should be established as the result of the measurements. Plots at various scales should be produced. It was decided to carry out the survey by means of a theodolite-based system and, in addition, by stereophotogrammetry. Both methods result in spatial coordinates of object points which can be transfered to a CAD system. In this case, AutoCAD was used.

Todate, the survey of the southern facade of the palace is accomplished (Fig. 1). The remaining facades and the ground plans and sections of the interior are to follow later on.

2. Surveying concept

In order to survey the palace as quickly, precisely and economically as possible, some basic considerations and decisions were made:

- The facade can be devided into a number of elements of the same kind such as windows, balustrades, niches etc. (Figs. 2 and 3). By means of on site measurement, it was ascertained that the differences between the individual elements of the same kind are very small. The reason is that the palace was built in a prefabricated construction, i.e. the elements were uniformly prefabricated, delivered and precisely mounted on site. Small differences do not influence the documentation and the repair work. Therefore, the recurring details of the facade were measured once and then inserted in the CAD model as blocks using a lot of control points.

- It was decided to survey the lower half of the facade including the windows of the first floor (Fig. 1) by the theodolite-based system CASOB (KORTE 1991; see chapter 3), i.e. the virtually identical elements (blocks) mentioned above and the control points used for integrating all the elements within the CAD system were measured with CASOB.

- The upper part of the facade could not be measured from the ground by the theodolite system. It was recorded photogrammetrically using a lifting platform and a crane respectively (Fig. 4). Then only the control points required for combining the blocks were obtained from stereomodels (see chapter 4).

- Both measurement systems, CASOB and photogrammetry, yield an accuracy of the object restitution of about 1 cm.

- The facade is richly decorated with figurative elements and sculptures (Figs. 5 and 6). The precise shape of these elements is without any significance to the restoration. They were photographed using a camera with long focal length and then scetched by means of monoscopic digitization of enlarged paper prints on a digitizing tablet. Subsequently, the data were introduced in the CAD system.

- Finally, the CAD system plays the decisive role in combining and editing all the elements of the facade.

3. CASOB

The measurement system CASOB (Computer Aided Surveying of Buildings) is designed to provide quick and precise three-dimensional recording of the interior and exterior of buildings and monuments. Hardware components are electronic theodolites equipped with laser pointer and electronic distance meter, some special tools to observe inaccessible or hidden points, and a portable personal computer. CASOB offers several observation modes such as polar measurement with reflector, intersection by means of two theodolites etc.

Polar measurement is the standard procedure. An electronic theodolite is coupled with an electronic distance meter for determining the distance between the theodolite and the reflecting mirror positioned at the object point to be surveyed. A laser pointer mounted on the top of the theodolite produces a visible red beam to identify the point.

An essential advantage of CASOB is given by the fact that the measurement data are immediately processed in a personal computer (laptop). The result of the survey is prepared on site and can be displayed on the

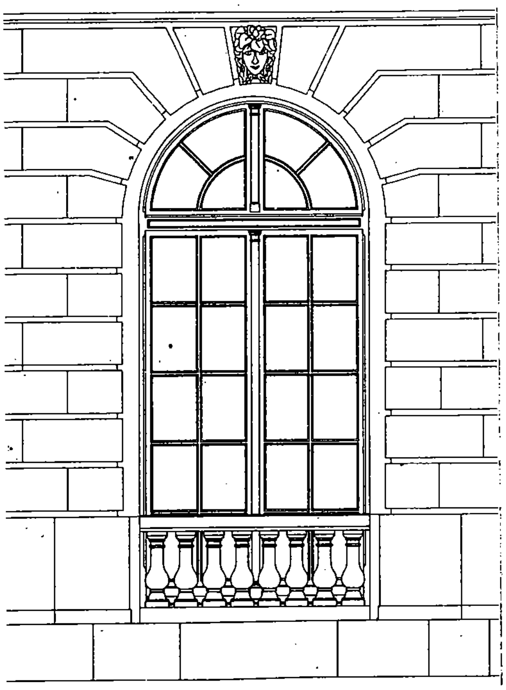


Fig. 2 Ground-floor window

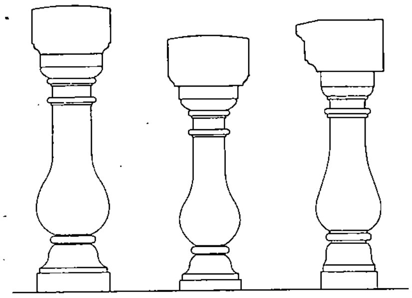


Fig. 3 Three types of balusters used in facade construction

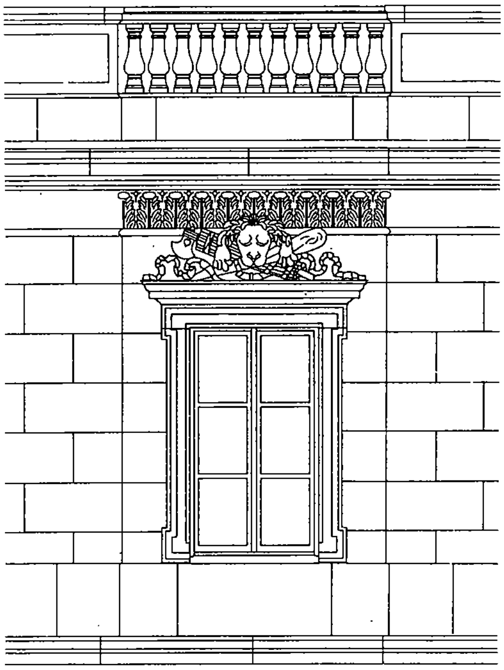


Fig. 5 Second floor window with figurative elements

Fig. 4 Taking the photographs from a crane

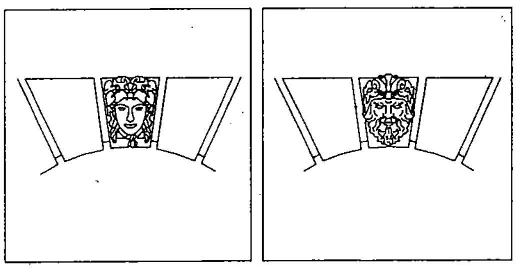


Fig. 6 Different types of sculptures

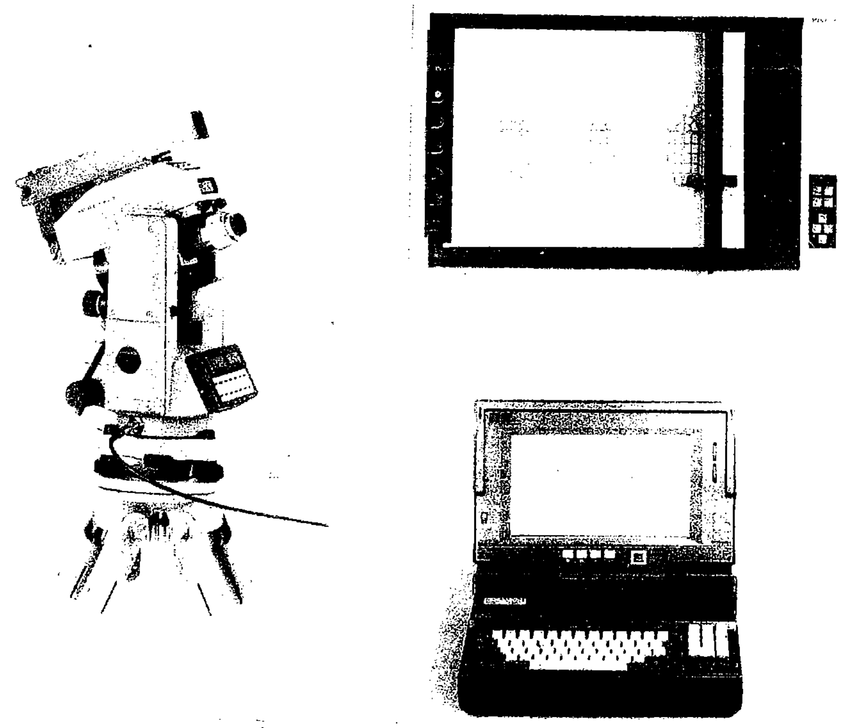


Fig. 7 CASOB for on site measuring and drawing: Electronic Theodolite with distance meter and target laser, laptop for on site calculation and data storage, and plotter

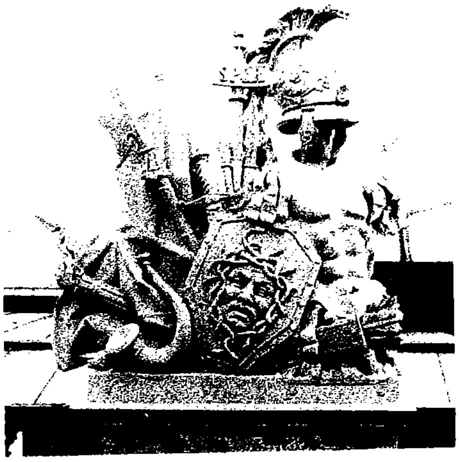
PC monitor or drawn with a draft plotter (Fig. 7). The calculation of 3-D coordinates of object points and the subsequent editing in the CAD system with the building in full view yield a true portrait of the object of interest.

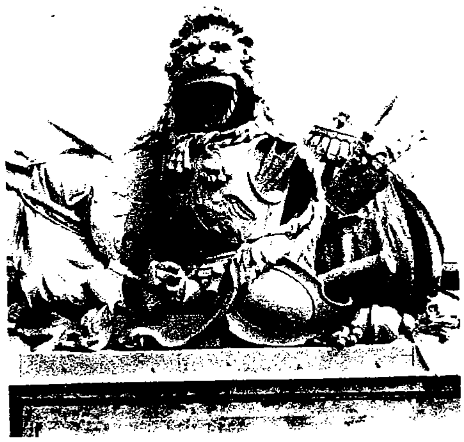
The described point-by-point measurement mode allows for an arbitrarily dense scanning of an object. Up to 1500 points a day can be observed with two members of staff. The definitive result of the survey can be viewed, controlled and completed on site. Of course, the final CAD handling and the plotting of the finished plans take place at the office. In some cases, this procedure leads to a better and more economic solution than even stereophotogrammetry.

4. Photogrammetric survey

Photogrammetry was used very conventionally in the project *Herrenchiemsee*. A metric camera WILD P31 with 100 mm wide angle lens was applied to record the upper part of the southern facade. The photographs were taken from a lifting platform at a photo scale of approximately 1 : 150 (Fig. 8). 12 stereomodels were selected for the object restitution in an analytical plotter Zeiss Planicomp P2. Control points for the orientation of the stereomodels were determined by CASOB. In each stereomodel, about 100 object points were measured in order to combine the different elements of the facade in the CAD system.

Fig. 8 Metric photograph of the upper part of the facade





Figs. 9 and 10 Different types of sculptures of the facade

On the other hand, photographs of figurative elements were taken with a Rolleimetric 6006 equipped with a telephoto lens (Figs. 9 and 10). As mentioned above, enlarged paper prints of these photographs were digitized on a tablet.

5. Concluding Remarks

In this project, stereophotogrammetry was applied in a rather curious way. A metric camera and normal case photography were used. But only a limited number of discrete object points was measured in the stereo-models in order to enable the CAD handling. This method proved to be very quick and cost-effective. The photographic recording of the southern facade of *Herrenchiemsee* required one day, the orientation of the 12 stereomodels and the determination of object points another two days.

However, the outlined procedure is only applicable to objects which are built in a kind of prefabricated construction like *Herrenchiemsee* with a number of identically shaped elements. Therefore, a rigorous analysis of the monument and its history has to be performed by the architect prior to the measurement.

In general, the combination of a theodolite-based recording system and photogrammetry may bring together the advantages of both surveying methods. The processing of the measured 3-D data within the CAD system results in a digital data base of the building suitable for all further investigations.

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A Test Object for Architectural Photogrammmetry: Otto Wagner's Underground Station Karlsplatz in Vienna

P. Waldhäusl, Vienna

A small test object has been selected, photographed, measured and documented, in order to have well-checked materials to train students and photogrammetrists as well as to evaluate internationally the results of the analytic photogrammetric process with various cameras, with different software and with different kinds and amount of control information. The test object is one of Otto Wagner's Stadtbahn Station buildings on the Karlsplatz in Vienna, a masterpiece of Art Nouveau, built in 1898/1899.

The above picture shows the building on an Austrian stamp issued in 1991 on the occasion of the 150th birthday of Otto Wagner. (* 13.7.1841, + 11.4.1918). Photography has been taken with metric and non-metric cameras, with medium and small format:

Camera	f [mm]	Format [mm]	Remarks
Rollei 6006	f=80	60x60	metric, reseau
Hasselblad 500 EL/M	f=51	60x60	non-metric
Leica R5	f=35	24x36	metric, reseau
Nikon FE2	f=28	24x36	non-metric

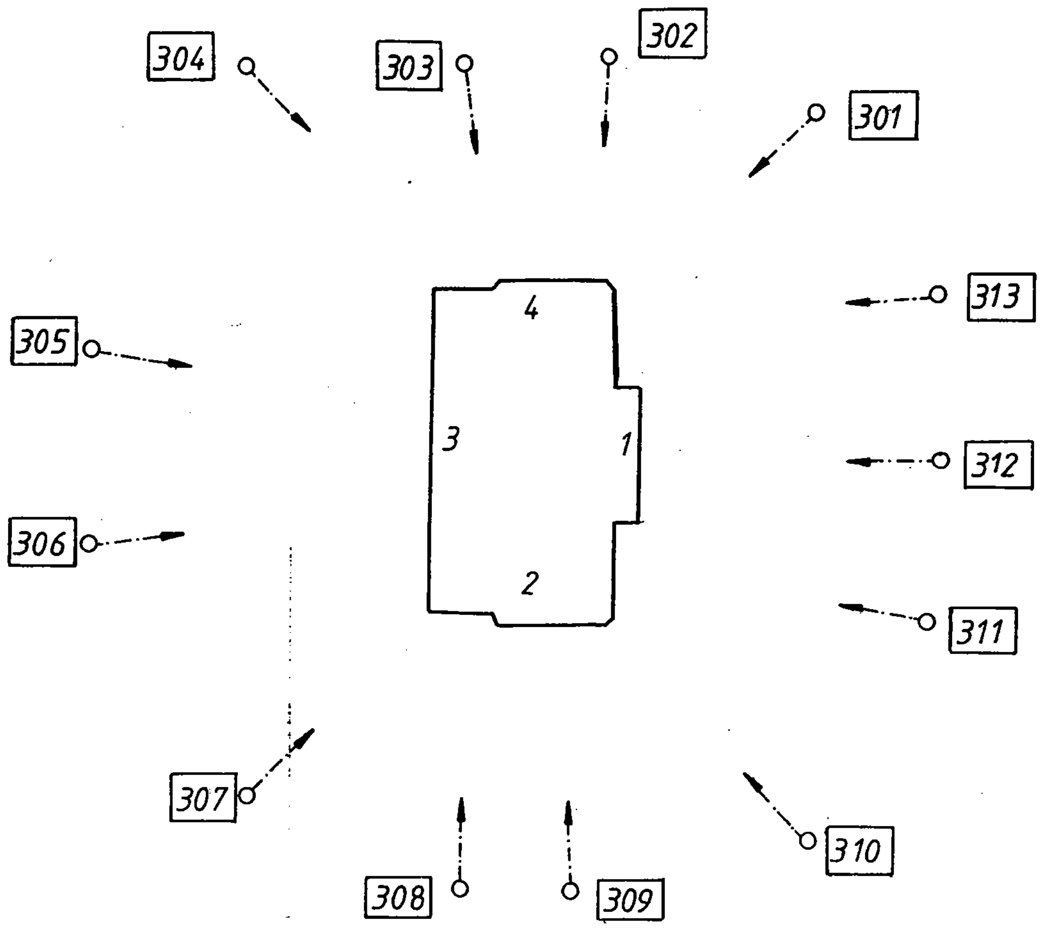
The film used is Kodak Ektachrome EPN 100 ASA. Alltogether, there are 52 colour diaposives available, well distributed all around the Otto Wagner pavilion (see Figure 1), 12, 13 or 14 per camera.

"Ground" control points, better to say object control points, have been measured and computed precisely. The original polar measurements are available on floppy disk as well as the computed, adjusted coordinates which have an accuracy of about 2 mm, and that is good enough for any test in connection with architectural photogrammetry.

Well done sketches show the natural control points, the end points of control distances and the position of control point targets (see Figure 2).

O. Wagner Pavilion

Configuration (schematic)



Camera: Hasselblad 500 EL/M

c = 51,47mm (calibrated)

Fig.1 The arrangement of photography.
(Example for one of the four cameras)

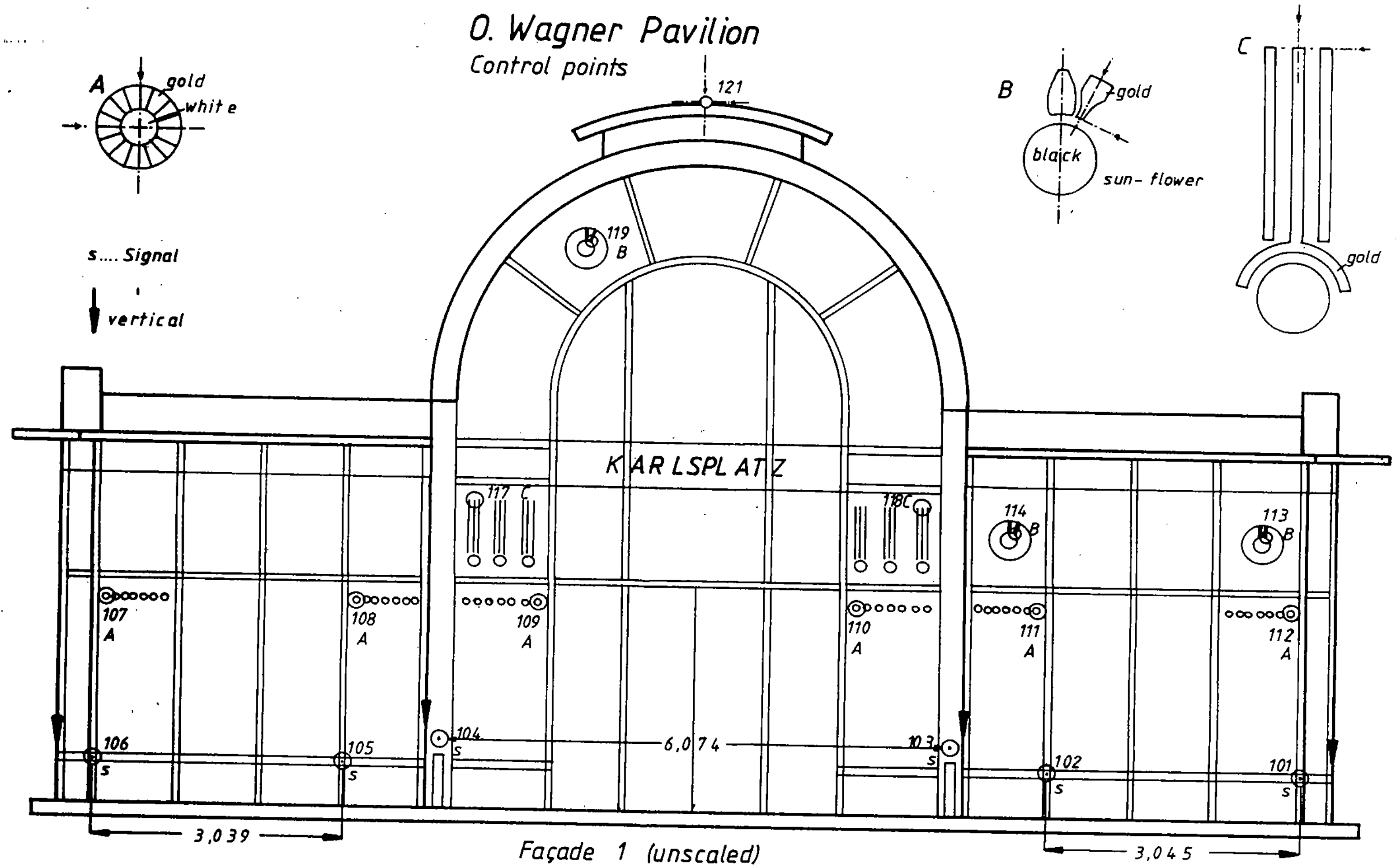


Fig.2 The arrangement of control information.
(Example for one of the four sides)

The work to be done is:

- to compare bundle adjustment software;
- to compare pre-calibration with self-calibration;
- to compare metric with non-metric cameras;
- to compare medium and small format results;
- to compare measuring devices/systems;
- to compare results of various institutes/persons;
- to test new methods/systems, e.g. CCD;
- to test the 3x3 rules of CIPA [1];
- to find out the optimum/minimum control information [2];
- to use materials for teaching/training;
- to make better proposals;
- to demonstrate results to CIPA and to others.

The material will be used also by seven university institutes of photogrammetry within a Hexagonale project started in 1991: Cracow, Brno, Bratislava, Budapest, Zagreb, Ljubljana and Vienna.

The results will be the basis for reports to CIPA which will be prepared together with, by and in cooperation of

- Arq. A. Almagro, Granada (Conservation, Photogrammetry)
- Dr. J. Jachimsky, Cracow (Photogrammetry)
- Dr. T. Fiedler, Zagreb (Photogrammetry)
- Dr. A. Detreköi, Budapest (Software comparisons, Photogrammetry)
- Dr. P. Patias, Thessaloniki (Centre pilote, Photogrammetry and Statistics)

and the author as well as others for new aspects, e.g. digital cameras, video-photogrammetry etc., whatever interests arise. The Vienna Institute of Photogrammetry assists in or takes care for photography and control data and can provide applicants with general bundle adjustment software (ORIENT) suitable to treat data from non-metric photography properly [3].

The Vienna Institute of Photogrammetry invites all Very Interested Persons in architectural photogrammetry to join the group, the "VIP-Club", with new ideas and new activities.

Summary:
The Vienna Institute of Photogrammetry and Remote Sensing has prepared a test object for architectural photogrammetry meant as a basis for international comparison of methods and technologies. It will be used by the CIPA Working Group 1 on Control information as well as by university institutes for training in analytical photogrammetry with metric or non-metric photography and general bundle adjustment including geodetic polar data. The test materials are available (against cost-price) for all those who are interested to compare their own methods of architectural photogrammetry with those of others or to check own new technology.

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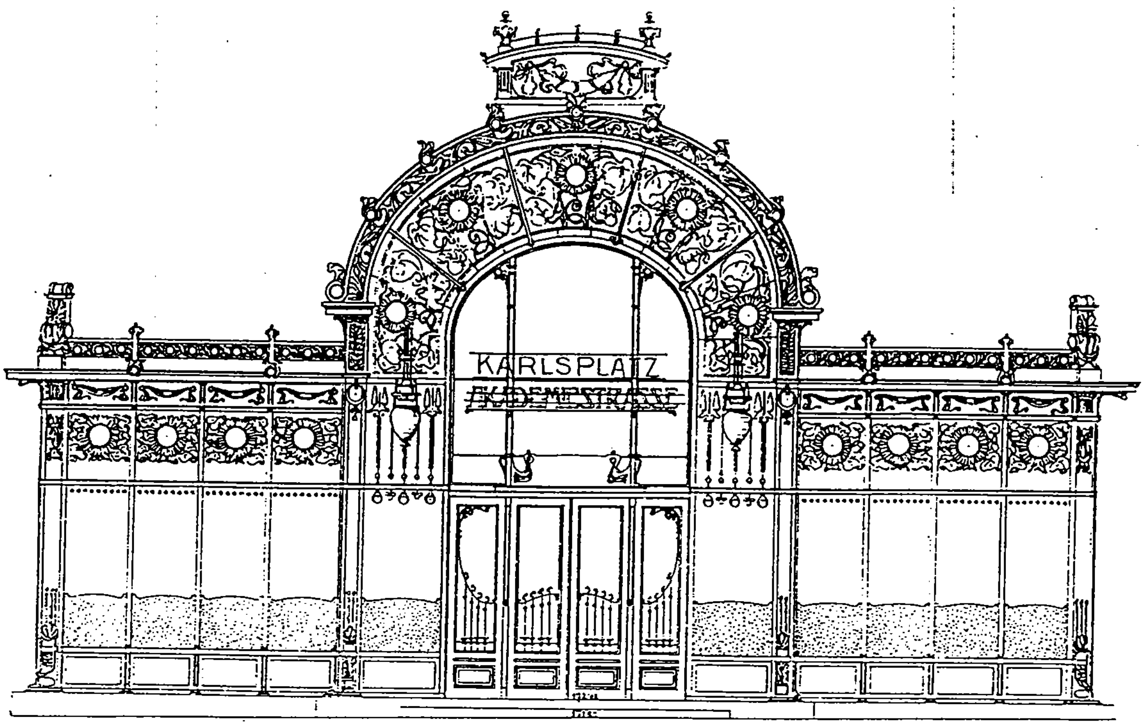

Applications of Architectural Photogrammetry I

Friday, October 4th, 1991, 11:30 - 13:00

Chair: A. Almagro

Authors - R.Brumana (Politecnico di Milano - Dip.I.I.A.R.)

The Hall of the Fountain in the Zisa's Palace and the Palatina Chapel in the Norman Palace (Palermo). Graph-numerical data bank and image data base to run and use different methods of survey.

The research here described deals with the Hall of the Fountain in the Zisa's Palace and with the Palatina Chappel in the Norman Palace.
It has been made a survey all over the monuments with modern methodologyes and instruments. With these surveyes it has become available an interesting data base.
The availability of heterogeneus data (numeric data and images), to get metric-geometric and documental informations, has improved the research.

Here is explained a methodology to run and use data from surveyes. It's made by archives of different nature: graph-numerical data bank (bi-threedimensional) and image data base, of which we studied how to connect them directly.

This thing has promoted the study of an integrated system to use them together and exchange each other.
It has requested to find representation forms diversified and more complex described in this paper.

The informations and cognitive levels already acquired are more and more available in large quantities and the quality becomes deeper.
The analitycal methods of surveying even of representation and description are diversified and complex.
The risk is to dissipate one's efforts and to loos data paradoxically, if there isn't an organic management of treatment.
The representation plays the role of mediation beetwen the phisic complexity of the nature, of the architecture, and all the intervention that can be carried out on the monuments: not only material intervention of restoration and conservations, but also cognitive and documental.
The reserch of exaustive shapes and syntetic kinds of representations, of reading filters on different level, are

here presented through a sequence of examples and different experiences ewed up again each other by the thread of this argument.

Digital sections and representation

The conservative restoration of the Hall of the Fountain has requested a survey of the structure, peculiar for the arabic covering (muqarnas), and a survey of the important decoration with mosaics and frescos.
It has been made a punctual survey of the cross-sections using modern and elettronic instruments (theodolite T1600 with DIOR 3002 and laser pointing device - Wild). This let to know carefully the geometry of the intrados of the hall. The sections are comparable with the profiles get cutting the structure on the preferential planes of symmetry: these planes cross the intersection point of the two central axes of the Hall.
Particularly the planes of section are orthogonal each other. Two planes are vertical and define the longitudinal and the trasversal section; the third is horizontal and define the planimetry.

The points surveyed (500) are located along the profiles without any materialization and are selected according to these general principles:

- special points located on the geometric discontinuances of projection and background, decorative discontinuances between mosaics and drip-stones, and at last materic discontinuances (stone and chalk of the muqarnas)

-points located homogeneously on the surfaces , plan and not plane, in order to determine the geometric trend and state.

The graphic elaboration employed an informatic system which let a direct management of numeric data bank of the Cartesian co-ordinates of the points.
The draw is built, like a dress, on the points surveyed: the same have one costant co-ordinate so that the planimetric section concern to xy plane (Fig.1), the longitudinal one to the yz plane (Fig.2) and the trasversal to the xz plane.
The survey, which is punctual, becomes continuous joining togheter the points with lines, acording to the contour conditions between one point and the one in contiguity, thank to the monographyes drawn up with accuracy.
This let to get high precision and sharpness of the outline, especially where the profile loses an elementary geometry and form to get folds determined by projections and background, indentation and gorge of the anfractuous muqarnas.

With this principle used to select the points to be surveyed we can describe even these complex state.
The management of treating the detail made possible to appreciate and esteem the richness of these forms: infact we cannot reduce them to elementar model enough exhaustive of the structure in exam. At the same time we notice and observe that the reading of the draw isn't immediatly, and becomes difficult in the interpretation, especially if related to realty.
The way backwords from the cognitive process get from the survey of an object to its draw can be proposed only in a syntetyc way and with immediatly.
The solution and alternative choice to stop to model semplified through the most important and principal form didn't agree to our aim, since it would mean to lose informations and knowledges intrinsically get with this methodology of survey.
For the complex case of the muqarnas it has been decided for an interpretation and reading of the draws scanned through three different level: first the reading of the structural function of fillet surface between the vertical wall offset each other; second the reading of the models (we define them 'eidotipi') directly related by the eyes to the image, and last the further definition of these.
So the profile has been integrated sketching the eidotipi connected to the section (Fig.2).
Eidotipi are the frontal draws of the structure elements cut from the section plane and represented upsetting the plane of 90 grads.

The contour line of the profile is the vertical one on the eidotipi intersected by the horizontal on the point surveyed.
These elements are a mediation between the reading of the section and the connection to reality.
The elementar models located one by one singularly have priority in the knowledge of the structural way of built, instead the knowledge of the details in which the model consists too, is limited inside them.
Infact a complex representation like this one, without filters, could made flat the interpretation, since the contour line is so rich to become only a corrugated and ondulated line, undoing the aim of the survey with a paradox.

Integration of the digital sections with the stereoplotting of the fronts

The only one datum system used for topographic survey and the photogrammetric one allowed the management of one graph-numeric archive relative to the Hall of the Fountain.
The stereoplotting of the fronts has been mutually integrated with the digital sections. This represented the

natural conclusion of the classic representation bidimensional of the section with its own front, overcoming the division necessary in the redaction of the two series of graphic elaborations in order to the different methodologyes used for the survey of the fronts and of the sections (Figg. 3-4).
Particularly the complexity of the fronts and of the fotographics models justified, in the stereoplotting, to specify and individualize some reading level diversified through the draw lines. This has been obtained giving priority to the interpretation of the structure with offset planes and filled though the typical arabic covering with muqarnas; only in second time proceeding to the reading and acquisition of the rich decorative system.
At last comes the localization of the state of degree relative to the structure and to the decoration.

Threedimensional management

The traditional representation kinds just explained, in some cases can be not enough exhaustive. So that it has been requested to find a different management to approach the representation of some architectural objects.
Two cases are here presented.

The survey of the intradox of a theatre (Palermo- Teatro Massimo) with the theatre-hall, tieres of boxes, orchestral cavea, has been semplified locating six radial sections and one planimetric section at the height of 1.80 mt on the floor.
The threedimensional system, numeric and graphic, in which the co-ordinate relative to the singular sections have been put and ordered, allows an integrated use of the same.
The section, if singularly drawed, represent an orthogonal projection, but in effects it is a threedimensional entity.
The survey has been made in order to determine and calculate the volume charaterized by asymmetrical profiles because of the form of the plain, like an horse-shoe, and by an iron vault, the geometric center of which doesn't clash with the highest point. This has requested to materialize graphically the envelope and the volume inveloped.
The spatial location of the single sections and the creation af a threedimensional box (Fig.5) achieve first of all a way of syntetic knowledge which would be realized with difficult and hard work, keeping each section separated.
But it could be, in second time, the starting-point for the natural representation of an ideal fillet-surfaces between the two contiguous half sections, going on the directrix of the planimetry broke in the intersection space between the two sections.

The generatrix and the directix in this case have a not linear profile.

The continuous and threedimensional representation of surfaces can make up for the lack of the orthogonal projections, if complex like these one.
Infact there are some geometric form not understood univocally through representation from only one point of view and through the digital stereoplotting of one object.

Here is presented an example. The stereoplotting of the five different covering structures of the Hall of the Fountain in the Zisa's Palace (Fig.6) is obtained with the connection of the single models of everyone part of this structure (the photogrammetric survey has been made with two cameras, Wild P31, 100 mm and 50 mm). But this kind of vectorial elaboration on line doesn't exhaust the understanding and comprehension of these arabic architectonics forms; therefore it can request a natural return to the photographic image or to the reality, in this case to lot of images because of the muqarnas surfaces muqarnas don't let to locate an only one preferential plane of representation.

Solid modelling and continuous representations in the Palatina Chappel.

The complexity of this famuos monument is determined by the contemporary presence of architectures and decorative patrimony coming from different historical cultures (norman, arabic, romanic...)
So it is very difficult to make synthesis and describe some formes so further from our architecture and culture only with traditional bidimensional representation. So they are here described and presented in a different way. Besides these kind of representation, already explained and trated in this paper, 3d model can be a solution to this problem too.

Infact if it's dressed with colors, lights and shadows, it has the continuity that let us to experience and know immediatly the complex shapes of nature.
The threedimensional management of thedata banks to create a solis model can be applied to the representation of the topographic network with ellipsoides: this make up the first grid and the natural ambient for the syntesis and the collocation of the different graphic elaborations (sections and stereoplotting on line too) like in Figg. 7-8.

Image archives and data base.

The comprehension and process of knowledge of the architectures come true in different ways, from numbers and digital data, but even through the images. Those are infact an endless and inexhaustible source of informations; above all they are enowed and provided of the continuity requisite and therefore of the direct perception.
At the Palatina Chappel it has been made the photogrammetric survey of all the surfaces, vertical and horizontal structures, inside and outside.
This rich and exceptional documentation, also expansive for costs and temps, has enphasized the problem of an use not only proceeding through the traditional stereoplotting on line, which fixes in only one way the modalityes of reading, as described for the case of the fronts of the hall of Zisa's Palace.

So it has been developed the acquisition (Bit -mapped graphics) of phothographics images to use them integrated with vectorial elaborations on line, bi-threedimensional. Fig.9).
As first step for the spatial location of the images it's necessary to create graphic archives of image data base,in order to be able to interfere with them.

This work has taken place thanks to the collaboration of of Prof. Salvatore Prescia (University of Palermo) and Prof. Carlo Monti (Politecnico di Milano), with contribution Murst 40% for the research, and with the commission of the Superintendence of B.B. A.A. and A.A. of Palermo.

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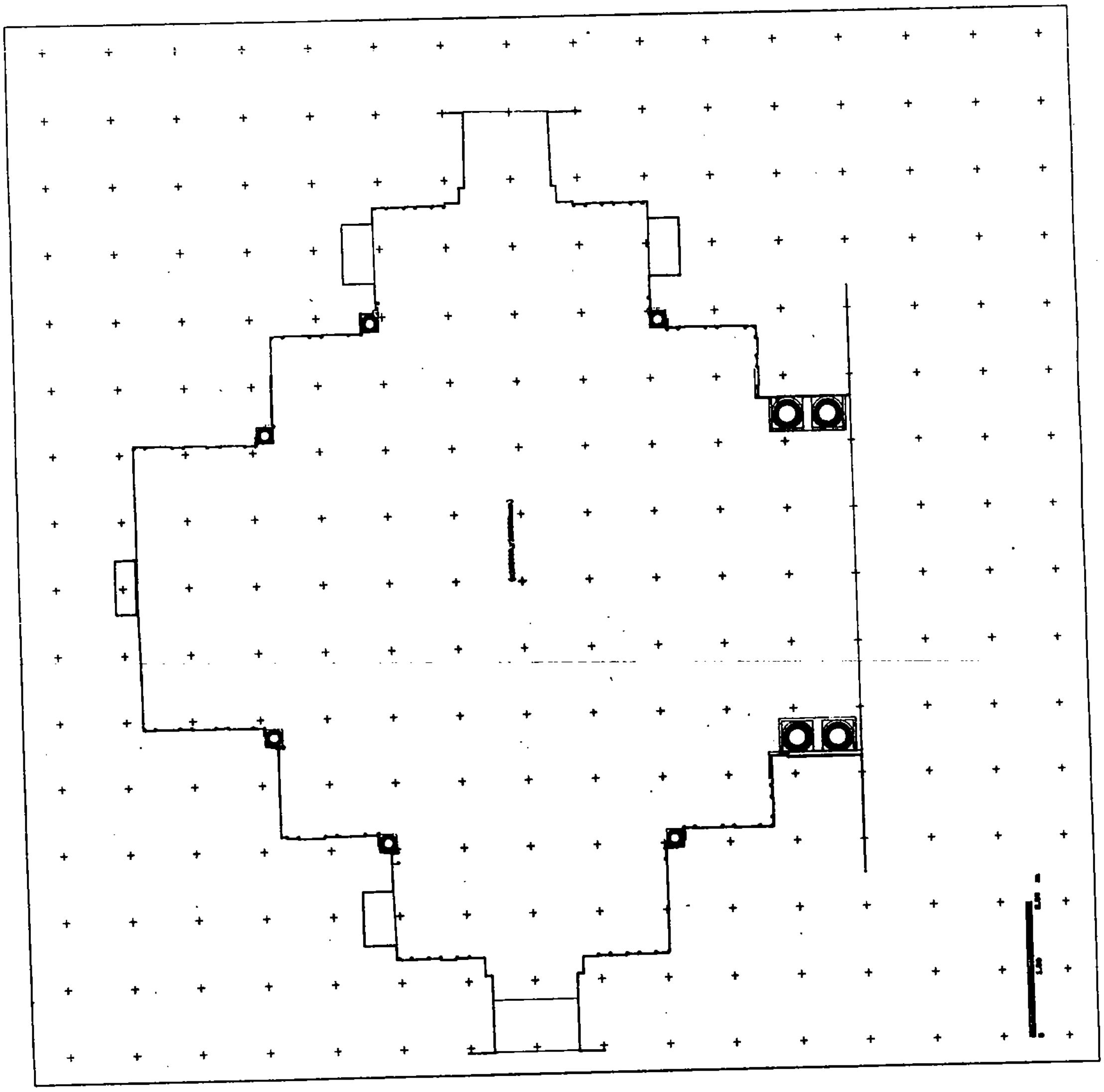

Fig.1
Zisa's Palace - The Hall of the Fountain. The planimetry, an horizontal digital section, has been puntually surveyed.

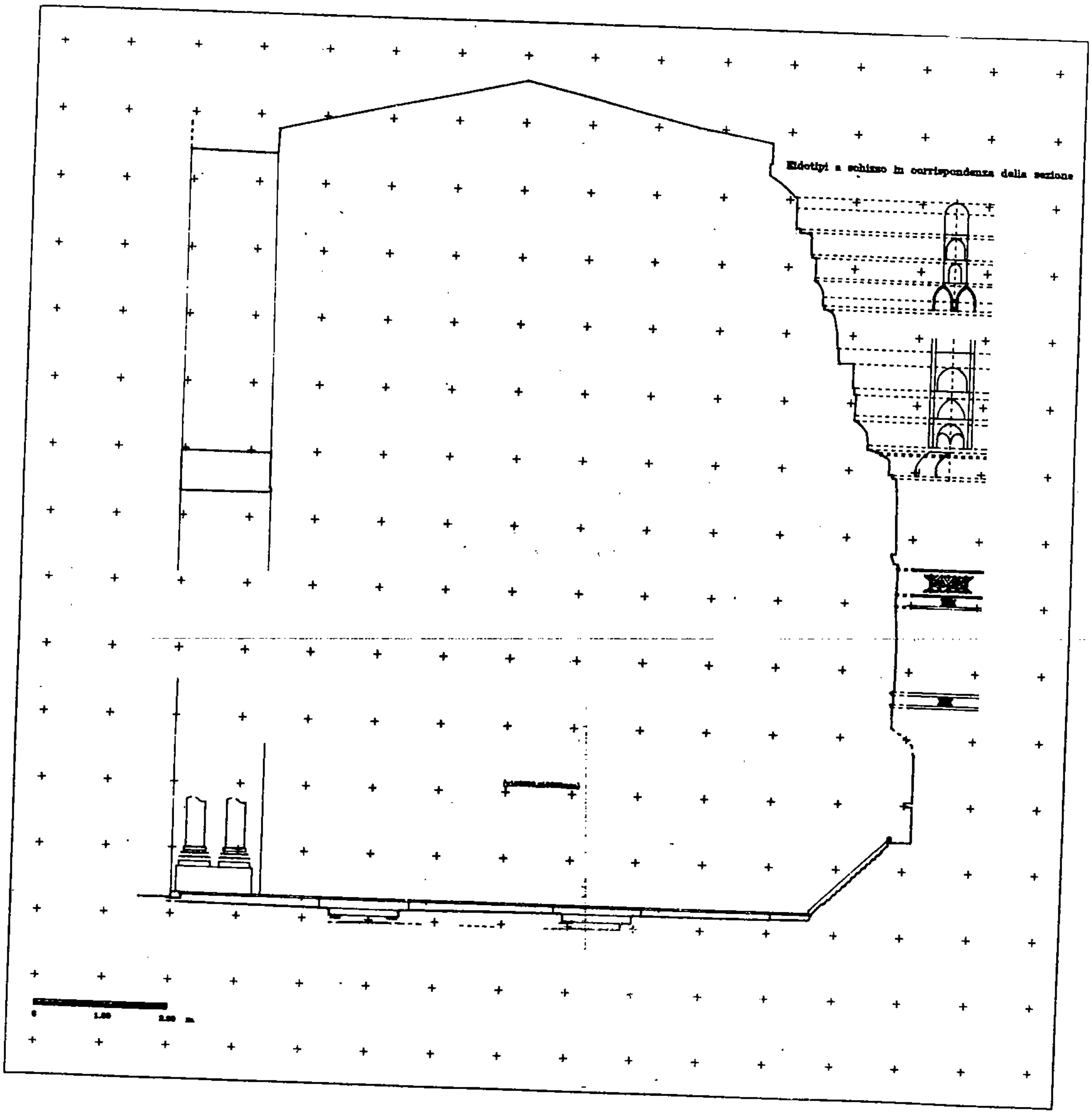

Fig.2
Zisa's Palace - Representation of the longitudinal section and drawing of 'eidotipi' through elementary model

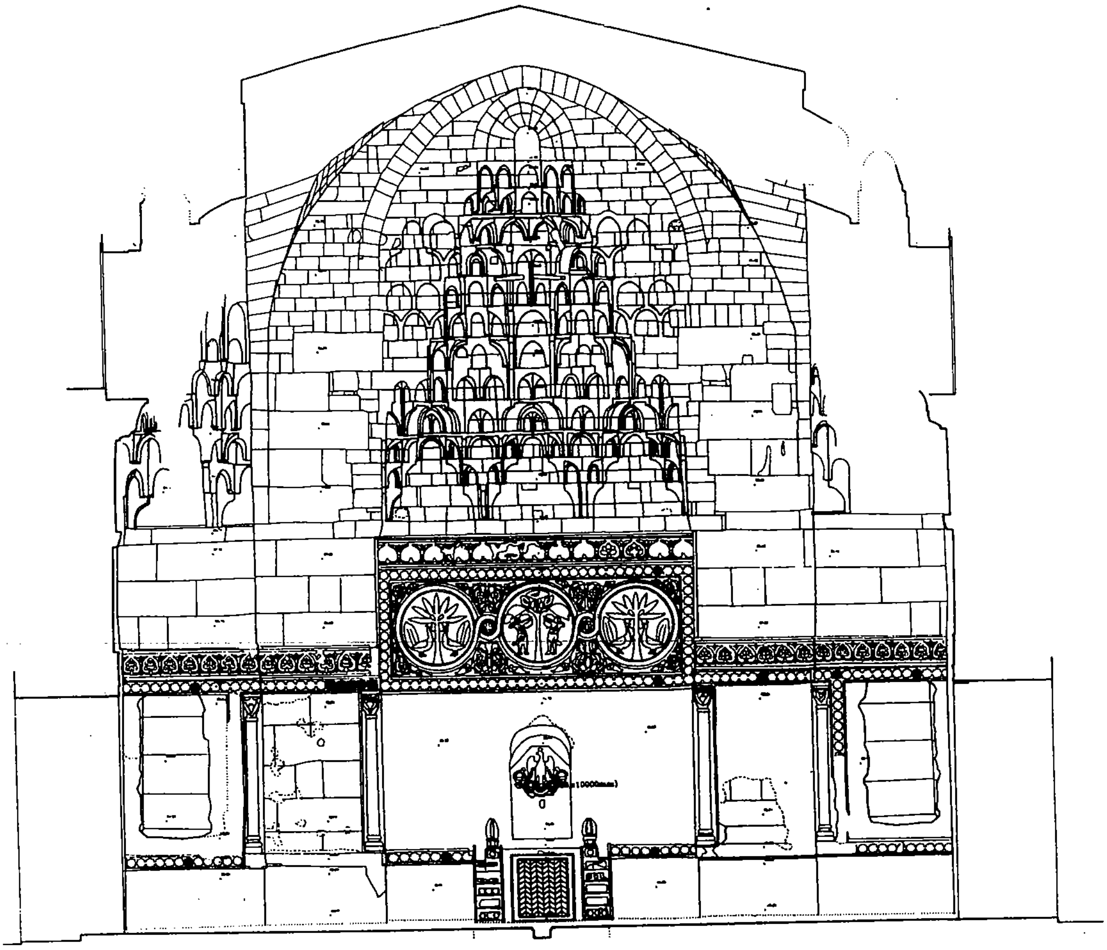

Fig.3
Zisa's Palace - The digital cross-section (transversal) has been mutually integrated with the stereoplotting of the front of the fountain.

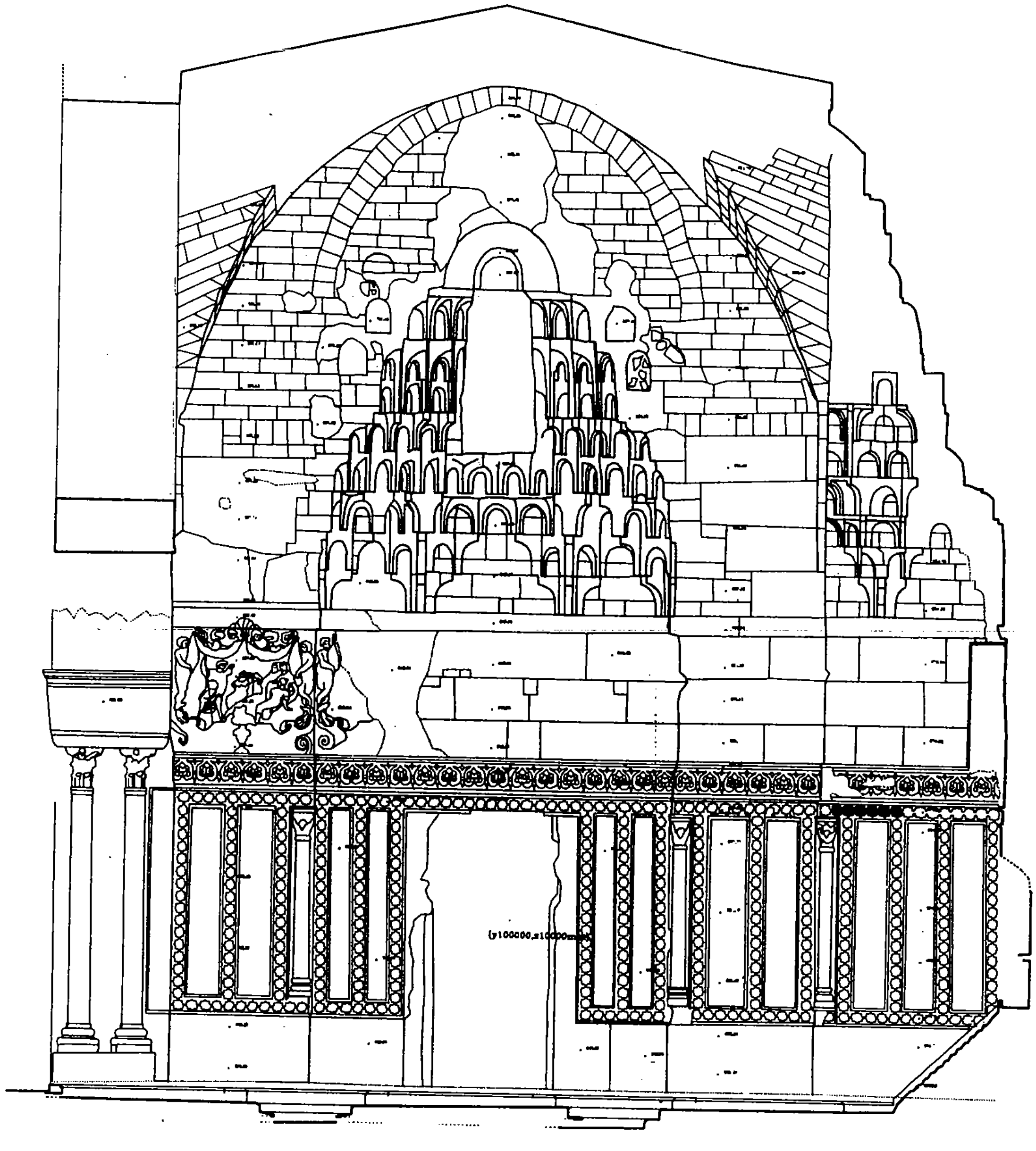

Fig.4
Integration of the other cross-section (longitudinal) with its own front

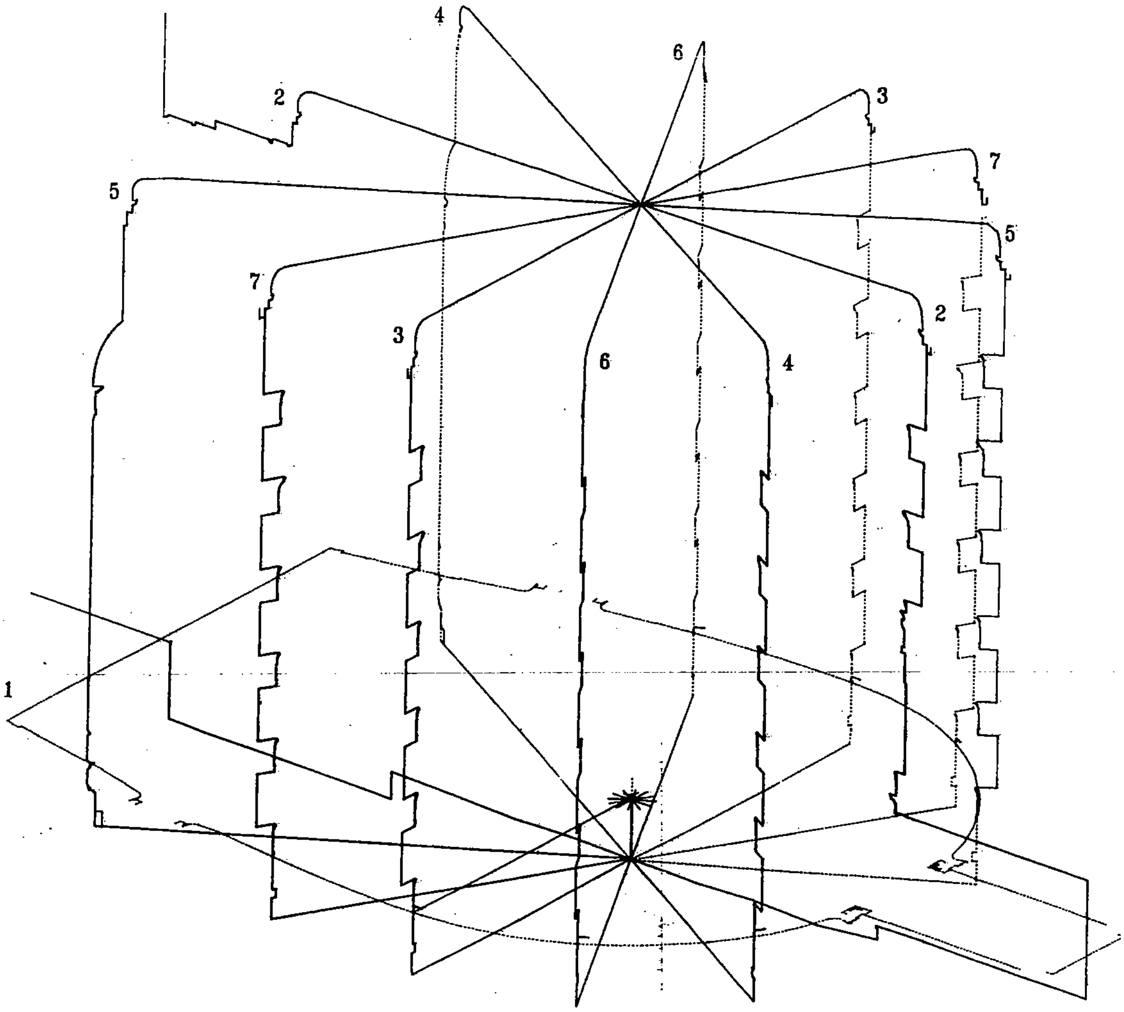

Fig.5
Teatro Massimo (Palermo) - Threedimensional model and spatial placement of the radial sections with the planimetric one.

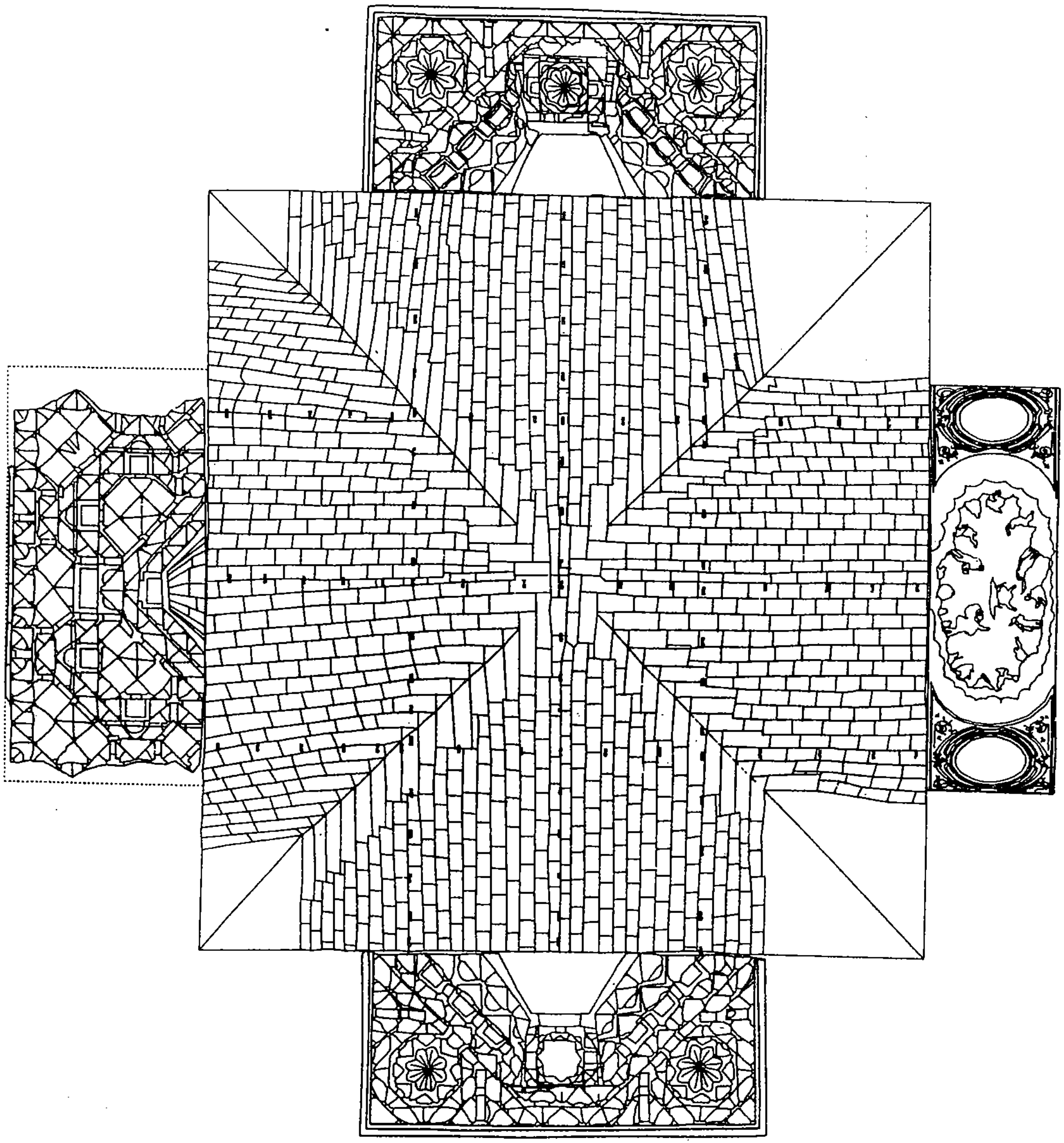

Fig.6
The stereoplotting of the complex covering structures with muqarnas in the hall of the Fountain. This kind of representation isn't enough exhaustive to describe its own geometry.

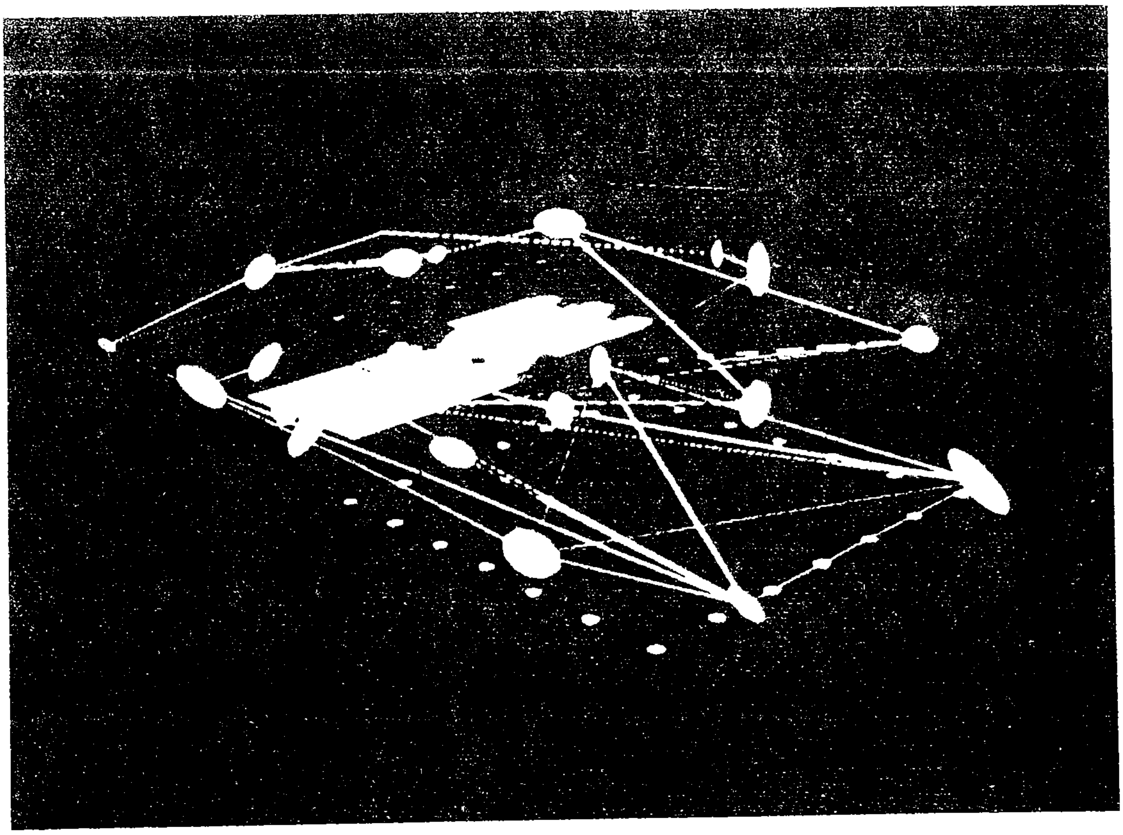

Fig.7
The Palatina Chapel - A perspective representation of the tridimensional topographic network with the ellipsoides and its own solid model.

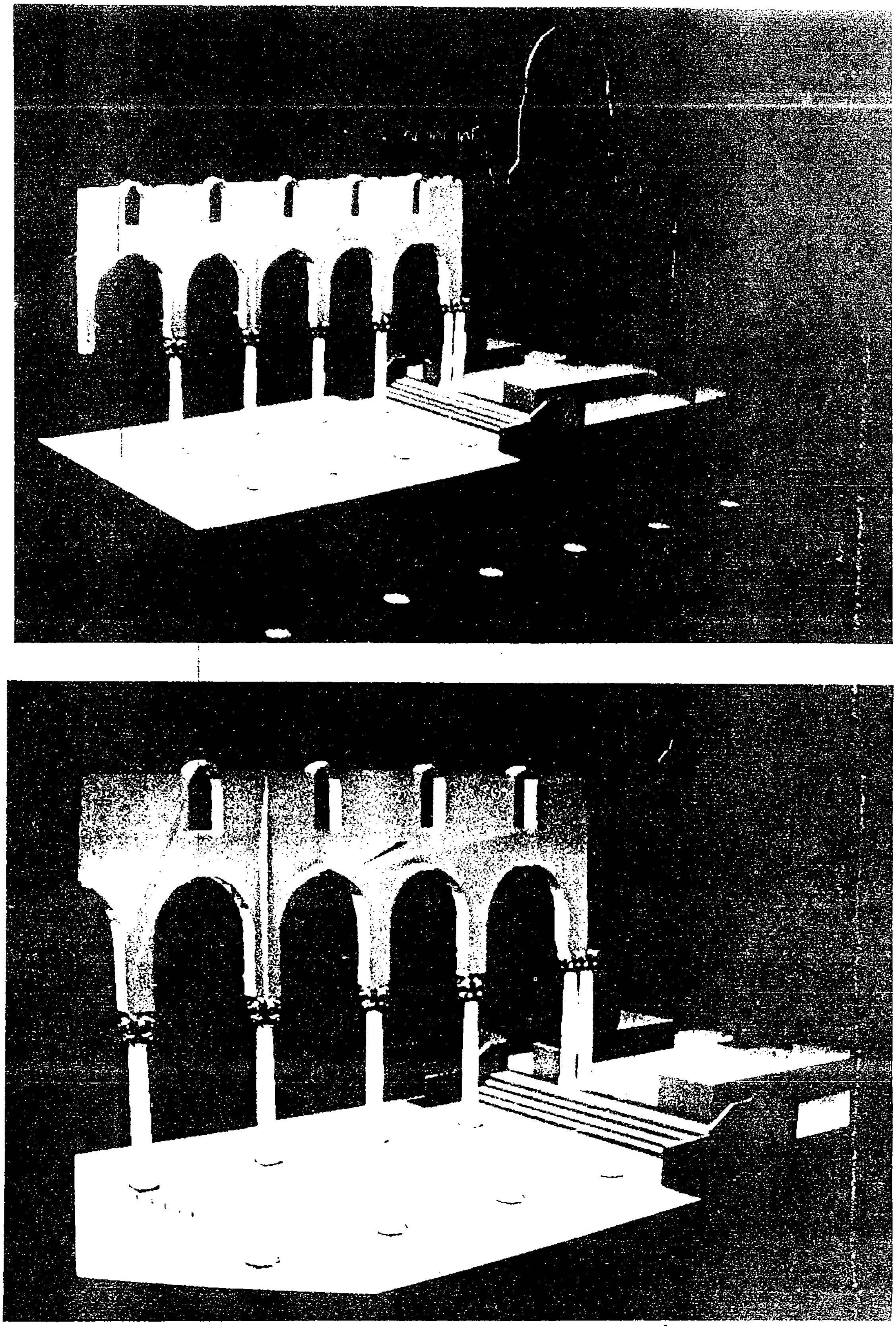

Fig.8

The Palatina Chapel - An example of spatial placement, in only one datum system, of different kinds of representation, solid modelling and digital sections of the intrados, in a graph-numerical data bank to adjourn progressively.

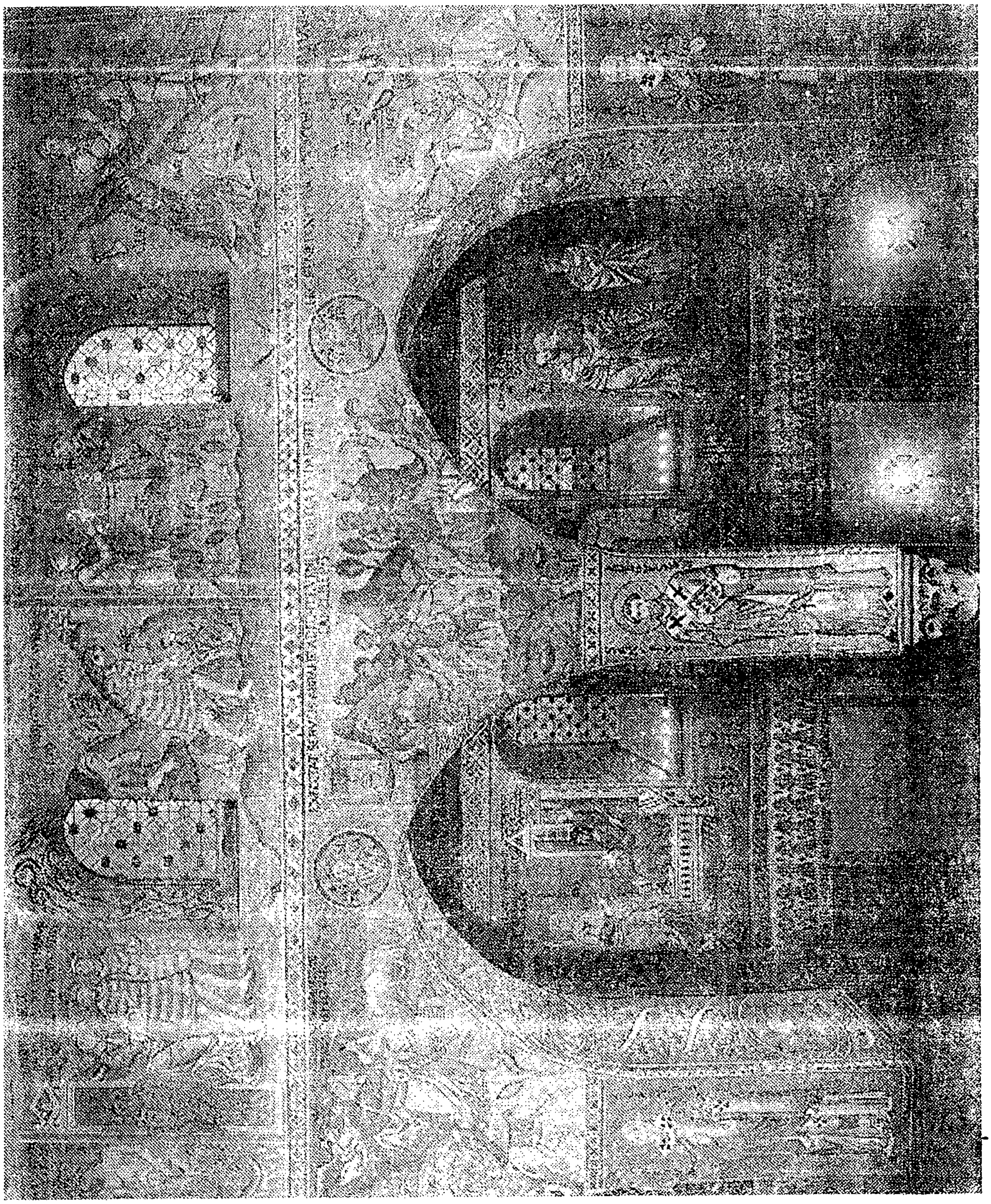

Fig.9
The Palatina Chapel - An image of the photogrammetric data bank acquired by high resolution scanner and printed on paper. Mutual integration of this image with its own digital section is possible too.

REDEVELOPMENT OF A QUARTER WITH SUPPORT OF ARCHITECTURAL AND SUBSURFACE PHOTOGRAMMETRY

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Presented Paper

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ABSTRACT

In interdisciplinary cooperation a team of archaeologists, architects, architecture and art historians, conservators, geologists and photogrammetrists tries to set up within the scope of a pilot study the basis to redevelop an urban area of Oppenheim/FRG at the river Rhine. The medieval town has got a lot of underground cavities, vein systems and cellars, which are of historical interest. The recording, inventorying and exploration of the complex phenomena are wished for finding out contexts of town development, construction, dating, function, house types and general typology. Terrestrial photogrammetry (Rollei 6006 Réseau) as well as light profile recording based on geodetic control serve as the means for producing plans, profiles and sections of surface and underground installations. All constructive elements, that have been evaluated by an analytical plotter Zeiss Planicomp C100 or that are related to out-door work, can be combined by a CAD-system and plotted. An option are even 3-D-plots. Photos, which are scanned and digitally rectified by a computer, can be fitted into cross sections. The output is done by a printer. All the various representations are used by different researchers, town planners and stress analysts.

INTRODUCTION

The term "subterranean cavities" expresses such excavation pits, which have been often developed by miner's experience but which served exceptionally for the winning or exploitation of mineral basic material and were more used for living, working and depot purposes. Such subsurface openings, "buildings", whole urban quarters can be proved since the bronze age and exist in many regions of the earth. The most famous complexes are situated near Göreme in the central part of Turkey, in the loess areas of China, in the Soviet Union, in Czechoslovakia, in France, in the tuff areas of central Italy and in Germany. Sometimes rather complex mixed shapes are now existing between above ground and underground architecture.
These subsurface "towns" have been driven into the soft material in place, they possibly have one or more entrances, can cover several levels and are often supplied with ventilating and draining systems. For making the life comfortable in such housings, the buildings are architecturally grouped and provided with installations for the daily need, which have been formed out of the material in situ (Leiszring et al. 1990, Slotta 1990).

HISTORICAL REMARKS AND ACTUAL SITUATION

The small romantic town Oppenheim on the left bank of the river Rhine, which is well-known for its wines and festivals as well as for its historical centre, is marked by an eventful history. In the 8th century it is mentioned for the first time, in the 13th century it got its freedom and flourished as a place of trade to the north, where palatial edifices were built. From this time the first underground store-rooms could definitely be dated. The wide expanded subsurface systems (at the slope between the castle and the old Rhine bank), veins, halls, cabins, manholes, springs and cistern, served the citizens as hiding-places and protection during the Middle Ages, where misery and pestilence, fires and wars shook the town in a terrible manner. The overhead town was almost totally destroyed during the 17th century by the Spanish under Spinola (1620), by the Swedish under Gustav Adolf (1631), by the Imperialists (1634) and by the French under Mélac (1689) (Brockhaus 1898).
Fortunately most of the "undergrounds" survived and bear witness of the past. Although the inhabitants were in the know of the subsurface systems since centuries, used at last in the second world war, they did not have exact knowledge about the stability conditions of the multi-storied cellars, which probably were combined and which are even situated under streets and other traffic lines. The vaults and tunnels are constructed in a variety of different shapes (round arch, catenary, triangle form, pointed gable, cross vault) and techniques (sealing, stone work, belt, rib, cf. Fig. 1 - 4)). A lot of systems have meanwhile been closed by masonry, others filled up with concrete and rubbish, some of them collapsed. Such cave-in can have different reasons: weathering of supporting vaults and walls, drainage and underground water, which flushed the soft loamy strata of the tertiary period or the underlying fractured chalk stone, so that problems of stability are arising. There might exist even unknown subsoil cavities, that can be detected by geophysical surveying.

Until today some thirty local depressions happened in the town, so the municipal council had to bring out a programme to solve these problems of stability and to save its architectural heritage. Three above ground and underground objects were chosen for a first pilot study. The complexity of the task concerning documentation and research requires interdisciplinary co-operation of specialists from archaeology, architecture, history of architecture and art, conservation, geology, geophysics, photogrammetry, restoration and statics with the support of the town council Oppenheim and the Land Rhineland-Palatinate. The following institutions were involved in the project: Land Office for Cultivation of Monuments, Section for Middle Ages' Archaeology and Monument Research/Mainz, Geological Land Office/Mainz, Limited Company StadtBauPlan / Darmstadt, DeutscheMontanTechnologie, Institute for Applied Geophysics, Institute for Water- and Ground-Protection and DBM-Department for Photogrammetry / Bochum. All together they evolved the basic materials for construction works, which can yield to the redevelopment of the historical centre under high financial expenditures.

DOCUMENTATION, METHODS OF SURVEYING AND MONUMENT RECORDING, CARTOGRAPHY, GEOLOGY, GEOPHYSICS

The documentation of the actual inventory of the three complex constructions is preferably organized by a homogeneous basic data bank, which can be handled by the users of the different subjects. Surveying and photogrammetric methods can produce the foundations for a later cartographic lay-out by evaluation at a CAD-system, for the judgement of statics and for the construction activities, which can be drawn off this estimation to garantee safety for the buildings and prevent dangers.
The base for all surveys is the above ground land-register grid (co-ordinate system). Starting on the cadastral points the natural photogrammetric control points at the buildings and points for site plans were determined by means of an automatic electronic tachymeter Zeiss Elta 4 as well as the underground control points via polygonal course (accuracy: cm). Points, which symbolize the characteristic features of the cellar geometry, were recorded too and lead to a generalized line information. In narrow spaces and niches details were measured by hand.
Much more informations for a metric evaluation can be achieved by a stereo-photogrammetric documentation and by photos from a light profile projector (developed by J. Heckes). The last mentioned were taken at representative profiles of a vein or gangway (single image photogrammetry, middled format camera, cf. Fig. 6, 7). After the measurement in a plotter the photo profiles can be combined arithmeticly by geodetic observations for producing three dimensional representations or for calculating volumes.
All stereo-photos were taken freely positioned with a partial metric camera Rollei 6006 Réseau (121) with automatic aperture and film transport using a lens Zeiss Distagon 40 mm. Control points served for the model orientation at an analytical plotter Zeiss Planicomp C100. The roughly stereo-plotted structures (Fig. 5) and façades are treated in an up-to-date way by the CAD-System AutoCAD (Autodesk 1989). The lines and polyline-segments, even as very small increments, are registered during the plotting on the HP 1000 computer of the plotter and transfered to a PC (DXF-files) and can be handled with all possibilities of modern CAD (Mauelshagen et al. 1990). All geodeticly determined co-ordinates are loaded as a data bank into an AutoCAD-file and treated graphically. On the screen the treatment and revision of photogrammetric plans and "geodetic" graphs are performed in layer-technique. Because of the same co-ordinate system (above and underground) the illustrations are joined together and plotted by a HP-DraftMaster using additional layer informations from a "catalogue" as map frame, legend, signs, colours etc.. Longitudinal and transverse sections, profiles and ground-plans are elaborated. They are all

situated at representative positions or levels and show a lot of special and differentiated signs (Fig. 6, 8 - 12, original scale 1 : 50, colours for different specific features and perceptions). Even scanned photos can be fitted into sections as pixel images (Fig. 9, rectified arch).
The cartographic concept is based on structural and editing drawing files, which includes the integration and implementation of features and informations from other research fields. The composition of the different layers depends on the themes, which the ultimate user considers as important, outstanding and significant.

At some places the archaeologists brought down an excavation for finding a better dating of the cellars (Fig. 10). Geophysical surveyings, such as refraction seismic, seismic in combination with drillings, electromagnetic induction and georadar (Rüter et al. 1989), detected, where dangerous and espescially dangerous parts are situated (Fig. 11); the analysis of data is still going on. The geologists took soil and water samples for finding out shear, grain-size distribution and plasticity (Fig. 12).
All results of the pilot study will drop into the concepts of redevelopment for the whole overhead and underground city Oppenheim. May be that in the near future a lot of the undergrounds can fortunately be used as wine caves and will be an attraction for tourism.

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Acknowledgement

Thanks to Birgit Heyer for the lay-out.

Fig. 1

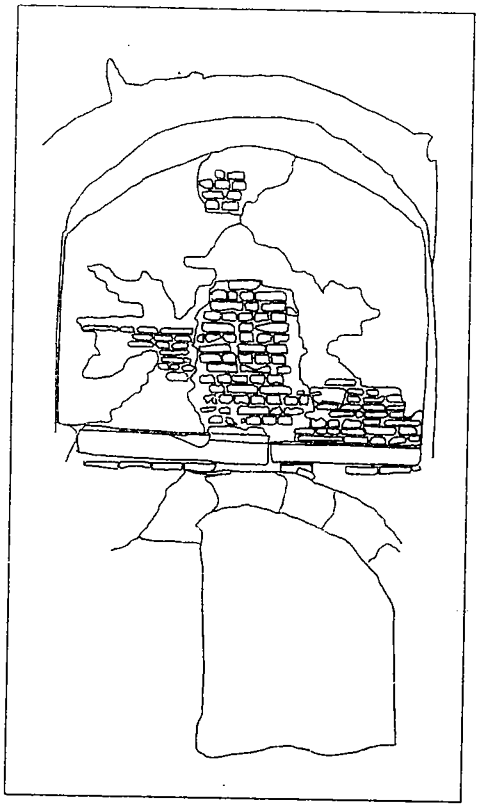


Fig. 5 Rough stereo-plot of a double storied underground scene of Oppenheim

Fig. 2

Fig. 3

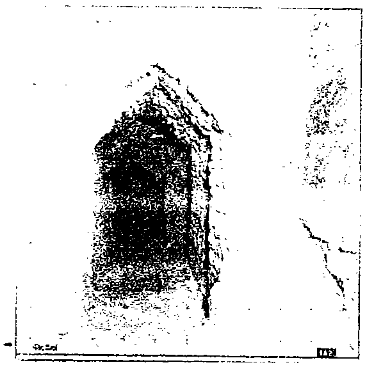


Fig. 4

Fig. 1 - 4 Rollei 6006 Réseau photos of different shapes of arches, tunnels and vaults from the underground of Oppenheim

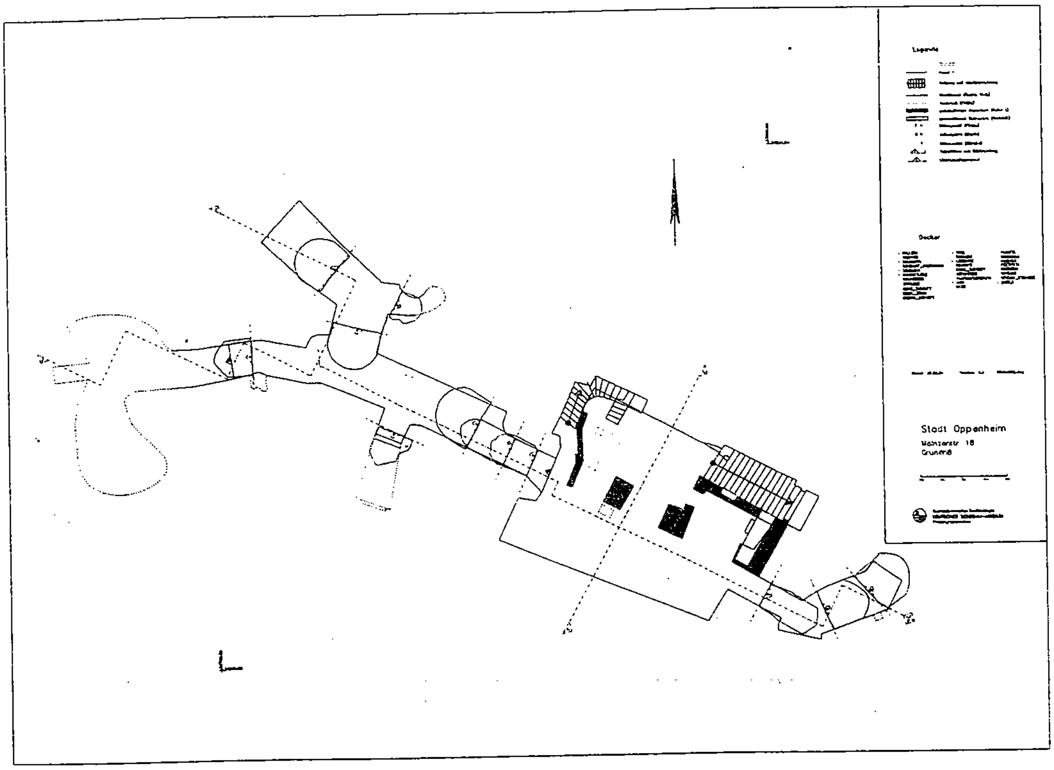


Fig. 6 Reduced underground-plan, Merianstr. 18, Oppenheim, with some profiles (light projector)

Fig. 7 Two photos made by the light profile projector from an underground passage

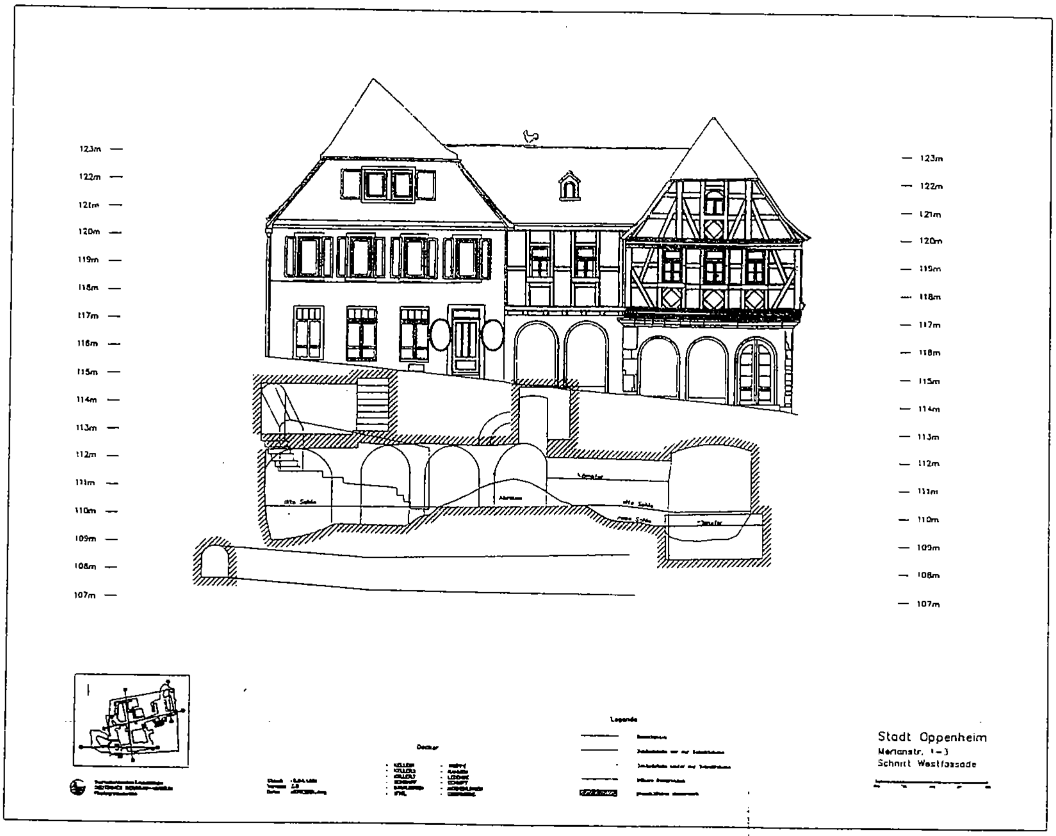


Fig. 8 Photogrammetric plot and longitudinal underground section from the western part of Merianstr. 1-3, Oppenheim

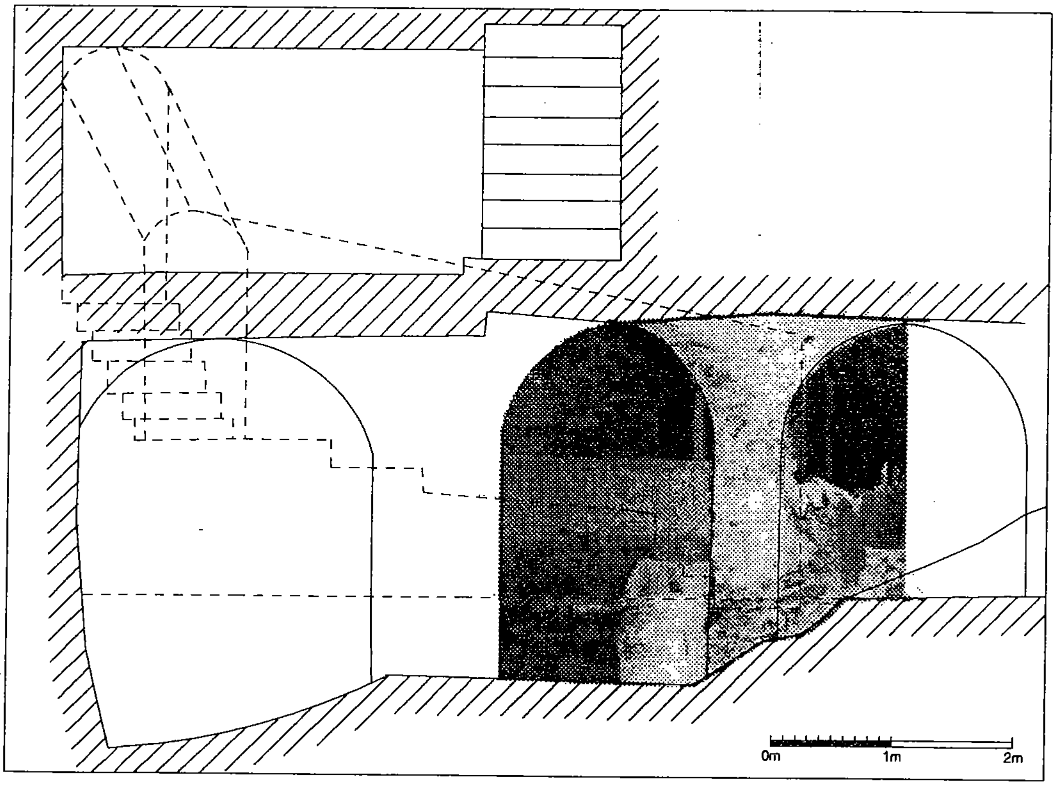


Fig. 9 Enlargement of the inferior part of the underground section Fig. 8 with fitted pixel image (rectified arch)

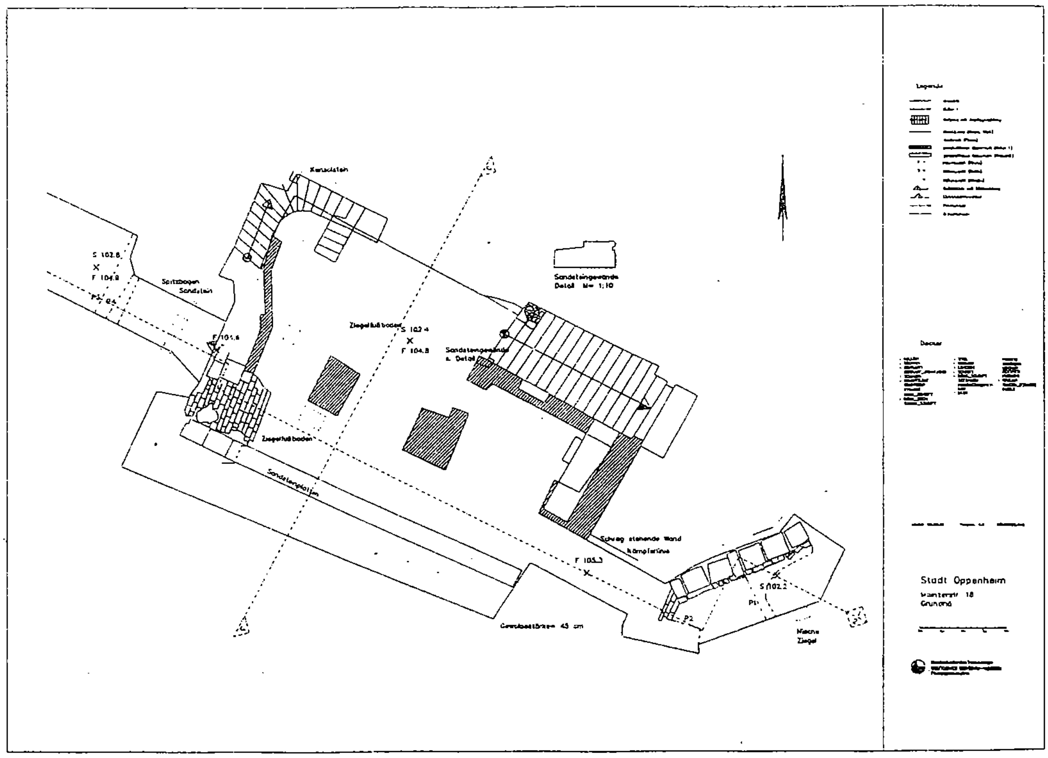


Fig. 10 Enlarged but reduced part of the underground-plan, Merianstr. 18, Oppenheim, with archaeological elaborations

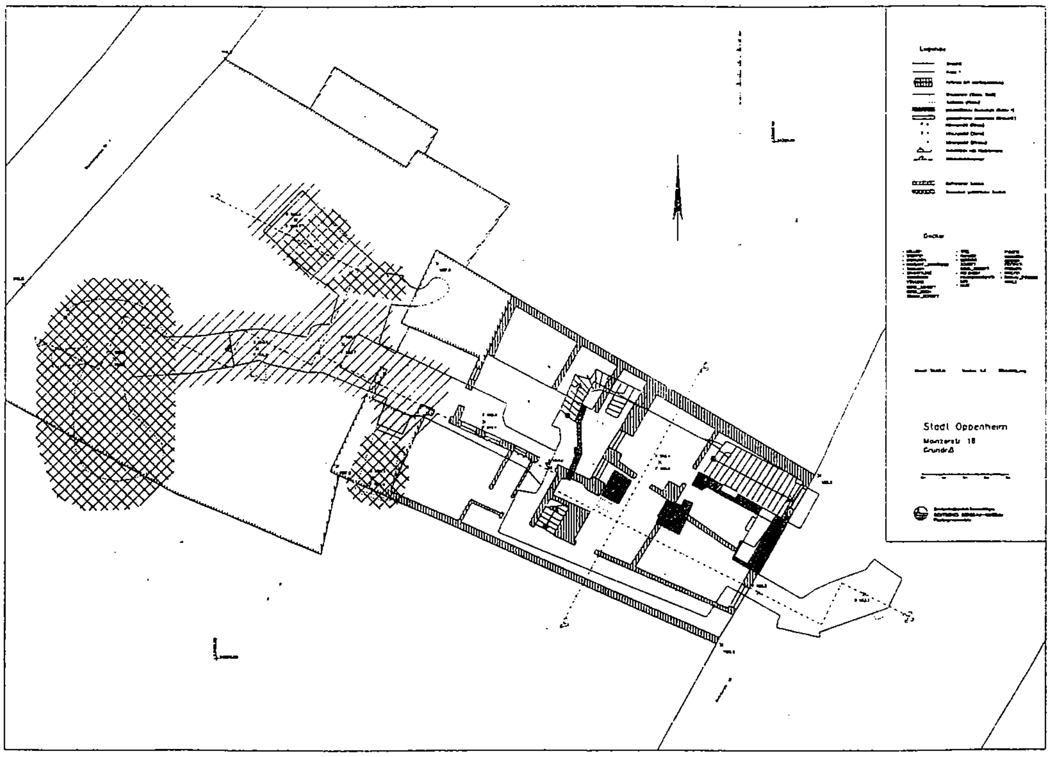


Fig. 11 Ground-plan of the subsoil including the ground-floor, Merianstr. 18, Oppenheim, with signs for dangerous (hatching) and particularly dangerous parts (cross hatching) - geophysical research -

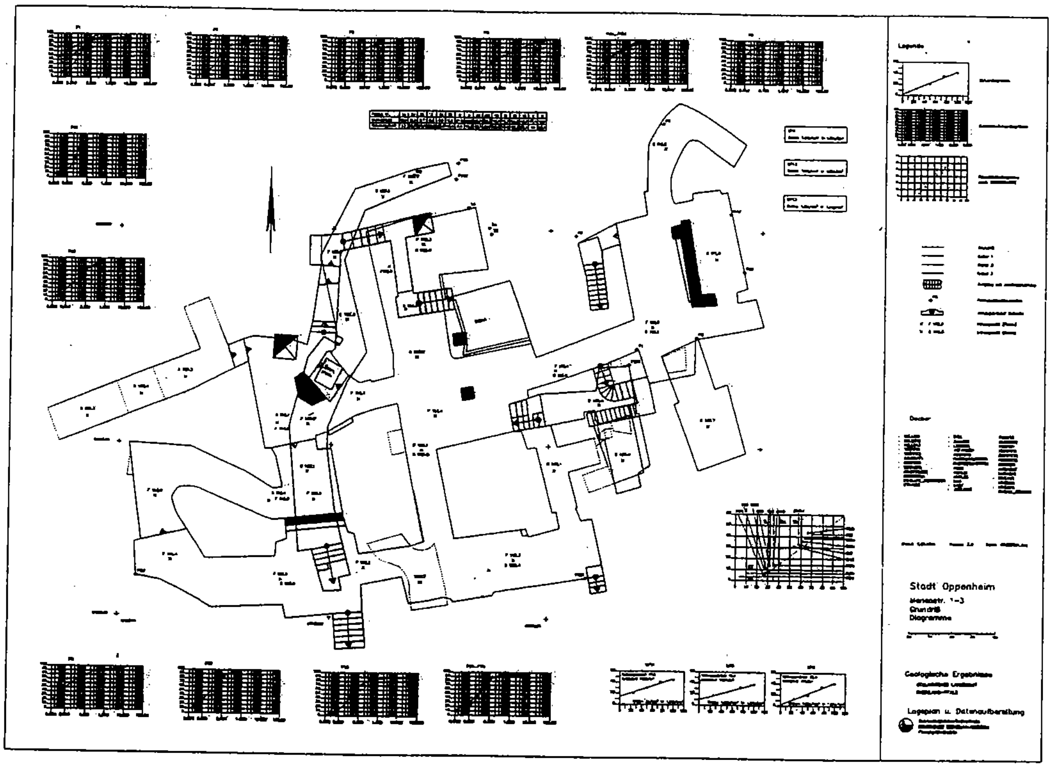


Fig. 12 Reduced underground-plan, Merianstr. 1-3, Oppenheim, with geological specifications (diagrams: shear, grain-size distribution, plasticity)

ANALISI E RILIEVO DI SISTEMI TRADIZIONALI IN MURATURA NELLE AREE ARCHEOLOGICHE ROMANO-LAZIALI.

di Stefano GIZZI
Soprintendenza Archeologica per il Lazio

1. PREMESSA.

Nell'attuale momento di ricerca di tecnologie appropriate[1] nel settore antisismico, nei campi specifici dell'architettura e dell'archeologia, particolare importanza assumono due ordini di problematiche:

1) Il rilievo e l'analisi delle caratteristiche dei "manufatti" esistenti;

2) La verifica della compatibilità o meno degli interventi consolidativi con la qualità del "manufatto" preesistente.

L'esperienza degli ultimi trent'anni ha indotto a diffidare di operazioni "pesanti" e occulte, quali eccessive inserzioni nelle murature di materiali speciali come l'acciaio, l'acciaio preteso, le cuciture armate *et caetera*, a causa della loro invasività, della poca durabilità e della loro irreversibilità.[2]

Come afferma, però, la "Carta del Restauro Italiana del 1987", "in ogni caso dichiararsi favorevoli al recupero delle tecniche tradizionali non è sufficiente, perché è necessario saperle attuare."

Pertanto, di particolare interesse si è appalesato uno studio sperimentale, teorico e di ricerca sui metodi tradizionali di consolidamento antisismico adottati su "monumenti" e su "beni archeologici" in ristretti e ben definiti ambiti territoriali nell'area laziale.

Lo studio si è articolato in due fasi:

I Fase.

E' stata effettuata una campionatura, corredata da rilievi fotogrammetrici e da documentazione grafica e fotografica, dei più interessanti provvedimenti consolidativi di epoca pre-industriale (speroni, contrafforti, catene, cerchiature, ammorsature degli spicchi dei padiglioni delle volte), e di provvedimenti attuali da verificare per confronto.

Conseguentemente, è stato realizzato un lavoro di inventariazione e di schedaura degli elementi consolidativi suddetti. Particolare importanza assumono gli speroni,per il rapporto tra peso specifico degli elementi costitutivi (in laterizio o in tufo) e il peso proprio della muratura da consolidare.

Gli ambiti territoriali laziali oggetti della ricerca sono stati rappresentati:

A) dalla zona di faglia tiburtina, dove è stata presa ad esempio Villa Adriana, con una ricca campionatura di catene, di tirantature e di alcuni speroni superstiti di notevole interesse, quali quelli del Camerlengato, del cosiddetto Stadio e del Quadriportico con peschiera;

B) dall'area sismica dei Castelli Romani,con la campionatura dei contrafforti di restauro (seicenteschi?) dell'Anfiteatro di Albano;

C) dalla zona settentrionale reatina, con il rilievo e con la riproposizione del modello di alcuni speroni pre-industriali delle aree termali sabine.

Al fine della documentazione esatta è stata utilizzato il rilievo fotogrammetrico che, date le sue caratteristiche di assoluta precisione, ha fornito, attraverso un archivio-lastre, una documentazione completa e controllabile.

II Fase.

Dopo la prima fase di acquisizione dati (attraverso la fotogrammetria) e di inventariazione e di schedatura, si è passati ad una seconda fase operativa, consistente nella riproposizione (attraverso modelli matematici e non-) di strutture simili (preindustriali di consolidamento antisismico) e, mediante la lettura storica e la riproposizione di microsismi simulati in laboratorio, nella verifica comportamentale delle strutture medesime e delle relative "curve delle pressioni".

A questo scopo sono stati adoperati metodi di elaborazione del tipo "ad elementi finiti".

Il modello è stato verificato, per mezzo del computer digitale, considerando la muratura come un insieme di elementi discreti, creando una analogia tra gli elementi prismatici della muratura e gli elementi discreti stessi e supponendo, naturalmente, che venissero osservate le condizioni basilari di compatibilità degli spostamenti, di equilibrio delle forze e delle leggi di comportamento dei materiali.

2. LO STUDIO DEL PROBLEMA: IL MOMENTO ATTUALE DI RIPENSAMENTO SULLE TECNICHE DI CONSOLIDAMENTO IN ZONA SISMICA.

2.1. In generale.

Al giorno d'oggi è in corso un processo di graduale e di generale ripensamento sulle metodologie e sulle tecniche tradizionali di consolidamento e di restauro di edifici storici e di beni archeologici ed architettonici, con particolare riguardo a quelli siti in zona sismica, specialmente per quel che attiene alla compatibilità ed alla interagibilità di materiali originari (in pietra o in muratura) con quelli metallici di consolidamento.

Come ultimamente rilevato, "il più recente dibattito sull'uso dei cosiddetti nuovi materiali e sulle tecniche connesse ha più volte evidenziato la relativa o la totale incompatibilità degli stessi con le strutture murarie preesistenti. In particolare, la ricerca finalizzata alla prevenzione antisismica o alla ottimizzazione dell'intervento su edifici colpiti dai sismi ha impostato un quadro di lavori interdisciplinari e di convergenze su un obiettivo comune: la riacquisizione conoscitiva e la verifica di funzione meccanica delle tecniche tradizionali".[3]

L'attenzione rivolta a tali problematiche, grazie anche al succedersi di vari Convegni e Congressi sull'argomento per merito di alcune Associazioni e di Dipartimenti universitari, ha prodotto un'inversione di tendenza rispetto all'entusiasmo finora dimostrato nei confronti dei materiali schiettamente moderni o di "espedienti supertecnologici" che "non mutassero l'aspetto dei luoghi"[4] e del monumento a restauro avvenuto.

Questo clima culturale ha condotto, quattro anni fa, alle «Raccomandazioni» emanate dal Comitato Nazionale per la Prevenzione del Patrimonio Culturale dal Rischio Sismico e, nel 1987, alla nuova Carta Italiana del Restauro, le quali superavano le precedenti normative, riproponendo le questioni delle tecniche di consolidamento in termini più aperti.

La seconda (Carta Italiana del Restauro 1987), come meglio vedremo in seguito, suggerisce il «ritorno» a metodologie di restauro sicure, attraverso lo studio e il ricorso a tecniche antisismiche pre-moderne (reintegrazioni murarie, speroni, tiranti non occultati, etc.)".[5]

Ecco, allora, il perché dell'interesse risvegliatosi in quest'ultimo periodo sulle tipologie tradizionali di rinforzo e, tra queste, per il particolare significato che rivestono nell'ambito "delle famiglie dei tipi costruttivi concepiti in funzione antisismica in cui prevale l'uso della massa muraria resistente, geometricamente determinata",[6] alcuni speroni e contrafforti lapidei e laterizi di restauro, realizzati tra il 'Settecento e l'Ottocento: si pensi agli esempi illustri degli speroni in laterizio dello Stern o del Valadier al Colosseo, a quelli proposti dal Canina per il consolidamento delle Biblioteche Greca e Latina di Villa Adriana, o anche ad altri meno noti ma significativi quali ulteriori contrafforti in laterizio o in tufo adoperati nel secolo scorso come opere provvisionali per il Castello dell'Acqua Giulia (i cosiddetti «Trofei di Mario») a Roma, per il Tempio di Ercole a Cori, per le arcate dell'Anfiteatro romano di Albano Laziale e per le mura di cinta di Alatri.

Certamente, oggi una delle operazioni più fortemente da stigmatizzare consiste proprio nello "sconvolgimento" della «storia statica» del monumento, con "l'inserimento di nuove strutture cui viene affidata completamente la funzione statica, riservando all'antica la sola funzione di elemento formale",[7] spesso dissimulando ed occultando le nuove strutture e commettendo, dunque, un "falso storico".

Giustamente, come nota Giovanni Carbonara, esiste l'esigenza "di un rispetto del sistema statico originale ed anche dei suoi eventuali difetti, visti come documenti di un momento della storia del costume".[8]

Sembra così definitivamente acquisito il concetto della conservazione degli organismi archeologici e architettonici "nell'interezza delle componenti tipologiche, strutturali e funzionali", laddove "privandoli di una componente se ne snatura l'essenza e il significato".[9]

Ecco, dunque, che la sperimentazione («esperienza» intesa come «conoscenza pratica» della durabilità e della riuscita nel tempo dei materiali e dei prodotti della nostra epoca, acquisita con la pratica, e come attenta verifica delle loro caratteristiche e delle loro funzionalità) diviene una delle condizioni fondamentali per l'adozione di tecnologie attuali.[10]

Oggi, il recupero delle tecniche tradizionali pre-industriali e "la rivalutazione di quanto di valido era contenuto nelle pratiche tradizionali" si accoppia ad una nuova maniera "di riconsiderare la Scienza delle Costruzioni dei manufatti murari (...) che non rinuncia (...) alla possibilità di ricostituire il filo rosso della cultura tecnica tradizionale, abiurando, se necessario, al giuramento modernista di rifiutare la cultura tecnica pre-moderna".[11]

Ultimamente, lo scontro tra i fautori del ritorno alle tecniche e alle tecnologie tradizionali e i sostenitori della bontà delle tecniche innovative e dei nuovi materiali applicati al consolidamento sembra aver trovato un momento di equilibrio nel sostenere (Giovanni Carbonara, Paolo Rocchi) che non si tratta tanto di scegliere tra tecniche premoderne o moderne, ma tra tecniche «appropriate» per quell'intervento.

Sostiene a tal proposito Paolo Rocchi che «non esistono interventi "leggeri" o "pesanti" -frutto di polemiche contrapposizioni pseudo culturali- ma solamente interventi "appropriati"».[12]

3. IL RECUPERO DELLE TECNICHE TRADIZIONALI DI CONSOLIDAMENTO "ALLE GRANDI MASSE MURARIE": SPERONI E CONTRAFFORTI. INDAGINI NELLE TRE AREE SPACIFICHE (VILLA ADRIANA, CASTELLI ROMANI E SABINA).

Si sono scelte alcune aree di indagine molto limitate geograficamente, per poter offrire dei confronti ben serrati e documentati in un territorio omogeneo, corrrispondenti a complessi noti dal punto di vista archeologico e del periodo costruttivo, ove risultassero presenti interessanti speroni di consolidamento, realizzati tra 'Settecento e 'Ottocento, od ove ne rimanesse comunque traccia (molti di essi sono stati demoliti negli anni 'Sessanta, a vantaggio di operazioni consolidative "occulte").

Come detto in premessa, le aree di indagine scelte sono state le seguenti:

a)- per la zona di faglia tiburtina: Villa Adriana;

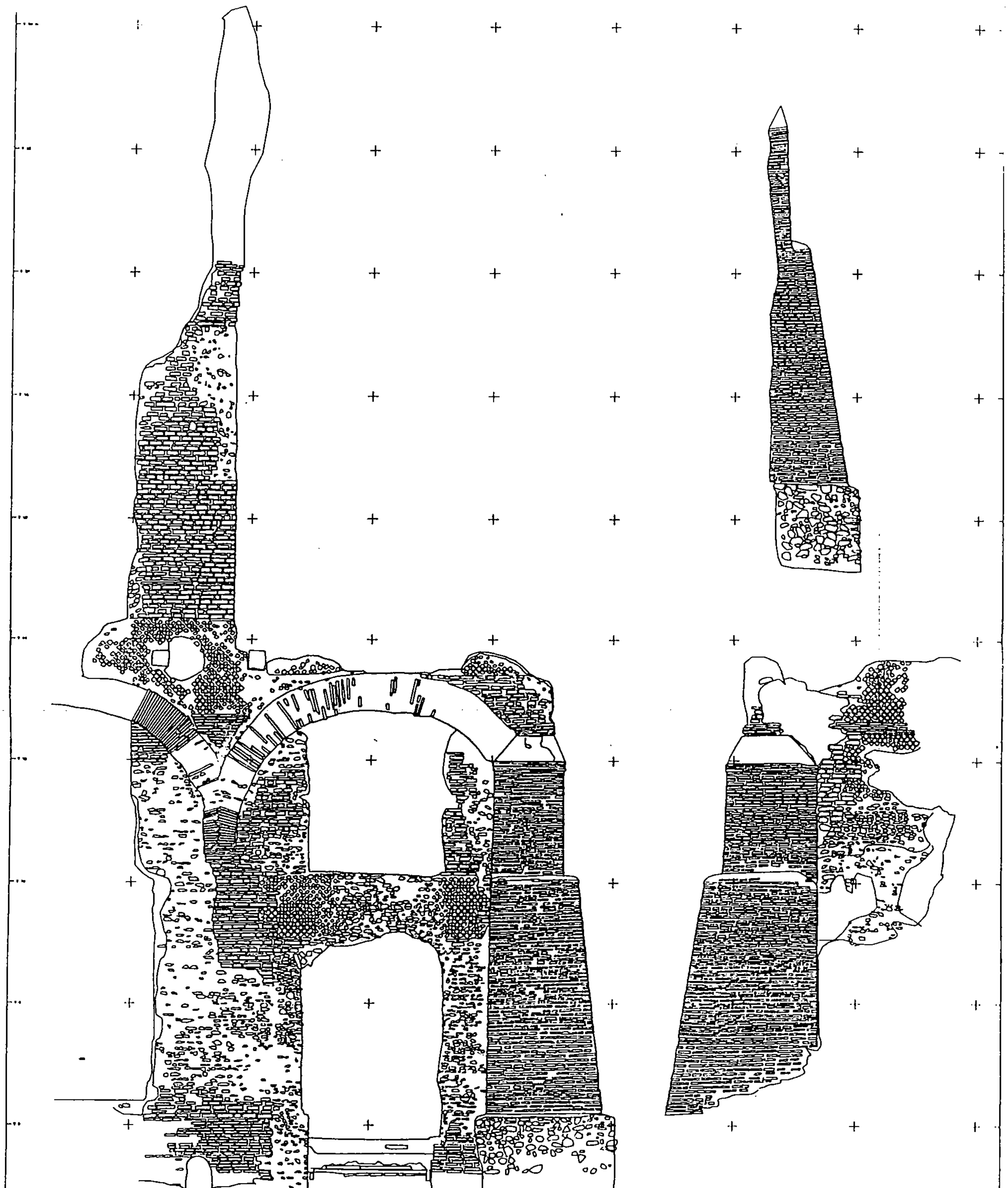
b)- per la zona dei Castelli Romani: l'Anfiteatro di Albano;

c)- per la zona di faglia sabina: le cosiddette "Terme di Tito Flavio Vespasiano" a Cotilia.

a)- A Villa Adriana attualmente ancora esistono speroni di consolidamento ottocenteschi al cosiddetto "Teatro Greco" (noti come «Speroni del Camerlengato»),al "Quadriportico con Peschiera" e al cosiddetto "Ninfeo" (ex "Stadio").

Per tutti è stato realizzato un rilievo fotogrammetrico, a varie scale, non limitato ai singoli elementi consolidativi, bensì esteso anche all'intorno. L'indagine sul comportamento rispetto alle scosse sismiche (effettuata per il tramite di modelli matematici) è stata compiuta (come campione) per gli speroni del "Ninfeo" (ex "Stadio").

La maggior parte di questi sistemi di consolidamento "alle grandi masse murarie" in Villa Adriana sono stati demoliti proprio con l'avvento della filosofia delle inserzioni occulte di materiali ferrosi od acciaiosi. Dalla documentazione fotografica che è stato



COMUNE DI TIVOLI – VILLA ADRIANA – NINFEO
PROSPETTI DEL SECONDO SPERONE DI RESTAURO

possibile rinvenire, di notevole interesse dovevano apparire gli speroni costruiti per sostenere le Biblioteche Greca e Latina, quelli presso il Pretorio e presso l'edificio con tre esedre.

Si era, così, in effetti, venuta a costituire una serie omogenea di interventi restaurativi e consolidativi a carattere "diffuso" nell'intera Villa.

Si trattava di speroni in opera laterizia, con filari di mattoni a tessitura molto regolare, posti leggermente "di controvento", con un'inclinazione di 7°-10° rispetto all'orizzontale.

Nell'Archivio di Stato di Roma, al titolo IV del Camerlengato, è conservata la descrizione di uno di questi speroni, ossia di quello costruito, a partire dal 1841, su indicazione della I sessione della Commissione Generale Consultiva di Antichità e di Belle Arti -di cui facevano parte il Canina, il Folchi e il Salvi- che agiva nella campagna romana.[13]

Molti di questi speroni, come detto, sono stati demoliti, soprattutto a partire dagli anni 'Sessanta di questo secolo.

Si può rilevare come, sia per la composizione dei materiali, sia per il disegno delle apparecchiature murarie, sia per i dati metrici, tali speroni, eretti tra gli anni 1841 - 1848, non fossero dissimili da altri leggermente precedenti nel tempo, realizzati a Roma, sempre allo scopo di consolidamento di complessi archeologici, quali quelli eretti nel tratto delle Mura Aureliane presso il Muro Torto a Roma dal Valadier (a partire dal 1828).

b) Ad Albano, di notevole interesse appaiono alcuni speroni di sostentamento murario realizzati alla fine del XIX secolo (1886) a sostenere i piedritti delle arcate dell'Anfiteatro.

Alcuni di essi sono costruiti in opera mista (blocchetti di peperino piuttosto irregolari e laterizio), altri in opera laterizia. Così ne parla Giuseppe Lugli: "[Al] 1886 (...) risalgono i restauri fatti al Monumento dall'ing. Salustri di Albano, con fondi avuti dallo Stato; alcuni fornici minacciavano rovina, altri avevano le pareti assottigliate dal continuo sgretolarsi dei coementa, la muratura della cavea, da lungo tempo priva di rivestimento, presentava avvallamenti e infiltrazioni d'acqua. I lavori furono eseguiti con zelo e con mezzi adeguati, sebbene l'indirizzoarcheologico, specialmente per quanto riguarda l'estetica dell'edificio, risultasse talvolta deficiente. Ma a questi restauri, e all'estirpazione radicale della numerosa flora cresciuta da secoli sui ruderi, si deve se da allora ad oggi ogni processo di distruzione del monumento sia fortemente cessato".[14] Si tratta di sei speroni rivestiti in peperino e di due in laterizio, più bassi, a mo' di camicia, forse più tardi. Le "fodere" di peperino sono a blocchetti sbozzati alquanto irregolari, sia a corsi sub-orizzontali e paralleli, con bozze a volte sdoppiate, a volte di altezze diverse (filaretti). In alcuni casi si presentano alternati a filari di laterizi. Nelle parti fondali, si notano riprese e "rattoppature" più recenti.

Gli speroncini in laterizio presentano una maggiore inclinazione della scarpa, ed hanno ricorsi alternati a due a due, "alla gotica" e "alla olandese".

c) L'altra area campione di studio è rappresentata dalle "Terme di Cotilia" in area sabina (Rieti).

Si tratta di un'area forse termale (per la presenza di una grande natatio), con ambienti succedanei disposti a vari livelli, distribuiti su quattro terrazze degradanti verso la via Salaria, sostenute da grandi muri di sostruzione, alcuni dei quali con nicchie e absidiole, che si articolano per oltre trecento metri di lunghezze.

Tali murature presentano un paramento in opus incertum piuttosto grossolano, unito ad alcune sezioni di macera a secco.

Il tratto inferiore di una di tali murature di sostruzione ha, posti di «controvento», una serie di speroncini, chiaramente più tardi rispetto al tratto in opus incertum originario, posti probabilmente quando l'intero settore murario iniziava a cedere.

Uno dei muri orientali di sostruzione presenta la particolarità di alcuni speroni (almeno dieci sono ben conservati in tale tratto di muro, che poi piega quasi ad angolo retto seguendo l'andamento del terreno) di epoca tarda, addossati presumibilmente quando si erano iniziati a manifestare fenomeni di rotazione dell'intera parete. Che i contrafforti siano stati realizzati in un momento successivo rispetto all'impianto originario è attestato dalla mancanza di ammorsature rispetto al muro in opera incerta originaria.

E' sembrato, dunque, assai utile, al fine della documentazione completa, effettuare un rilievo grafico e fotografico anche di questa parte.

ANALISI DI STABILITA' IN CONDIZIONI DINAMICHE DI SPERONI DI CONTRAFFORTATURA DEL NINFEO DI VILLA ADRIANA.

Grazie al rilievo fotogrammetrico è stato possibile effettuare anche studi ed analisi per accertare le condizioni di stabilità in campo statico e dinamico di due speroni di contraffortatura, costruiti nel secolo scorso per sostenere un muro perimetrale di un edificio romano appartenente alla villa di Adriano in Tivoli.

Gli studi e le analisi svolte per questo scopo hanno riguardato:

-le indagini preliminari di tipo conoscitivo delle diverse tipologie di strutture esistenti;

-le analisi numeriche effettuate in condizioni dinamiche, in accordo con la normativa italiana vigente, volte alla verifica di stabilità del complesso strutturale costituito da speroni di contrafforte, antichi muri e volte romani, e rocce di fondazione.

Le analisi numeriche sono state svolte con il metodo degli elementi finiti, discretizzando con due modelli tridimensionali i due speroni esaminati, i muri perimetrali e le volte romane e le rocce di fondazione e di spalla degli edifici romani.

Allo scopo di analizzare in modo più realistico il comportamento delle strutture, le analisi ad elementi finiti in condizioni pseudo-dinamiche sono state svolte in campo elasto-plastico. I limiti tra il comportamento elastico ed il comportamento plastico dei diversi tipi di strutture murarie esistenti è stato definito dai risultati delle prove di laboratorio effettuate.

A conclusione di queste considerazioni si può mettere in evidenza come la prima struttura discretizzata da un modello FEM si trova in buone condizioni di stabilità, in caso di eventi sismici. Questa situazione è principalmente legata alla mancanza di strutture snelle ed all'effetto del contenimento laterale apportato dalle rocce tufacee. La seconda struttura è, invece, potenzialmente soggetta a fenomeni di crollo degli archi, del muro romano sovrastante e della parte del piede delle murature posto a rinforzo nel '900.

1. Per il concetto di tecnologia appropriata, con riferimento al "restauro dei monumenti", si veda l'ultimo volume di Virginia GANGEMI (a cura di), Architettura e tecnologia appropriata, Milano 1968. Ivi, vedasi Gabriella CATERINA, Tecnologia appropriata e progetto di recupero, pp. 249-280.

2. E' interessante ciò che sostiene Mauro CIVITA, ossia che non si può parlare di vera e propria reversibilità nel "restauro dei monumenti".

3. Sulla necessità, ormai, di dare una "paritetica importanza degli aspetti disciplinari, da quelli storici a quelli della tecnologia, cfr. Amedeo BELLINI, Presentazione a Salvatore BOSCARINO, Sul restauro dei monumenti, Franco Angeli ed., Milano 1987, pp. 7-11, spec. p. 11. Cfr., altresì, Giuseppe RALLO, Il rilievo degli elementi strutturali per la conoscenza delle tecniche tradizionali , in "Il cantiere della conoscenza-Il cantiere del restauro", Atti del Convegno di Studi, Bressanone 27-30 giugno 1989, Libreria Progetto ed., Padova 1989, pp. 125-136. La citaz. è da p. 125.

4. Paolo MARCONI, Relazione introduttiva alla sessione dedicata ai problemi di conoscenza delle tecniche tradizionali, in "Problemi storici, tecnici e normativi per la conservazione dei centri urbani in zona sismica", Ed. a cura dell'Associazione Nazionale di Ingegneria Sismica, Roma 1988, pp. 107-122. La citaz. è da p. 107.

5. Cfr. la Carta 1987 della Conservazione e del Restauro, pubblicata su «Il Giornale dell'Arte», a. VII, n° 57, giugno 1988, pp. 34-40. (Testo coordinato da P. Marconi, con contributi di C. Maltese, U. Baldini, F. Del Grano Manganelli, G. Di Geso, M. Lillì Di Franco, P. Mora, A. Papa, G. Rizza, G. Tempesti, I. Toesca). Il testo è stato poi ripubblicato, con note e commenti, in «Ricerche di Storia dell'Arte», n° 35, 1988, dal titolo «Dalla Carta al Cantiere».

6. Vittorio CERADINI - Antonio PUGLIANO, Indagini conoscitive sulle tecniche premoderne di prevenzione sismica, ,in «Problemi storici, tecnici e normativi ...», cit., pp. 205-223. La citaz. è da p. 207.

7. Cfr. le "Raccomandazioni del Comitato Nazionale per la Prevenzione del Patrimonio Culturale dal Rischio Sismico", cit.

8. Giovanni CARBONARA, Il cemento nel restauro dei monumenti, in "L'Industria italiana del cemento", n° 11, 1980, pp. 1097-1118. La citaz. è da p. 1099.

9. Tancredi CARUNCHIO, L'identità delle prassi peculiari al restauro ed al consolidamento al fine della conservazione degli organismi architettonici, in "Atti del III Congresso Nazionale ASS.I.R.C.CO. «Conoscere per intervenire: il consolidamento degli edifici storici»", Catania, 1988, pp. 9-15. La citaz. è da p. 14.

10. Sulla delicata questione legata alla «sperimentazione» e alla «reversibilità», cfr. Paolo FANCELLI, Il progetto di conservazione, Guido Guidotti ed., Roma, 1983, pp. 112-120.

11. Cfr. Paolo MARCONI, Editoriale di Ricerche di Storia dell'Arte n° 35, 1988, pp. 4-8. La citaz. è da p. 8. L'importanza di un consolidamento inteso come intervento non indifferente, non affogato e non "nascosto nelle profonde strutture degli edifici antichi", da non attuare "al di fuori di un attento controllo storico-critico" per non "snaturare il modello statico originale dell'edificio", è ancora ribadito da Giovanni CARBONARA, La reintegrazione dell'immagine, in Francesco PERGO (a cura di), Anastilosi- L'antico, il restauro, la città, Laterza, Roma-Bari 1987, pp. 81-85. La citaz. è da p. 83.

12. Paolo ROCCHI, Manuale del consolidamento- Guida alla nascente trattatistica, Ed. D.E.I., Roma 1991, p. 14.

13. Questa Commissione era formata dai più insigni architetti del tempo: l'architetto Gaspare Salvi era noto per i restauri al Colosseo (lato verso il Celio); Clemente Folchi è noto per il traforo del Monte Catillo presso Tivoli, per convogliare le acque dell'Aniene. Cfr. Goffredo BENDINELLI, Luigi Canina (1795-1856) - Le opere e i tempi, Alessandria, Società di Storia Arte e Archeologia, Accademia degli Immobili, 1953, p.283. Nel 1849, dopo la morte del Salvi, terzo membro divenne il Poletti.

14. Giuseppe LUGLI, L'Anfiteatro di Albano, in "Ausonia", X, 1920, pp. 210 e segg.; la citaz. è da p. 259.

Applications of Architectural Photogrammetry II

Friday, October 4th, 1991, 15:00 - 16:30

Chair: E. Stambouloglou

A NEW SOFTWARE FOR THE SOLUTION OF CONTROL NETWORKS IN CLOSE RANGE PHOTOGRAMMETRY

Giorgio Vassena[1]

ABSTRACT

This paper deals with a new software package supporting the treatment of topographic data needed by a stereoplotter working in close range photogrammetry.
The main characteristics of each program and their way of working are here briefly presented.

INTRODUCTION

The software MILANO is made by 6 programs. It leads the user, step by step, through the different phases of solution of a topographic control network for close range photogrammetry.
The approximate values of the points coordinates are automatically evaluated through an empirical adjustment.
Besides, it is possible to run a rigorous least squares adjustment and to plot a planimetric view or an altimetric section of the network (with error ellipses).
All the points coordinates of the network can be rotated and translated in the space according to the needs of the stereoplotter. A methodology for the determination of the approximate values of the external orientation parameters of each taken is given. For this purpose a sketch of the main geometrical characteristics of each taken must be provided.
The drawing is then read by the computer through a graphic table. The operator is thus guided by the program from the solution of the topographic network to the determination of the approximate values of the external orientation parameters of each photogrammetric taken.

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1. AIM OF THE SOFTWARE MILANO

The project MILANO was born from the need to have an appropriate tool of data treatment made apt to the solution of problems of close range photogrammetry.
The ability of solving topographic networks, of rotating coordinates in the space and of determining approximate values for the external orientation parameters of the camera is usually demanded to several programs, having often big problems of relative interface (data format, etc..) and use by the operator.
For this reason MILANO is made by a sequence of programs able to solve all these situations without the above mentioned problems.

2. PROBLEMS IN CLOSE RANGE PHOTOGRAMMETRY

The stereoplotters used in close range photogrammetry are projected for working in aerophotogrammetry.
The software supporting these instruments thus envisages the axis of the quote of the object surveyed, being turned towards the camera and coincident with the topographic one.
Furthermore the external orientation of the camera in aerophotogrammetry, regarding its angular parameters, is easily and well approximable.
Not the same occurs in close range photogrammetry.
In this case the axis of the heights coming out of the ideal plan on which we suppose the surveyed object lies, doesn't usually coincide with the topographic one.
Beside the geometries of each taken can be very particular and consequently also the determination of the approximate values of the external orientation parameters can be of complex evaluation.
The use of a steroplotter instrument for close range photogrammetry requests a well-done data pre-treatment.
The software MILANO runs this phase of restitution work in such a way as to facilitate the work of the operator.
This semplicity of use implies in any case that the operator has to master a good knowledge of photogrammetry; without that, the program obviously becomes unusable.
An adequate formation of the operators thus remains an absolute necessity.

3. MAIN CHARACTERISTICS OF THE MILANO SOFTWARE

MILANO is composed by 6 programs: PUNT, TOPO, TOPL, PERT, ROTA, TAVO programmed using different languages.
The software runs on a Ms-Dos compatible computer; a coprócessor is needed.
To test the program a 80386 computer, a Calcomp 1023 plotter and an HPGL compatible plotter have been utilized.

On fig.1 the main characteristics of the software, dimension in byte, number of subdirectories, language of programming, are shown:

		Dimension KByte	Language	Sub.
MILANO	PUNT	229	Q.BASIC	23
	PERT	132	Q.BASIC	21
	TOPO	293	FORTRAN	7
	TOPL	47	FORTRAN & C	9
	ROTA	132	Q.BASIC	11
	TAVO	168	Q.BASIC	18

Fig.1

The communication among the different programs of MILANO is made by using ASCII files. In this way the user can easly read the files and use them also for different purposes not already planned by the program maker.
On the other hand any operation made in these data files, without using the video-windows provided by the program, can of course damage the file itself. For this reason the manipulation of the data files is recommended to expert operators only.

4. INTERFACING WITH THE SOFTWARE

Further to the reading of the manual, no particular other training is required for working on MILANO and learning software's commands and options.
Through suitable windows the user is lead to the use of each program (Fig.2-3).
No necessity of remembering any command; the operator is simply asked to answer to the particular questions posed by the computer, to choose with the cursor the options or to insert data into the right boxes as requested.
Such a way of working reduces to a minimun the possibilities of making mistakes in the data input and allows more operators to make use of this software.
Moreover, several tests are implemented into each program. More difficult is thus the chance of wrong operations or of insertion of incongruous measurements, making quite rare the case of not convergence of the adjustment programs.

GALILEO
12/09/1991 17:19:23 C:\TEST\APPOGGIO.GAL

MENU' PRINCIPALE

Scelta del File
Dati: inserimento e variazione
Conversione dati forniti da registratori

Libretto di campagna
Elaborazione e controlli

Visualizzazione rete topografica
Plottaggio rete topografica

Uscita al DOS

Selezione del file o scelta di un nuovo file
Selezionare la voce prescelta con ↑↓ o con l'iniziale - RETURN per conferma

Fig. 2

GALILEO File NON selezionato
12/09/1991 17:12:36

Directory corrente:
C:\TEST

APPOGGIO GAL	4817	6/11/91	11:12	
SOSPESOL GAL	16609	30/10/91	12:05	
..	Directory superiore			

File selezionato:

APPOGGIO.GAL

Selezionare il file o la directory con i tasti ↓↑ PagUp PagDn e premere INVIO
F1=Nuovo file F2=Copia file F3=Cambio drive F9=Cancella file ESC=Esce

Fig. 3

5. STRUCTURE OF THE SOfTWARE

Each program of MILANO has a specific function schematically shown in fig.4 More details about each program have been also provided in the following paragraphes.

5.1 PUNT

The acquisition of the measurements, made in PUNT, can be done automatically from the data recorders of the most popular topographic instruments or manually through appropriated video masks (Fig.5-6-7).
The fig.8 shows the typologies of measurements admitted by the programm that fulfil the tests of data input:

Azimut	Zenit	Distance	ADMITTED
X			Yes
X	X		Yes
X	X	X	Yes
	X	X	No
X		X	No
		X	No
	X		No

Fig.8

The points are divided in PUNT into two categories: station points and control ones (See fig.9).

The connections among station points must be done with all the three typologies of measurements (Azimut, Zenit, Distance).
After the data acquisition an empirical adjustement of station point network solving all the polygonals going through the fixed points is made.
If the closing of the polygonals correspond to the tolerance decided at the beginnig of the work, taking into account the instrument precision, the software evaluates the coordinates of the control points, otherwise points out mistake.
At each calculated coordinate value, in case of superabundant determination, an indication of the precision is also given.
As output it is also provided:

- A plot of the network on video or on paper.

- An ASCII file containing all the measurements (fig.10).

- An ASCII file containing the adjusted coordinates of each point (fig.11) and the solution of any polygonal (fig.12).

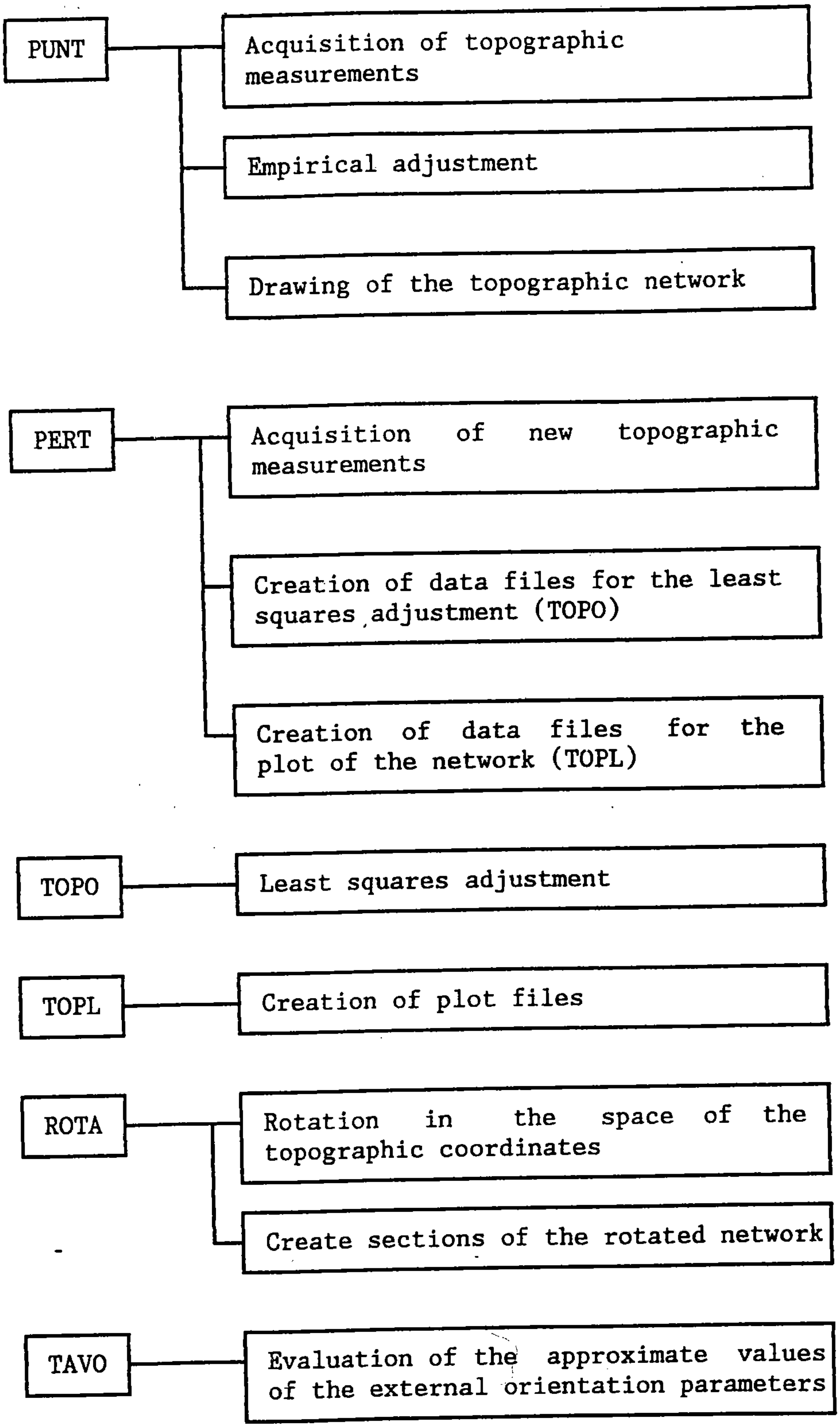
PUNT
Acquisition of topographic measurements
Empirical adjustment
Drawing of the topographic network
PERT
Acquisition of new topographic measurements
Creation of data files for the least squares adjustment (TOPO)
Creation of data files for the plot of the network (TOPL)
TOPO
Least squares adjustment
TOPL
Creation of plot files
ROTA
Rotation in the space of the topographic coordinates
Create sections of the rotated network
TAVO
Evaluation of the approximate values of the external orientation parameters

Fig. 4

```
GALILEO
12/09/1991  17:17:38                                        C:\TEST\APPOGGIO.GAL
================================================================================
Punto Stazione -    6          PIL.MET.     ===== PUNTO STAZIONE =====
        Punto -    quattro4     399.99260
        Punto -    7103         254.38524    Nome del punto:      6
        Punto -    7303         262.19566
        Punto -    7403         265.72291    Descrizione:         PIL.MET.
        Punto -    7503         269.04540
        Punto -    7603         272.24887    Altezza strumentale:   .237
        Punto -    7703         275.36071
        Punto -    7803         278.38274
        Punto -    103          281.28767
        Punto -    203          284.28809
        Punto -    303          287.47900    84.48238              0.0000
        Punto -    403          290.85626    85.11936              0.0000
        Punto -    503          294.43359    85.67939              0.0000
        Punto -    603          298.15830    86.18468              0.0000
        Punto -    703          301.89051    86.60411              0.0000
        Punto -    803          305.64079    86.95001              0.0000
================================================================================

            Muoversi con ↑↓ o return - ESC per terminare
```

Fig. 5

```
GALILEO
12/09/1991  17:14:36                                        C:\TEST\APPOGGIO.GAL
================================================================================
Specifiche      - RETE TOPOGRAFICA PER LA DEFINIZIONE DI PUNTI D'APPOGGIO - IN
Dati Generali   - U.M.: m   - Asse x: E - Asse y: N - Asse z: Q
Punto Stazione  -    quattro4  PIL.MET.     .2375
         Punto  -    7103         226.88624    85.28886                0.0000
Altra Misura    -  quattro4  6            -0.0334   94.5990   0.0000   0.0000
         Punto  -    7303         232.84147    85.74436                0.0000
         Punto  -    7403         235.79341    85.98105
         Punto  -    7503         238.72566    86.21595                0.0000
         Punto  -    7603         241.69290    86.44954                0.0000
         Punto  -    7703         244.69668    86.68330                0.1233
         Punto  -    7803         247.73189    86.91752                0.0000
         Punto  -    103          250.74418    87.14030                0.0000
         Punto  -    203          253.86173    87.34752                0.0000
         Punto  -    303          257.16046    87.52376                0.0000
         Punto  -    403          260.63040    87.66218                0.0000
         Punto  -    503          264.29234    87.76290                0.0000
         Punto  -    603          268.07598    87.82603                0.0000
================================================================================
1 Help          2 Ins Stazio     3 Ins Collim     4 Modifica      5 Elimina
                                                  8 Abbandona     9 Fine
```

Fig. 6

GALILEO
12/09/1991 17:18:33 C:\TEST\APPOGGIO.GAL

Punto -	7803	247.73189
Punto -	103	250.74418
Punto -	203	253.86173
Punto -	303	257.16046
Punto -	403	260.63040
Punto -	503	264.29234
Punto -	603	268.07598
Punto -	703	271.85974
Punto -	803	275.64405
Punto -	903	279.42948
Punto -	1003	283.21020
Punto -	1103	286.98463
Punto -	6	199.99289
Punto -	2	299.99250
Punto -	502	263.98348
Punto -	802	275.83526
Punto -	902	279.78236

PUNTO COLLIMATO

Dal punto stazione: quattro4

Nome del punto: 2

Direzione: 299.99249

Angolo Zenitale: 100.00466

Distanza inclinata: 105.4150

Altezza strumentale: 0.2380

92.07282 216.618 0.0000

Muoversi con ↑↓ o return - ESC per terminare

Fig. 7

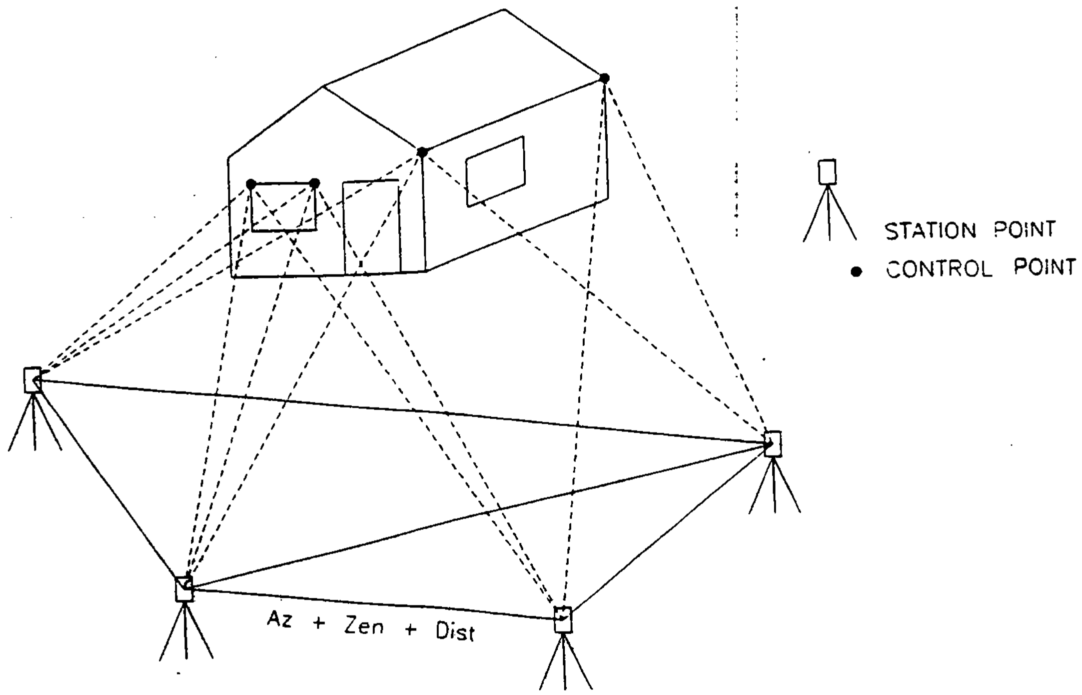

Fig. 9

```
Titolo lavoro      RETE TOPOGRAFICA PER LA DEFINIZIONE DI PUNTI D'APPOGGIO
Tipo lavoro        INTERSEZIONE SEMPLICE E MULTIPLA IN  AVANTI  E CON DISTANZE
Data               11 GENNAIO 1990
Committente        POLITECNICO DI MILANO  -   DIP. I.I.A.R.
Unita' e assi      m    E    N    Q
Tolleranze         0.0050    0.0210
Punto riferi 1     6         100.0000  100.0000  100.0000    0.0000
Punto riferi 2
    1   quattro4  PIL.MET.    0.2375
    2   7103        226.88624     85.28886                 0.0000
    8 quattro4  6            -0.0334     94.5990   0.0000  0.0000
    2   7303        232.84147     85.74436                 0.0000
    2   7403        235.79341     85.98105                 0.0000
    2   7503        238.72566     86.21595                 0.0000
    2   7603        241.69290     86.44954                 0.0000
    2   7703        244.69668     86.68330                 0.0000
    2   7803        247.73189     86.91752                 0.1233
    2   103         250.74418     87.14030                 0.0000
    2   203         253.86173     87.34752                 0.0000
    2   303         257.16046     87.52376                 0.0000
    2   403         260.63040     87.66218                 0.0000
    2   503         264.29234     87.76290                 0.0000
                                                           0.0000
```

Fig. 10

Titolo: PROVE OPERATIVE DEL NUOVO PACCHETTO SOFTWARE "MILANO"
Tipo di lavoro: RETE D'APPOGGIO TOPOGRAFICO
Data lavoro: 11 LUGLIO 1991
Committente: POLITECNICO DI MILANO - DIP. I.I.A.R.
Studio: Ditta: Paolo Rossi e C.

Punto	X (m)	Num. Det.	Diff.max (m/1000)	Y (m)	Num. Det.	Diff.max (m/1000)	Z (m)	Num. Det.	Diff.max (m/1000)
7103	-39.2499	1		1.7614	1		140.3381	2	3.74
7303	-52.8566	3	6.82	12.3061	3	3.91	140.3674	4	6.41
7403	-59.4730	3	1.31	18.0888	3	0.94	140.3660	6	1.42
7503	-65.9492	3	3.61	24.2089	3	1.77	140.3677	6	0.34
7603	-72.3383	3	2.23	30.8015	3	5.74	140.3734	6	8.41
7703	-78.6136	3	5.71	37.8940	3	2.54	140.3789	6	2.44
7803	-84.7503	3	1.91	45.4805	3	0.80	140.3859	6	2.41
103	-90.5526	3	6.28	53.4411	3	2.47	140.4053	6	9.45
203	-95.8237	3	3.87	62.2023	3	5.06	140.4043	6	6.31
303	-100.4188	3	2.88	71.9902	3	4.29	140.4033	6	9.08
403	-104.0616	3	7.29	82.7450	3	8.17	140.4207	6	9.72
503	-106.5666	3	2.54	94.4517	3	8.94	140.4514	6	4.64

Fig. 11

Poligonale numero: 1

Stazione	E (m)	N (m)	Q (m)	Orientamento (GRAD)
2	-5.4106	99.9924	100.0134	0.0002
5	138.3128	53.3818	100.0219	0.0005

Chiusura angolare (GRAD)= -0.00043 Tolleranza (GRAD)= 0.01559
Chiusura laterale (m) = 0.00131 Tolleranza (m) = 0.05196

Poligonale numero: 2

Stazione	E (m)	N (m)	Q (m)	Orientamento (GRAD)
2	-5.4105	99.9923	100.0126	0.0002
5	138.3133	53.3816	100.0204	0.0004
8	-5.3573	5.3548	100.0347	0.0005
1	-43.2417	52.9432	100.0227	0.0007
6	100.0118	5.4093	100.0381	0.0009

Chiusura angolare (GRAD)= -0.00087 Tolleranza (GRAD)= 0.02205
Chiusura laterale (m) = 0.00436 Tolleranza (m) = 0.07348

Fig. 12

```
GALILEO
22/09/1991  13:54:43                                              C:\TEST\APPOGGIO.GAL
--------------------------------------------------------------------------------------
Dati Generali    - PROVE OPERATIVE DEL NUOVO PACCHETTO SOFTWARE "MILANO" - RETE
Specifiche       - U.M.: m   - Asse x: X - Asse y: Y - Asse z: Z
Punto Stazione   -  4        PIL.MET.                           .2375
Dist.  Disliv.   -  7303     7603        26.8650     0.0070    0.0000     0.0000
          Punto  -  7103     226.88624   85.28886              0.0000
          Punto  -  7303     232.84147   85.74436              0.0000
          Punto  -  7403     235.79341   85.98105
          Punto  -  7503     238.72566   86.21595              0.0000
          Punto  -  7603     241.69290   86.44954              0.0000
          Punto  -  7703     244.69668   86.68330              0.0000
          Punto  -  7803     247.73189   86.91752              0.0000
          Punto  -  103      250.74418   87.14030              0.0000
          Punto  -  203      253.86173   87.34752              0.0000
          Punto  -  303      257.16046   87.52376              0.0000
          Punto  -  403      260.63040   87.66218              0.0000
          Punto  -  503      264.29234   87.76290              0.0000
          Punto  -  603      268.07598   87.82603              0.0000
--------------------------------------------------------------------------------------
 1 Azinut+zenit   2 dist Obliqua   3 dist+Zenit   4 Modifica     5 Elimina
 6 dist+Disliv    7 dist.oRizzo    8 disLivello   9 Fine         0 Quit
```

Fig. 13

- An ASCII file describing a list of points of the network with the corrisponding coordinates.

Obiously the solution obtained from the adjustment it is not a completely rigorous one, because resulting from an empirical process.
In any case when a much better accurancy is needed and when a much variegated complex typology of measurements is present, it is possible to run a rigorous 3D least squares adjustement (TOPO).

5.2 PERT-TOPO-TOPL

Through PERT three data files necessary to run TOPO program are automatically created and a much bigger typology of measurements can be added to those ones already typed through PUNT.
In particular differences in height, isolated distances connections among station points, also uncompleted ones, are now admitted as input for the rigorous adjustment (Fig.13-14).
In this way all the measurements made on the object can be stored together into one file and unitarily managed. Vincula of the network, the instruments precisions and the characteristics of the plot of the network can also be automatically inserted in the data file through the video-windows of PERT.
Several tests controlling the congruency of the new measurements with those ones previously inserted in PUNT are also present (Fig.15).
The approximate values of the unknowns needed by TOPO are taken from the results of the PUNT adjustment.
In the present paper it is not specifically detailled the modality of empirical and least squares adjustment hereby used.
At this regard please consider the enclosed references and the papers of next publication, which will consider in details the algorithms of data treatment present in the programs of the software MILANO.
As a result of the rigorous adjustment all the points coordinates and the angles of orientation of the station points are obtained.
To every adjusted value of the unknowns it is associated a rigorous m.s.e.
It is obviously possible to run not only a planoaltimetric adjustment of the network but simply a planimetric one too. All the solutions are printed on a specific file or directly sent to a LPT1 parallel port (Fig.16).
The parameters of the network plot, scales, spacial rotation, pens colours, kinds of measurement connection to be plotted, are set in PERT that automatically prepares a file usable by TOPL to create the drawing (Fig.17).
For every point of the network, using the values of the covariance and variance, are valuated the values for the plot of the error ellipses.
TOPL creates 2 plot files.

```
GALILEO
22/09/1991  13:53:56                                              C:\TEST\APPOGGIO.GAL

Dati Generali     - PROVE OPERATIVE DEL NUOV  DIST. ORIZZONT. e DISLIVELLO  E
Specifiche        - U.M.: m    - Asse x: X -
Punto Stazione    -  4          PIL.MET.       Punto A:              7303
Dist.   Disliv.   -  7303       7603                                          O
         Punto    -  7103       226.88624   8  Punto B:              7603
         Punto    -  7303       232.84147   8
         Punto    -  7403       235.79341   8  Dist. orizzontale:     26.8650
         Punto    -  7503       238.72566   8
         Punto    -  7603       241.69290   8  Dislivello:             0.0070
         Punto    -  7703       244.69668   8
         Punto    -  7803       247.73189   8  Altezza strumento A:    0.0000
         Punto    -  103        250.74418   8
         Punto    -  203        253.86173   8  Altezza strumento B:    0.0000
         Punto    -  303        257.16046   8
         Punto    -  403        260.63040   8
         Punto    -  503        264.29234   8
         Punto    -  603        268.07598   87.82603             0.0000

            Muoversi con ↑↓ o return - F1=Help - ESC per terminare
```

Fig. 14

```
GALILEO
22/09/1991  14:01:29                                              C:\TEST\APPOGGIO.GAL

Dati Generali     - PROVE OPERATIVE DEL NUOV        DISTANZA OBLIQUA          E
Specifiche        - U.M.: m    - Asse x: X -
Punto Stazione    -  4          PIL.MET.       Punto A:              7303
         Punto    -  7103       226.88624   8
         Punto    -  7303       232.84147   8  Punto B:              7803
         Punto    -  7403       235.79341   8
         Punto    -  7503       238.72566   8  Distanza obliqua:      47.1230
         Punto    -  7603       241.69290   8
         Punto    -  7703       244.69668   8  Altezza strumento A:    0.0000
         Punto    -  7803       247.73189   8
         Punto    -  103        250.74418   8  Altezza strumento B:    0.0000
Dist.   Obliqua   -
         Punto    -  203        253.86173   8
         Punto    -  303        257.16046   8
         Punto    -  403        260.63040   8
         Punto    -  503        264.29234   8
         Punto    -  603        268.07598   87.82603             0.0000

            Muoversi con ↑↓ o return - F1=Help - ESC per terminare
Errore su Distanza > 10 volte la tolleranza. Distanza =  46.0190
```

Fig. 15

Titolo: PROVE OPERATIVE DEL NUOVO PACCHETTO SOFTWARE "MILANO"
Tipo di lavoro: RETE D'APPOGGIO TOPOGRAFICO
Data lavoro: 11 LUGLIO 1991
Committente: POLITECNICO DI MILANO - DIP. I.I.A.R.
Studio: Ditta: Paolo Rossi e C.

Coordinate compensate e SQM

Punto	Coordinata X(m)	SQM (mm)	Coordinata Y(m)	SQM (mm)	Coordinata Z(m)	SQM (mm)
4	100.0000	.0	100.0000	.0	100.0000	.0
6	51.8558	2.2	18.5684	1.3	100.0322	1.8
2	9.2586	.3	153.6499	.2	100.0079	1.9
7103	-39.2445	9.7	1.7599	5.8	140.3372	5.7
7303	-52.8573	5.3	12.3023	5.2	140.3726	4.2
7403	-59.4726	5.4	18.0835	5.1	140.3695	4.2
7503	-65.9514	5.6	24.2063	5.1	140.3716	4.2
7603	-72.3392	5.9	30.7972	5.1	140.3772	4.3
7703	-78.6156	6.2	37.8905	5.0	140.3823	4.4
7803	-84.7531	6.5	45.4779	5.0	140.3892	4.4
103	-90.5551	6.9	53.4376	4.9	140.4084	4.5

Fig. 16

GALILEO
22/09/1991 13:50:00 C:\TEST\APPOGGIO.GAL

DEFINIZIONE DEI PARAMETRI DI PLOTTAGGIO

Visione Planimetrica o Altimetrica (P/A): P

Formato del foglio (0=A0, 1=A1, 2=A2, 3=A3, 4=A4): 3
Angolo rotazione del disegno (gradi): 0.00
Fattore di scala asse X: 1: 581.695
Fattore di scala asse Y: 1: 618.430
Fattore di scala assi ellisse di errore: 1: 1.0000
Fattore di scala asse ellisse in quota: 1: 1.0000

Numeri penne per le parti del disegno:

cornice:	1	SQM in quota:	1
linea distanze:	1	punti collimati:	1
tratteggio azimut:	1	punti stazione:	1
tratteggio zenit:	1	nomi punti:	1
ellissi di errore:	1	testi:	1

Muoversi con ↑↓ - Completare i campi - ESC=Fine

Fig. 17

The first one is an HPGL ASCII file (Fig.18), the second is a Binary one readable through CAD systems to permit more interesting manipulations of the drawing.

5.3 ROTA

The coordinates values obtained using PUNT or the more sophisticated program PERT can be rotated in the space using ROTA.
This program solves the problem of transforming the coordinates obtained from the topographic convention to a coordinate system congruent to that one used by the stereoplotters.
In order to carry out this operation, the operator is not expected to know the rotation angles. He has simply first to identify the ideal plan on which he wants the object to be considerd liying; then he has to indicate the direction of the axis coming out from the object. Everything is done in an easy and well understandable way.
The user has just to select three points of the network and to indicate their relative position.
At first he is asked the position of one point, called 'A', then he has to say if the second point 'B' lies on the left or right hand side with respect to A.
At last he is asked if the third point, 'C', is located above or below the A-B segment.
In this way the roto-translation can be done.
The Z axis is oriented towards the observer, the X axis along the direction A-B with versus from A to B and the Y axis orthogonal to the plan X-Z (Fig.19).
The rotation parameters are memorized so that at the end of the restiution work the coordinates calculated through stereoplotter can be written back to the terrestrial topographical coordinates system.

5.4 TAVO

The TAVO program deals with the determination of the external orientation parameters of the photogrammetric takens.
The possibility of carrying out such a determination is subordinated to the solution of the previous phases. For the evaluation of these parameters it is planned the acquisition of the geometries of each taken through some draft read by the computer trough a graphic table.
The drawings can be of two different kinds:

- The first one, planimetric, aims to the definition of the outline of the surveyed object, the approximate position of the taken and the direction of the line of the sight camera-object. It is also requested the scale of the draft and the planimetric coordinates of one point, in order to fix the translation in the space, and also the same data for a second point in order to bind its rotation on the plan.

```
IN; PS 3; SP 1; IP       0      0 16000 10919; SC       .000     40.000       .000
SP  1;
PU        .000       .000;
PD      40.000       .000;
PD      40.000     27.300;
PD        .000     27.300;
PD        .000       .000;
PU      37.000       .000;
PD      37.000     27.300;
PU      37.500       .200;
SI     .14667     .22000; DI       .0000     1.0000;
LBPROVE OPERATIVE DEL NUOVO PACCHETTO SOFTWARE "MILANO"♥
PU      37.900       .200;
SI     .14667     .22000; DI       .0000     1.0000;
LBRETE D'APPOGGIO TOPOGRAFICO♥
PU      38.600       .200;
SI     .14667     .22000; DI       .0000     1.0000;
LB11 LUGLIO 1991♥
PU      39.300       .200;
SI     .14667     .22000; DI       .0000     1.0000;
LBPOLITECNICO DI MILANO -    DIP. I.I.A.R.♥
PU      39.700       .200;
```

Fig. 18

GALILEO
22/09/1991   13:48:59

C:\TEST\APPOGGIO.RES

DEFINIZIONE ROTOTRASLAZIONE

Nome del punto A: 7303
Nome del punto B: 7403
Nome del punto C: 103

Posizione del punto B rispetto al punto A: D (D/S)

Posizione del punto C rispetto al segmento AB: A (A/B)

		Coord. X	Coord. Y	Coord. Z
Punto 7303	:	-52.8573 m	12.3023 m	140.3726 m
Punto 7403	:	-44.0718 m	12.3023 m	140.3695 m
Punto 103	:	2.5972 m	18.4699 m	140.3726 m

Muoversi con ↑↓ - Completare i campi richiesti - F1=Help - ESC=Fine

Fig. 19

It is also possible to omit the scale of the draft, providing simply the coordinates of the two points.

-the second drawing scheme on the other hand must allow the observation of the altimetric scheme, thus in section, of the taken.
It is in details requested a section of the surveyed element, the approximate position of the point where the picture has been taken and the inclination of the line of the sight camera-object. Further to that it is asked to know the height of a point of the outline of the surveyed element and the drawing scale or to know the coordinates of two points of it.
The drafts of the takens are digitalized through a graphic table and acquired by the PC. The operation is visualized in real time on the computer screen and guided with a mouse.
The so acquired data are then elaborated providing the approximate values of the coordinates X,Y,Z and the angular parameters Omega, Phi, Kappa of the takens.

6. CONCLUSIONS

MILANO turns up to be a valid support to operations of close range photogrammetric surveys.
In particular all the measurements carried out on the object can be stored in the software and thus managed in a, also metrically speaking, rigorous way.
Both the empirical and the rigorous compensation, the possibility of rototranslation in the space, the determination of the parameters of external orientation of the taken, though rigorously managed, are usable also by any photogrammetric operator.
MILANO exemplifies the fact that methodological rigour is not synonimous of complexity of use; also the everyday operator can be thus made acquainted with high-quality systems of data management and treatment.

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"The Iconometric Model"

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Aprile 1991

Abstract

The project shown in these pages realizes a new system for metric documentation and catalogation of cultural estate.

At present we know that photogrammetric methods are too expensive and onerous. For instance only in Italy the immovable patrimony to be catalogued is in the order of hundreds of thousands of units.

The proposed method is aimed to techniques and instruments for a simplification and standardization of some operations made by surveyors; its principal characteristic, beside functionality and precision, are quickness and saving.

The iconometric model has been applied in the Erocare project "RE.FRAN" and will be realized by the holding LEICA in conjunction with ITALCAD.

Its hearth is a semimetric kind of photo camera which is provided with a built-in system for distance measurement. Furthermore a tools for drawing vectors on raster helps to calculate distance, areas or to get thematic maps directly from photo - image.

A specific software for digitized images management is employed in order to get scaling and rectification of the photograph.

Introduction.

The need to realize such a project rises originally in the field of knowledge, classification and arrangement in catalogues of the Italian cultural estate, which is under the Direction of the Ministry for the Cultural and Environmental Assets. This does not prevent the proposed realization from finding a large application also in other fields.

As for what concerns the above stated main purpose, it is well known that one of the emerging fundamental imperatives for the preservation and restoration of the huge Italian artistic-cultural patrimony consists in its knowledge through a systematic work of documentation and classification.

The State Organizations which are in charge of this within the Ministry for the Cultural and Environmental Assets are: the Istituto Centrale per il Catalogo e la Documentazione (I.C.C.D.) as for what concerns reconnaissance of the historical and artistic aspects of the cultural estate, and the Istituto Centrale del Restauro (I.C.R.) for what concerns the ascertaining of their state of preservation.

The catalographic activity of both Institutes shows itself in the drawing up of suitable cards allowing the survey and the computerized data recording of the relevant graphic and alphanumeric data. One of the main difficulties which may arise during the graphic data survey consists, in most cases, in the lack of availability of existing and reliable surveys and graphic representations. This fact forces to execute the surveys according to each case with a remarkable waste of time and a high increase of the catalographic costs.

Besides, the photogrammetric equipment, too, is expensive and can't be proposed for an extensive application if one just thinks that only the historical-artistic real estate to be card-indexed can be estimated in the order of magnitude of hundred of thousands of units.

Hence, the need to project and execute procedures and instruments to put at the cataloguers disposal in order to simplify and standardize some surveying operations having the necessary requirements of cheapness and low operating costs as well as of ease of handling and of high capacity and operating speed.

The herewith proposed "iconometric model" has been thought to satisfy such requirements.

It will consist in a semi-metric photographic camera, i.e. equipped with marks inside the camera body which detect a cartesian coordinate system. After being inserted, they allow to print an image which can be reconstructed geometrically and dimensionally. The camera will also have an EDM (Electronic Distance Measurement) which, by means of a simple software, detects the graphic scale of the obtained image. It will then be able to treat this image, inserted by a scanner in the screen, in order to obtain a scale drawing by means of a CAD system.

On the drawing it will be possible to realize any type of different graphic themes in order to point out the degree of deterioration of the materials and components of the building.

Such a system may be useful to survey the fronts of the historical buildings and of the decorative details, sculptural groups, moving artistic objects allowing to carry out these operations with a remarkable speed and an acceptable degree of accuracy.

The accuracy degree and the image resolution capacity have been studied in order to be used in the future cartographic campaigns envisaged by the law 19.01.90 no 84 which finances with 130 Milliards of Lit. in the next years program of interventions for the classification and the drawing up of an inventory of the cultural and environmental assets as well as of a cognitive up-to-datable map of the risk situation of the cultural estate.

Particularly, as for what concerns the risk map of the Italian cultural estate, the illustrated system corresponds to what requested by the technical specifics enclosed to the instruction for the card-indexing of the deterioration of the architectural estate, which were proposed by the Istituto Centrale del Restauro.

In conclusion, the "Iconometric Model" represents an efficient and technologically advanced answer to the need of a graphic documentation which can't be satisfied by the traditional manual surveying systems.

Project description and organisation

The realization of the project is divided in 3 sectors:

- **Iconometric camera realization.**
  Made by Leica Heerbrugg AG Special Product Division (Swiss) and Leica Wetzlar (Germany).
- **Software development.**
  Made by Italcad Tecnologie & Sistemi (Italy).
- **Field testing.**
  Research and experimentation developed in the Università dell'Aquila (Italy), Istituto Centrale del Restauro (Italy) and branch office in Rome of Leica Italia S.p.a.

Sector A. The iconometric camera

A.1. The iconometric model

In the process of catalogue of cultural estate the archive of photographic images has a particular importance to allow later further analysis even if the object is destroyed.

It is evident the necessity that the above mentioned photographs are to be achieved by those who, experts in photographic documentation of cultural estate, are able to signify the possibility offered by the means.

But if we add to such ability some metrical informations, the process of catalogue becomes more complete, moreover giving to future users a mean for analysis on artistic objects surely reliable, from the quantitative point of view.

The here proposed *iconometry* is based on the geometric relationships between the real object and the corresponding positions on the photo image.

With such a method is possible to carry out a plan of quick catalogation by the input of an "*iconometric model*" in workstation image treatment aimed to the acquisition of metrical and thematic data on architectonic degraded surfaces.

The different possibilities offered by photogrammetrical methods may today be distinguished, with relation to the resulting image, in:

- photographic
- only graphic
- numerical graphic

The first, by ortophotogrammetry or optical rectification, produces enough definite metrical documents.

The others, just or numeric graphic, offer for a resulting product some sketched out drawings following the principal lines of the object. Realized by mono- or stereoscopic photogrammetric methods, such drawings loose the strength of the photo image, acquiring in precision and accuracy.

Furthermore the result is submitted to the operator's interpretation.

The *iconometric model* belongs to the first above mentioned techniques. His intent is to acquire a document that is at the same time expressively clear (the photo image) and metrically distinct (the geometric relationship), without lack of precision.

A.2 - The geometric relationship.

Assuming the hypothesis to minimize the work for photo documentation and related topographic operations, accepting besides the natural consequence of loosing high precisions, is possible to proceed to a brief survey of objects assimilated to planes (with only two principal dimensions because the third is negligible), like paintings, wall of buildings, etc., by rectification of a photo image.

The possibilities of extrapolating measures from this photo rectified image, are surely suitable for the aim of quick catalogation and documentation of cultural estate, where usually high precision and its related costs are not justified.

The high precision resulting from stereo-photogrammetric methods is not always required from the historians of arts, architects, or specialists working in the field. In that case a general dimensioning of the image may come from the knowing of the external orienting parameters of the camera and the distance from the object.

This may be realized in all cases when the object is assimilated to a two-dimensional plane rectifying the image if the film plane and the object are not coplanar.

Obviously if we want to measure in the third dimension (depth) we are forced to use only the usual stereoscopic photogrammetry, with the consequent increase of work in the taking phase, in the topographic phase and in the plotting phase.

The parameters needed for the projective transformation in a single photo image are:

- the distance from the object;
- the vertical angle between the film and the object plane;
- the horizontal angle between the film and the object plane.

In the case of a double model from 60% overlap, many more parameters are needed in order to proceed to a stereo plotting:

- the distance of the two takings and their relative position;
- the vertical angle for both photographs;
- the horizontal angle between the film plates and the line trough the two taking points;
- the rotation angle around the taking axes for both photographs.

To obtain a "iconometric" photograph containing in itself the data for its identification and for the metric aim, it is necessary to print directly on the film this data:

- 1) Object code, at least 10 digits
- 2) Data, 6 digits, with automatic set.
- 3) Scale, or distance, 4 digits, automatic measurement from the film plane to the object point on the target of view-finder also marked on the reference-plate.

Such minimal configuration, defined **SOLUTION 1**, is an economical way to get an iconometric archive of cultural estate.

Adding two more elements:

- 4) Vertical direction of taking axes, 7 digits 3 decimals,
- 5) Horizontal direction of taking axes, 7 digits 3 decimals,

it is possible to get more simplification in the rectification phase and moreover a little increase of accuracy.

The above mentioned directions might be determined with at least two methods:

The first is measuring distances also in two corners of the photograph so that the relative position of film plate and the object surface are known.

A second way is direct measurement of the two directions by theodolite or a compass electronically connected to the camera.

This last possibility is said **SOLUTION 2**.

A.3. - Technical specification for the camera.

The technical specifications for the iconometric camera are:

- Automatic distance measurement from the principal point of the lens to target on the object. Projection and recording on the film of such distance or the derived scale by the focal length.

- Superimposition on the film of a reference reticle similar to that of semi-metric cameras.

- Superimposition on the film of numeric or alphanumeric code.

- Possibility to use the same body camera with normal, metric or iconometric lens.

- And only for SOLUTION 2, superimposition on the photograph of data about vertical direction and horizontal direction to a target point or to the North (azimuth).

Required accuracy in distance measurement: 1/1000 of the distance from the object (better if possible 1/5000) (I.e.: for 50 m of distance, accuracy = 5 cm or in the second case = 1 cm).

Then in the photograph we'll have in superimposition:

1. OBJECT CODE
2. DATE
3. SCALE(DISTANCE)

moreover for SOLUTION 2:
4. ZH DIRECTION
5. HO DIRECTION

The use of iconometric photographs are to be foreseen in:

1. Quick automatic plotting (image rectification by acquisition during the scanning process of a.m. data about distance and angles)

2. Stereoscopic plotting by classic methods but with automatic raster acquisition of orientation parameters.

Sector B. Software development.

The use of "iconometric" photograph may be only that to archive the images in order to get a metric images card-index or that of a qualitative and quantitative immediate data acquisition. In such a case is previewed the acquisition on a video computer of the scanned image for a further treatment.

For this purpose a computerized system for images management and projective rectification will be assembled with the possibility to output an hardcopy of the treated image.

The hardware and software specifications have to satisfy the following list:

- Raster acquisition of photograph by scanner
- Raster acquisition of orientation parameters printed in superimposition on the film.
- Determination of the parameters for the projective transformation.
- Raster transformation by metrically relating pixel to the real position and subsequent stretching.
- Vector on raster annotation by mouse or tablet to draw line or polylines. Simply metrical determination like areas or distance to be put in the data base management system.
- Hardcopy black and white (shade of grays) or colour.
- Data archiving.

B.1. Software Architecture

The application software is made by a set of different modules integrated in a single user interface environment. The software modules needed to implement the information system are the following ones.

1. Scanner driver
This software module, usually a standard module supplied by the peripheral vendor that needs some integration work, is responsible of the control of the scanning device.

2. Raster editor
The purpose of this module is to enhance the scanned image and suit that one to exigency of a accurate damage documenting. Functions performed by this module among the others are: edge enhancement, edge softening, cutting of subimages, scaling.

3. Metrical raster
This module allows projective transformations in a automatic way, or by dialogue with the user and imposition of simply geometrical relations; for example parallelism conditions and orthogonality.

4. Raster annotation
This module allows the use to "annotate" the picture, drawing polylines and filled polygons on the raster image; the coordinate system in which this object are drawn is the one defined by the module previously described, so it is possible to measure the length or the area of the annotation and this measure is congruent with the effective measure of the architectural object.

5. Hardcopy unit driver
The function of this software module, usually a standard one supplied by the peripheral vendor, is the control of the hardcopy device.

6. Data archiving
This module is made by a set of custom made procedures built on top of commercial relational data base management system (RDBMS) conforming the SQL standard. The purpose of this module is to store and to retrieve in a "user friendly" manner all the data (text, images, annotation, etc.)

7. Integration and user interface
This is the module that integrates and controls all the other modules. It is made by a graphical user interface (G.U.I.), built

with the standard tools found in the X Window environment, and a set of interfaces between the different modules.

B.2 Hardware Configuration

In this section we describe the hardware requirements of the information system, taking in particular evidence the standards the system itself relies on.

Workstations

The software is based on what is now a de facto standard in the graphical workstation market, the Unix operating system coupled with the X Window graphical environment; this allows us to be independent from any particular hardware vendor, since all major computers makers are compatible with these standards. The computers used in this project has some particular needs, imposed by the graphical and interactive nature of the application: it is mandatory to have an high resolution visualization system (at least 1024 x 768 pixels, with a depth of 8 bit that allows the display of 256 colours from a palette of 16777216; (colour means shade of grays too); furthermore the workstation, to achieve acceptable response times, has to be generously configured in terms of RAM (Random Access Memory); we think that it must be equipped with no less than 12 Mb of RAM. The need to interconnect different workstation leads to the adoption of a network standard; we chose Ethernet with TCP/IP protocol and NFS, one of most used combination today.

Peripherals

Since we operate with continuous tone image, we need some particular device to bring those images in computer readable form and to output the modified images in "Human readable form.

Scanner

A digital scanner is a device that reads an image producing a digital equivalent on which computers operate. The price range of these devices is very Wide, depending on spatial resolution, input format and colour possibility, so we plan to support three configurations. The entry level solution is an A4 size gray shades scanner with a resolution of 300 dpi; the medium priced solution is an A3 colour scanner capable of 400 dpi; the top level solution is a 35 mm film colour scanner with a resolution of 4000 dpi.

With this last device is possible to skip the photographic printing phase. Assumes great importance in this contest the future possibility to get images on magnetic form directly from Kodak laboratories.

Hardcopy unit.

The purpose of this device is to generate an hardcopy of an image; we plan to support two different solution. The entry level solution is an A4 size black and white laser print (Postscript compatible) with a resolution of 300 dpi; the more priced solution is an A4 or A3 colour thermal transfer hardcopy unit, with a resolution of 300 dpi.

Sector C. Field testing

The realized prototypes will be subject to a field testing by the researchers of Università dell'Aquila, by the technicians of Istituto Centrale del Restauro in Rome and in Laboratories of branch office in Rome of Leica Italia S.p.a.

The program foresees:

1. Field survey and data acquisition aimed to relevant objects in historical centres under the co-ordination of the Dipartimento del Architettura e Urbanistica dell'Università dell'Aquila.

2. Singling out of samples and standards for the draft of a file-card aimed at quick catalogation directly related to iconometric images, by technicians of The Istituto Centrale del Restauro.

3. The improvement over relation between the iconometric camera and the management software executed by samplings and tests in the laboratories of branch office in Rome of Leica Italia.

Actual production phases.

The Special Product Division of Leica Heerbrugg actually make the camera. The work in progress phases are:

Step 1. Assemblage of the first functional model with this characteristics (see pict. 1):

A) An optical measurement system (ODIN) based on the optical-rangefinder principle. Measurement are made at constant time interval (every 0.15 s) in about 0.05 s. The treatment by least-square error method give the resulted distance with a precision now reached of 0.10 m in a range from 10 to 70 m.

B) A particular Databack permits to project and record on the film the measured distance (or the scale on the target in the object of survey) with the informations required like Data, Code Number, etc...

Step 2. AMO System. The Functional model above mentioned is projected only in order to study and develop a second model AMO System that will have better characteristic in functionality and suitability.

The need of compactness in this camera is aimed to satisfy quick work in catalogation. High technologic integration of electronic components such as not to compromise the possibility to take snapshots.

The high cost of the reduction of electronic pieces dimensions is now a limit that will bring to a second model not yet fully compact.

This will be realized as follows (see pict. 2):

A) A range-finder (AMO) positioned near the lens in a more reduced dimension compared to the functional model.

B) A Databack R specially modified to accept more data then the standard one.

C) An electronic device in a pocket container which is able to calculate distance and scale referring to the focal length.

Step 3. Final Iconometric Camera. The integration between the system for distance measurement and the lens is the goal to be reached in short time. Moreover the direct connection of the measured data to the Databack through the body of the camera will bring to a real compact iconometric camera.

In that way will be realized a camera similar to a standard one and the final philosophy should be to have one only body with more optional components.

Conclusions.

The integrated system is studied for the research in the Cultural Assets, but may be useful in other scientific fields or professional use.

Its originality consists of versatility in surveying large scale campaigns, keeping the level of accuracy near values higher than the allowed maximal standard error.

Index.

RE.FRAN - EUREKA\Eurocare Project: EU598.	LEICA	Author: Carlucci	Date: April 1991
OBJECT: Iconometric Camera specifications aimed to pre-classification of Historical-Artistic assets.			

SOLUTION 1.

Recorded data :

1 - OBJECT CODE : 10 digits
Manual input in the Data-Back

2 - DATE : 6 digits
Automatic input

3 - SCALE (DISTANCE): 4 digits
Automatic measurement of distance from point of view to the center of photograph and evaluation of scale referred to principal distance of lens.

Recording form :

Directly on the film in alphanumerical and if possible in code bar form (this eventuality is to be studied in function of the automatic scanner acquisition by Italcad).

Distance Measurement :

By EDM integrated into standard lens ELMARIT-R 1:2.8/35 mm.
Range from 1.5 to 100 m, precision required 0.10 m.

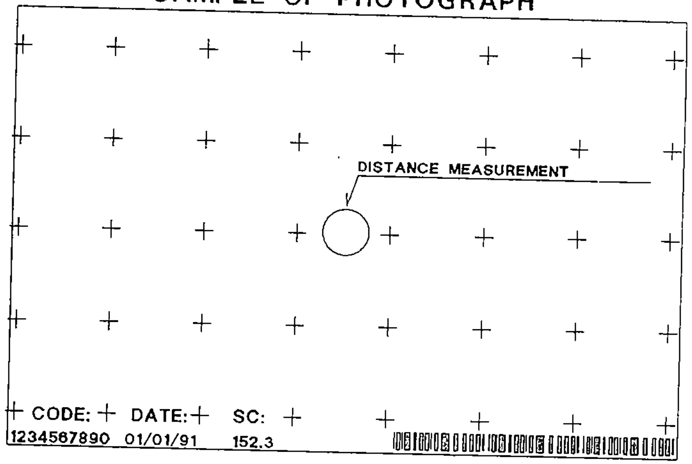
Data input :

By Data-Back. Allowed input of

OBJECT CODE (every photograph used)
DATE set. (rarely used)
LENS princ. dist. " "

Possibility to switch from SCALE mode to DISTANCE mode.

SAMPLE OF PHOTOGRAPH



SOLUTION 2.

Recorded data :

1 - OBJECT CODE : 10 alphanumeric digits

Manual input in the Data-Back

2 - DATE : 6 digits

Automatic input

3 - SCALE (DISTANCE) : 4 digits, 1 decimal digit

Atomatic measurement of distance from point of view to the center of photograph and evaluation of scale referred to principal distance of lens.

4 - HORIZONTAL DIRECTION : 7 digits, 2 decimal digits

Interface to Compass or theodolite

5 - VERTICAL DIRECTION : 7 digits, 2 decimal digits

Interface to compass or theodolite

Recording form :

Directly on the film in alphanumerical and if possible in code bar form(this eventuality is to be studied in function of the automatic scanner acquisition by Italcad).

Distance Measurement :

By EDM integrated into standard lens ELMARIT-R 1:2.8/35 mm. Range from 1.5 to 100 m, precision required 0.02m.

Manual input of data:

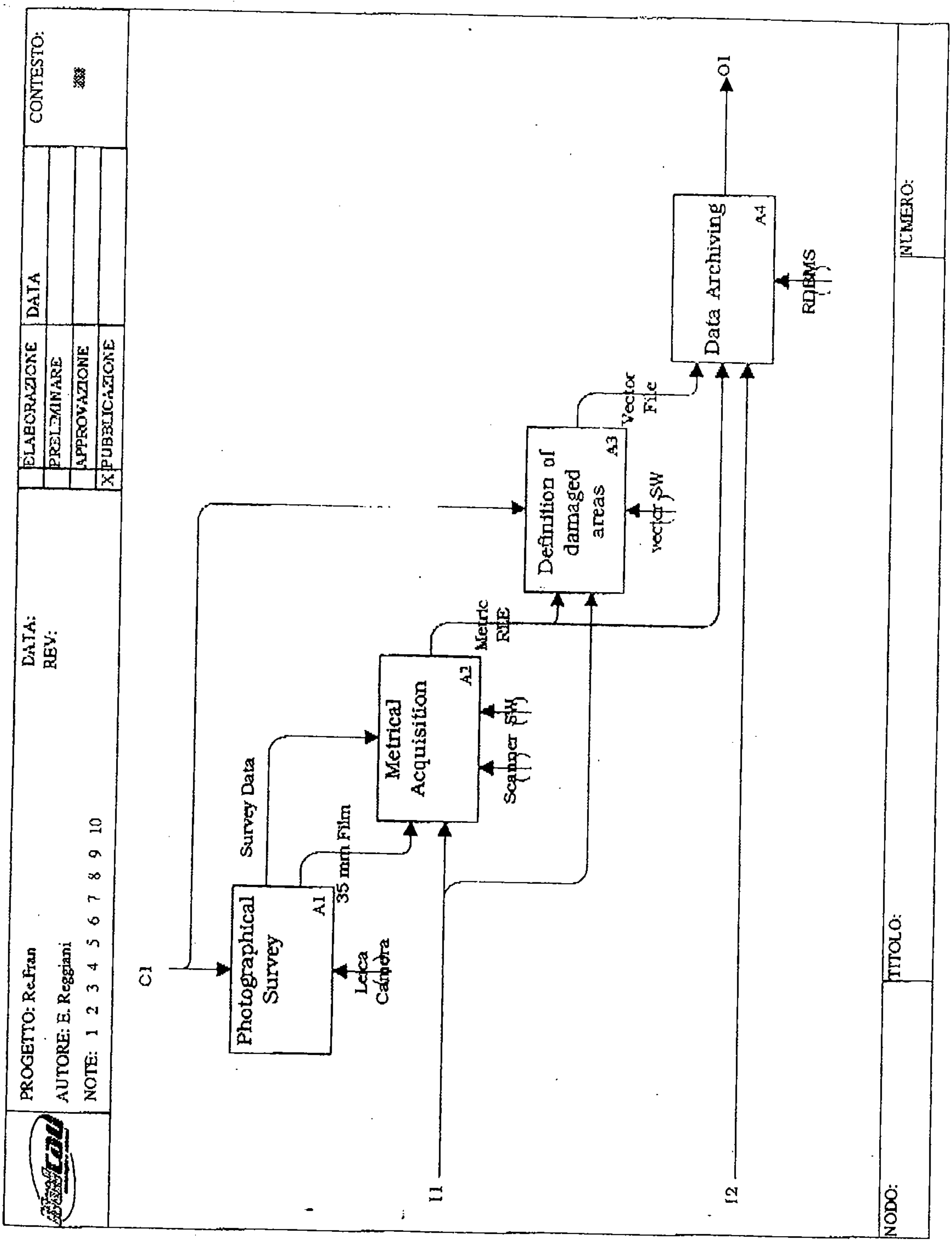
By Data-Back. Allowed input of

OBJECT CODE (every photograph used)

DATE set. (rarely used)

LENS princ. dist. " "

Possibility to switch from SCALE mode to DISTANCE mode.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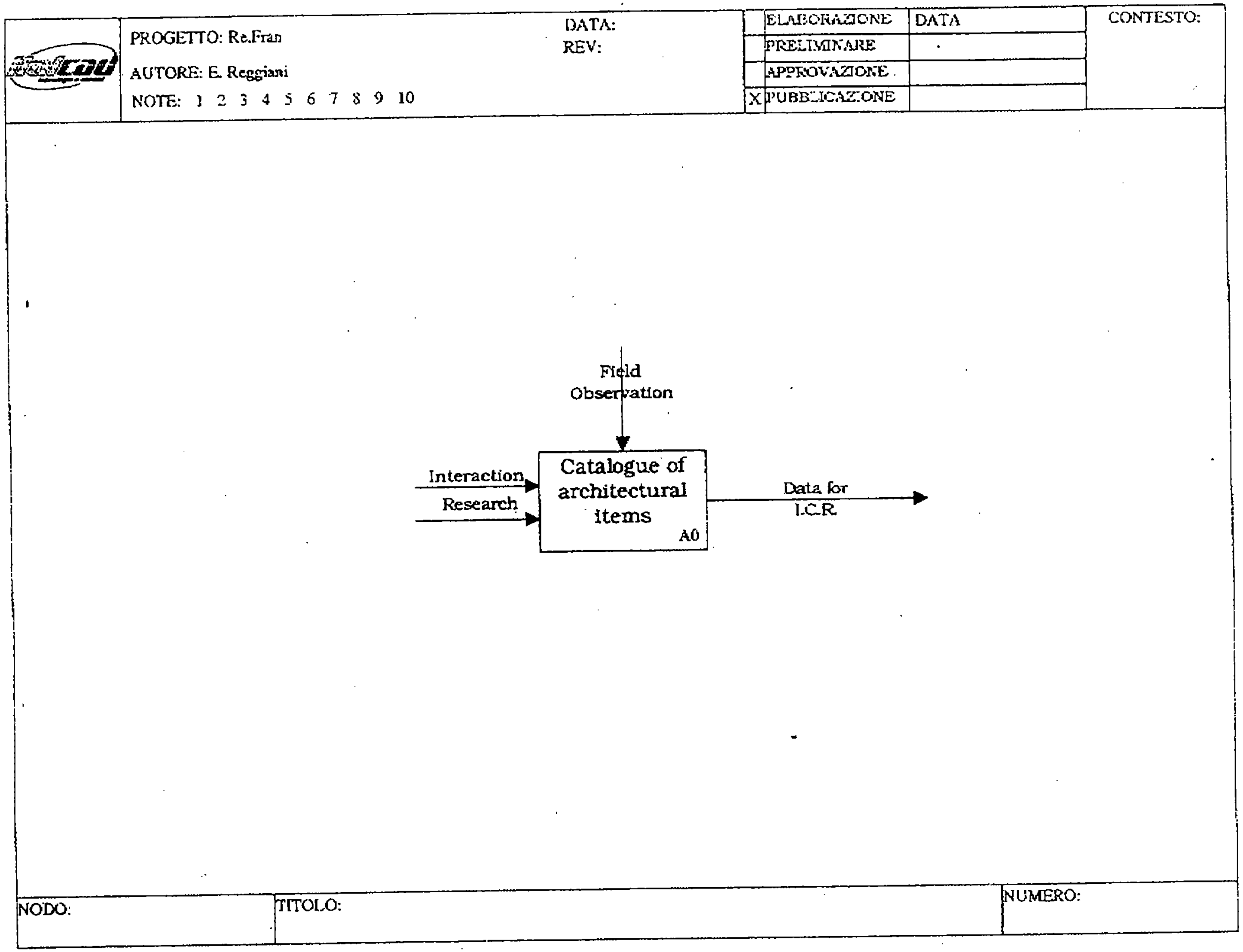
AUTORE: E. Reggiani
NOTE: 1 2 3 4 5 6 7 8 9 10
DATA:
REV:
ELABORAZIONE
PRELIMINARE
APPROVAZIONE
X PUBBLICAZIONE
DATA
CONTESTO:
C1
Photographical Survey
A1
Leica Camera
35 mm Film
Survey Data
Metrical Acquisition
A2
Scanner SW
Metric RLE
Definition of damaged areas
A3
vector SW
Vector File
Data Archiving
A4
RDBMS
O1
I1
I2
NODO:
TITOLO:
NUMERO: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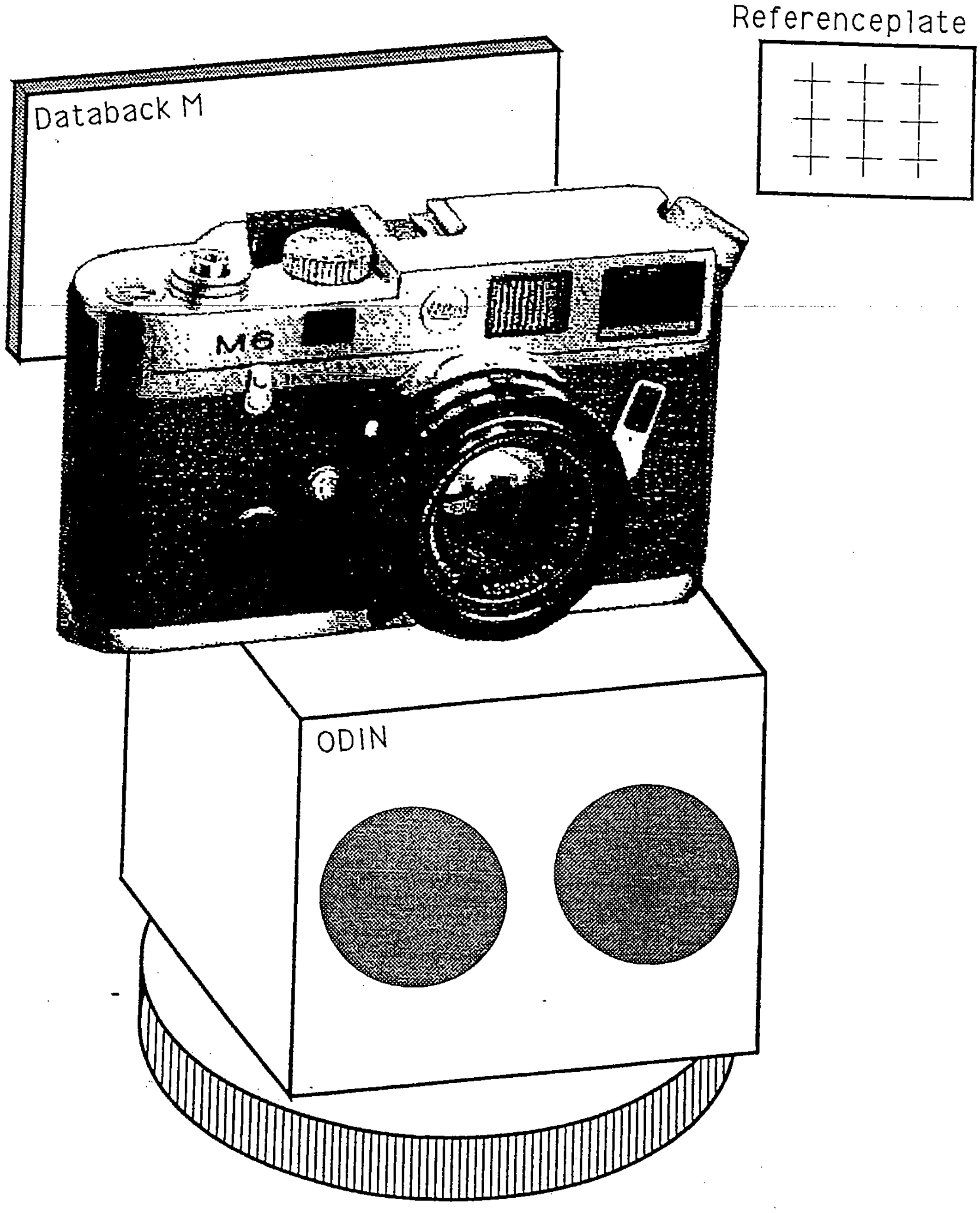
AUTORE: E. Reggiani
NOTE: 1 2 3 4 5 6 7 8 9 10
DATA:
REV:
ELABORAZIONE
PRELIMINARE
APPROVAZIONE
X PUBBLICAZIONE
DATA
CONTESTO:
Field Observation
Interaction
Research
Catalogue of architectural items
A0
Data for I.C.R.
NODO:
TITOLO:
NUMERO:

Leica
Heerbrugg AG

Tij 3465
22. Juli 1991

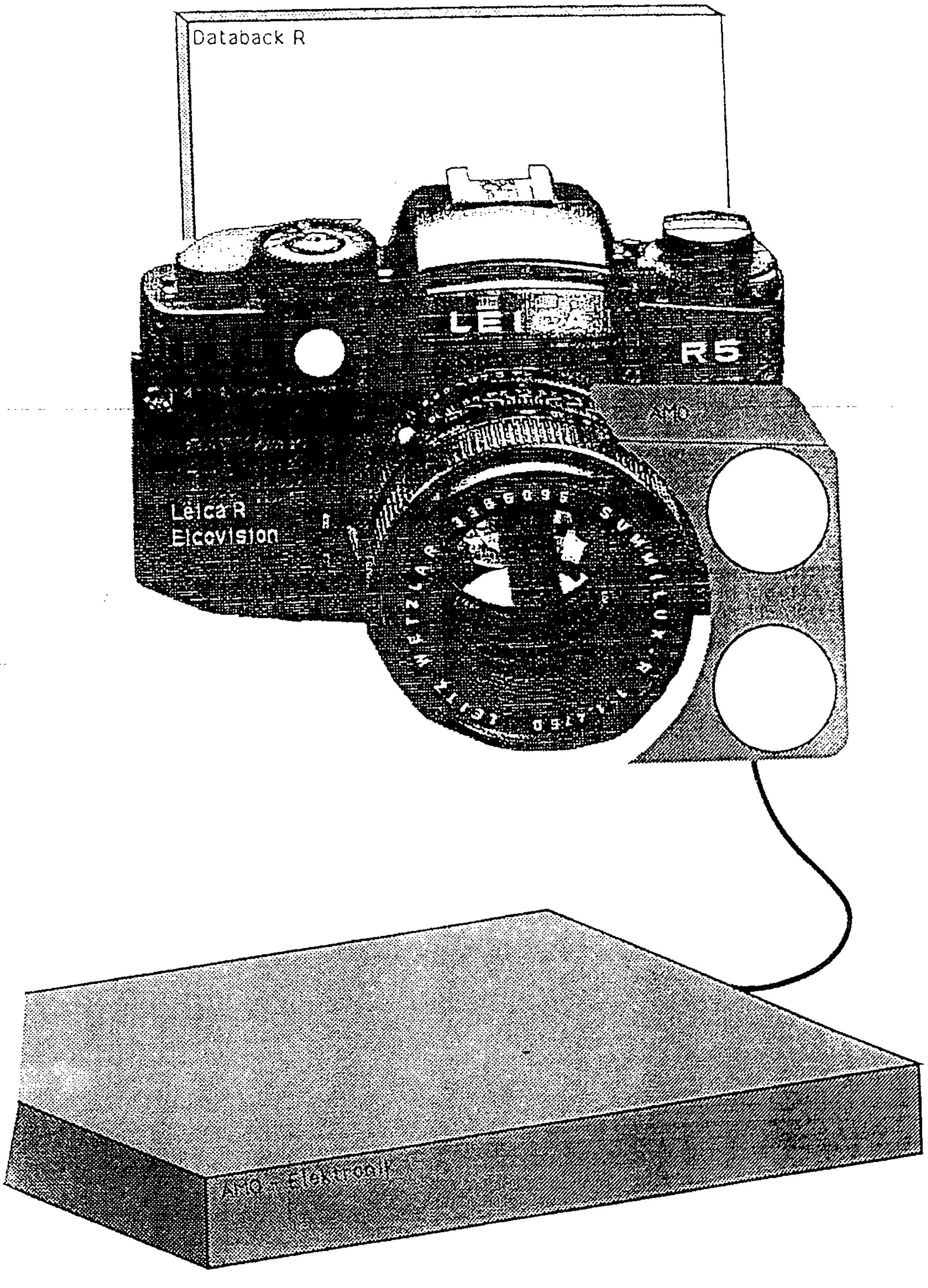
AMO
Functional Model



Leica
Heerbrugg AG

AMO System

Tij 3465
22. Juli 1991



Panel Discussion

Friday, October 4th, 1991, 17:00 - 18:30

Chair: A. Grün

PANEL DISCUSSION

Chairman: Prof. A. Gruen

Panellists: Prof. W. Wester-Ebbinghaus
Dr. P. Patias
Prof. Dequal
Mr. M. Carbonnell
Prof. J. Badekas

A. Gruen: We are gathered here in order to find out about the outlook of Photogrammetry in the near future from this panel discussion. In this panel we have Prof. W. Wester-Ebbinghaus from the Technical University of Braunschweig, Dr. P. Patias from the University of Thessaloniki, Prof. Dequal from the University of Bari and Mr. M. Carbonnell former President of CIPA. All will express their views and make some remarks on a special subject which I have specified for each one of them.

Firstly I will make a short introduction to the subject and I will show you some overheads, where I have defined some areas of interest which gave raise to extensive discussions during the Symposium.

First (Overhead G1) we have the aspect of Information systems. As a general definition I have listed the world of information systems (IS) and its subsystem the Spatial Information Systems of which a subsystem are the GIS and in parallel a Monument (or Architectural) Information System and as part of it we could consider a CAAD (Computer Aided Architectural Design) system or a Monument documentation system. Most of the presentations here related to this particular Monument documentation system.

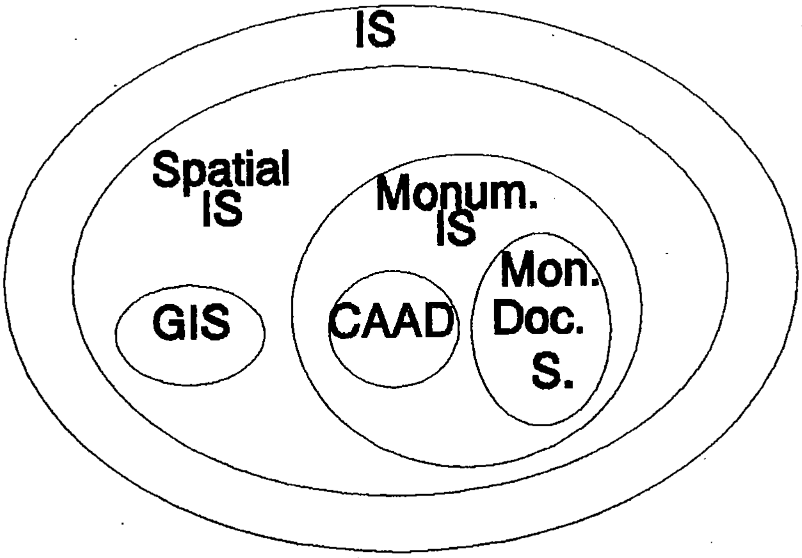
It pays off to look at the components of an Information System, as we easily realize how difficult it is to build such an information system for our purposes.

First of all Data Acquisition should be a component of such a system. CAAD may be used as a major component and quite a number of sensors are being integrated. This of course is not very complicated.

Then we have the processing and editing aspect, which again is not a big deal. Image Processing and Image Analysis techniques are being used, leading finally to a 3D-description of the object space. Then we have functions of plan or map editing.

Thirdly we have the Analysis functions of an Iinformation System. We must be able to ask queries about type geometry, composition, history situation status and many more. Here the DB issue comes into the picture and one realizes that we are really talking about hybrid databases (vector data + raster data). This problem has not been solved yet in a GIS. We even don't know what the data structure would be for Architectural Systems of this type. We know that in a GIS we have basically

(1) INFORMATION SYSTEMS



Components of IS

(a) Data Acquisition: CAAD (initial object description)
Sensors

(b) Processing, Editing: IP, IA --> 3D description
Map/Plan editing

(c) Analysis: Queries on Type, Geometry, Composition, History, Preservation Status etc.
--> database (hybrid), data structure
Need: 3D structure
GIS : 2.5D structure

(d) Documentation, Storage:
Administration of vector + raster data (incl. topology)
--> large databases (aerial photo: 0.5 MB)

(e) Representation: Visualisation (IA, IS --> live video + synth. images) ---> image sequences / animation

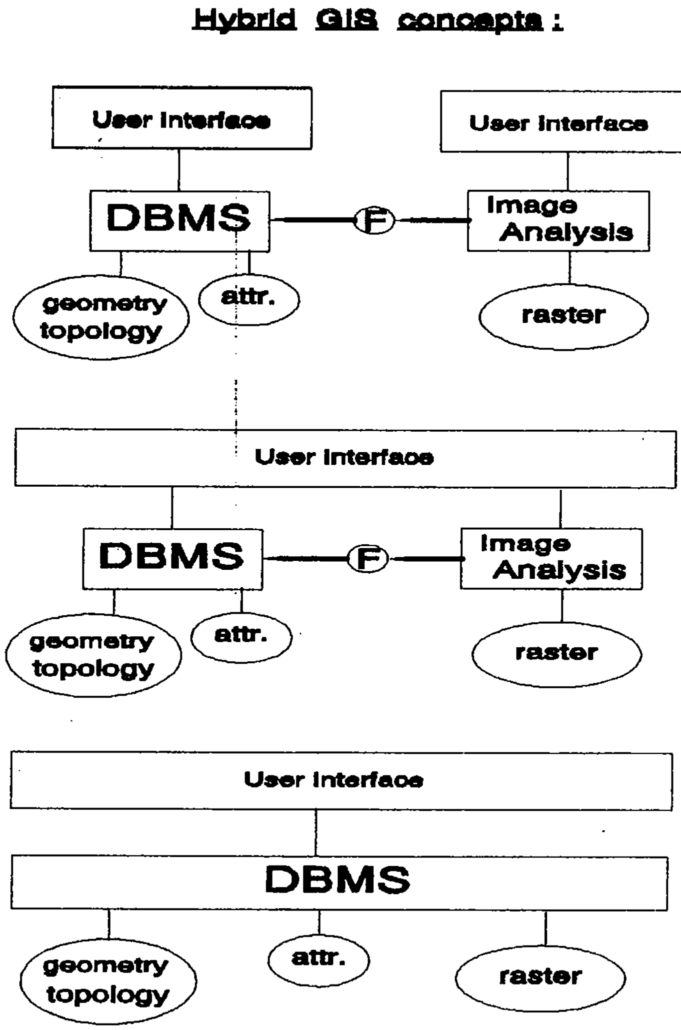
Requirement: Hybrid System

Overhead G1

three types of DataBases (hierarchical-relational-network). It is not sure a priori that those structures are appropriate for our purposes. We really need a truly 3D structure of data, which we don't have. Instead we have 2.5D structure. Therefore we are faced with additional problems requiring further investigation. I would not be very optimistic for the near future.

Then there is the Documentation and storage aspect. Here we have to deal with vector and raster data (including topology of course). This leads to very large DataBases.

The **Representation aspect** is easier to tackle as a lot of software is already available (Image analysis + synthesis + video + animation).



Overhead G2

The requirement today is a hybrid system

The approaches used today for these Hybrid systems are basically the following 3 (state-of-the-art in GIS) of different sophistication (Overhead G2).

At the lowest level we have two systems: one DBMS (vector as kernel) - Image analysis with separate user interfaces and the information exchange is done via a file system.

On the next level we have a joint user interface (eg. ERDAS livelink to ARC/INFO)

The last one does not yet exist ! Even Intergraph's TIGRIS does not handle raster properly. This is the concept for the future and to my knowledge it is not realised yet.

Introducing now the other panel members and on the issue of Data acquisition (cameras, scanners etc.) I invite Professor Wilfried Wester-Ebbinghaus to take the floor.

W. Wester-Ebbinghaus: During the presentation we have heard a lot of expressions were used for recording systems - I will give a systematic presentation for them.

Firstly we can distinguish between metric, non-metric and semi-metric systems. Their principles are:

A Metric camera is the one with defined image surface and defined interior orientation. For such a camera we can reconstruct the bundle of rays and we only have to orientate the camera in the object space.

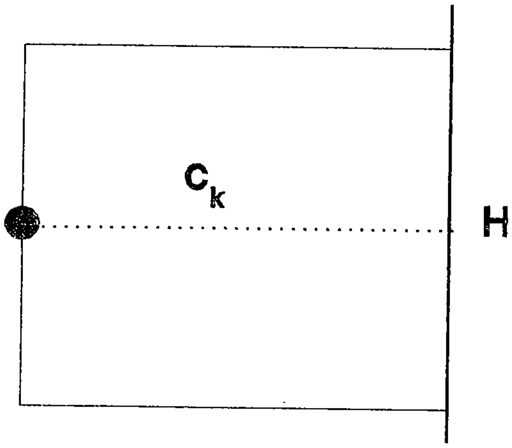
Non-metric cameras are usually ordinary photographic cameras with no interior orientation and no image surface defined.

Thirdly the semi-metric or partial metric cameras, where we have defined image surface but no interior orientation known with sufficient accuracy and over a longer period of time.

I will show you now what is in use nowadays and what are the consequences of the instrumental preconditions.

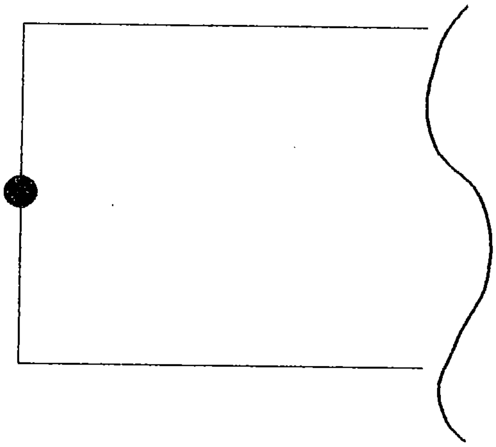
All available photogrammetric cameras may be regarded as metric for the purposes of Architectural Photogrammetry. The image surface is realised by glass plates or vacuum. Need for control to calculate the exterior orientation.

Photographic cameras are considered as non-metric. Everything (image surface and perspective centre position) is unknown hence we need to provide a dense network of Control Points in order to describe the recording and to determine all the unknowns. The density of this network is related to the accuracy of the calculations, which is a serious disadvantage, not very much stressed durind the Symposium. Much effort needs to be put in order to calculate and provide the appropriate Control Points. Therefore I would suggest that the use of non-



metric

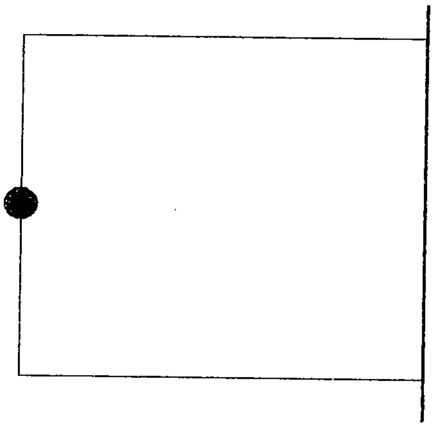
defined image surface
defined interior orientation



non-metric

undefined image surface

undefined interior orientation

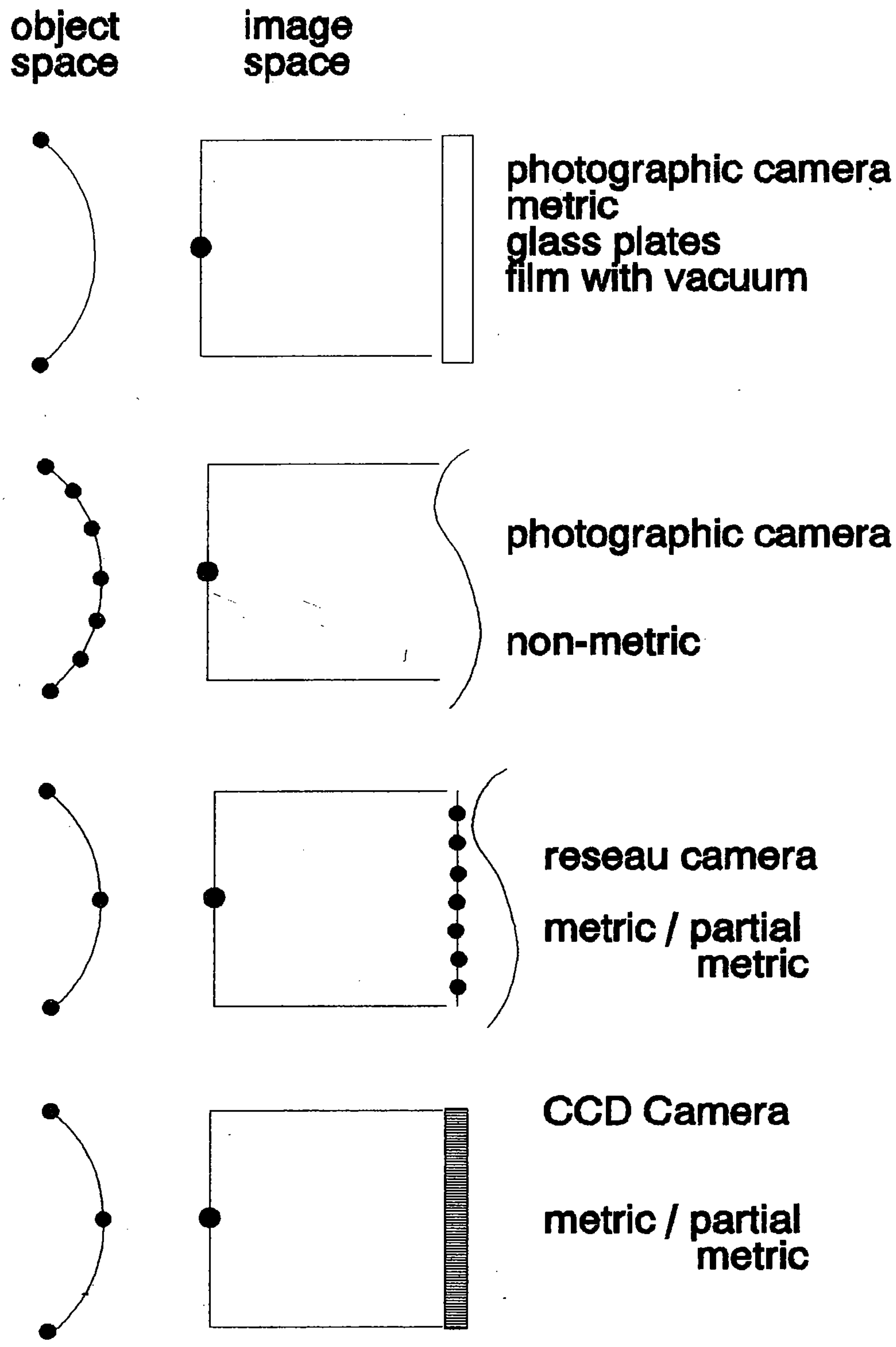


partial metric
(semi)

defined image surface

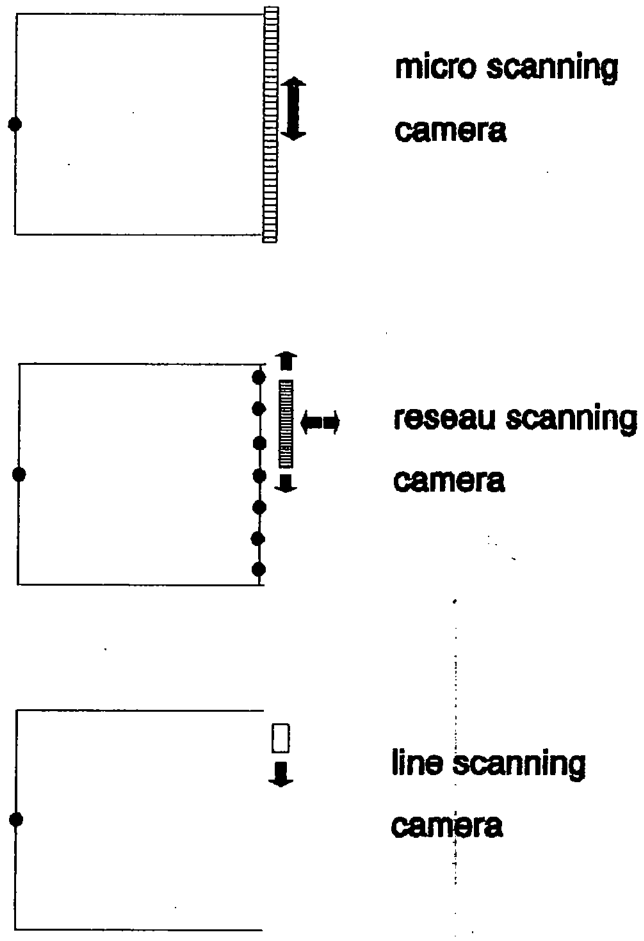
undefined interior orientation

Overhead W1


object space
image space
photographic camera
metric
glass plates
film with vacuum
photographic camera
non-metric
reseau camera
metric / partial metric
CCD Camera
metric / partial metric

Overhead W2

metric cameras is really not economical.



Overhead W3

A better solution is reseau cameras. Control is provided in image space in order to describe the image surface. Perspective centre position is usually unknown, or rather defined with no great accuracy. More CP's requirements as compared to metric cameras, but very much less than for non-metric ones.

The next recording system to be discussed is CCD cameras. They can be regarded as partial metric because the image surface is well defined by the sensor itself (solid state). For not high accuracy demands they can be used as metric and for high accuracy as partial metric, by adding control information to describe the object space.

The previously described systems are of rather low resolution. To improve this I present the Micro Scanning Camera (Overhead W3) a sensor with very small picture elements which is shifted along the image surface and which may provide a resolution four times better than normal systems. Another alternative is to use a reseau camera and use a CCD sensor which scans the image surface, thus recording an image of rather high resolution. Another possibility is to use a line CCD sensor scanning the image surface of the camera, a system just like the one shown today by Mr. Godding.

A very important issue is the Calibration of these systems

If we use partial metric camera we need to determine the position of the perspective centre. There are two possibilities for this:

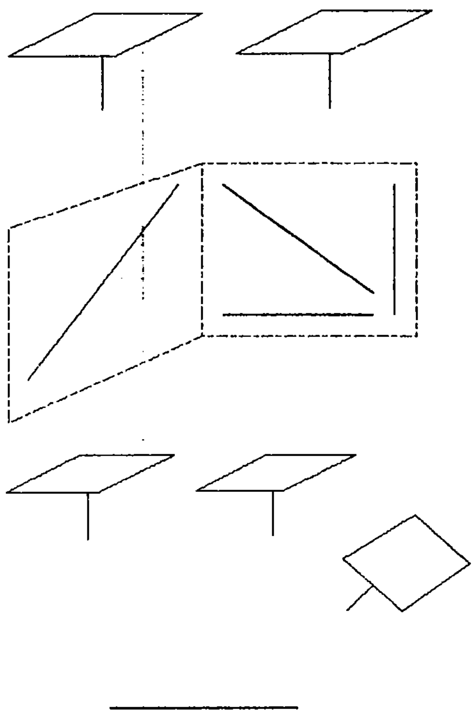
1. Without CP's: We need two photos and orientation of them by bundle adjustment with the help of some distances arranged as presented in Overhead W4.

2. If we have at least three photos of the same object, we only need one distance to define the scale. Hence we don't need CP's for calibrating partial metric cameras.

3. Non-metric cameras need more effort for their calibration.

Concluding my presentation I will refer to means of digitisation of photographs

1. We can use a line scanner with enlarged prints (accuracy of cheap l.s is questionable hence one should use reseau photos thus providing the necessary control for calibrating the system)



Overhead W4

2. Flat bed scanner by shifting a CCD matrix sensor over the image.

Thank you

A. Gruen: Any questions for the issues presented by W. Wester-Ebbinghaus?
I have a statement : Low cost systems are OK! Cheap cameras are OK! Untrained personnel is OK !! But these three do not go together. I mean that the more cheap instruments you use the more photogrammetric expertise you really need, not only for calibration but also for processing.

W. Wester-Ebbinghaus : I would like to stress the use of Réseau and NOT the use of amateur cameras.

A. Gruen : Let's turn now to the next topic: Digital stations in general. THey can be used in a lot of applications. However a digital rectification station as presented by Dr. Patias is standard nowadays. He will comment on this issue in detail.

P. Patias : Everything started from Remote Sensing. The problem was not to work with stereo images. The problem was to IDENTIFY what they saw, than measure certain things. Stereo viewing started with SPOT. Now we can derive co-ordinates of points photogrammetrically, hence we have the necessity to measure accurately and give attributes.

In photogrammetry we have the problem to measure something that moves. Only recently we may use metric or non-metric CCD cameras. Problems with calibrating the cameras, and the scanners with which we scanned the analogue images. The resolution from CCD cameras is not enough most of the times. One thing we don't yet have is differentiating the resolution while scanning (by zooming) hence change the conception of the scanned image. For example one would like to have high resolution in some control points, but lower resolution over the rest of the area.

However no system could do all jobs (collect, process, present and store the data). If all this would be considered as the necessary functions of a Digital station, then what we have presented is only a part of it.

Is all this really needed in all cases? Theoretically the stereo problem is solved and we have to wait for the technology to improve. Hence small and dedicated stations seem to be the first to be developed in the near future for the applications discussed in this Symposium.

A. Gruen : Thank you very much. I repeat the statement that some subsystems are already operational, plus other products combining raster and vector data already available. Are there any questions or contributions??

One remark from my side: Self focussing CCD's exist in cases where one records or monitors restricted or prohibited areas, working with very coarse resolution and as soon as it detects a change it zooms in to record in detail. But the question arises how do you know when you should zoom in ??

I would like to switch over to the next topic, which was raised in this Symposium and it concerns the low cost systems.

Prof. Dequal is invited to comment on it.

Dequal : We all know what cost means, but do we really know what low-cost means when referring to a photogrammetric system?

Hence it would be appropriate, before anything else to put things in order and propose some definitions of the parameters involved: Many speakers used the term cost in connection with the proposed methodologies employing non-rigorous solutions far from traditional photogrammetric methodology.

It has been at least 15 years that an analogue instrument was last presented to the market. Analogue instruments compared to analytical for Architectural Photogrammetry are not so advantageous any more, due mainly to their flexibility.The serious question arises: What happens with the existing analogue instruments? It is evident that only a small part of the photogrammetric restitution cost is due to the original cost of the instrument. Usually cost is increased by the time necessary to set-up a model.

By simplified system I don't mean NOT traditional photogrammetric methods or approximate methods. Is monoscopic Photogrammetry a full photogrammetric method? Yes, but let's not forget the importance of the stereo viewing, i.e. the advantage of plotting continous lines, while in surveying one has to resort to the ... Pythia method

In the future the real alternative will be analytical or digital photogrammetry. The advantages of Digital Photogrammetry in DTM creation, automation and pattern recognition are already recognized. I ask the experts: Are certain problems already solved? eg. quality & resolution of raster images, quality and cost of data aquisition, health and comfort of the operator due to radiation and finally COST of the already available solutions. Prices are decreasing and computer power is increasing nowadays, so there are practically no limits of the future Photogrammetric system. The photogrammetric instrument is becoming more or less a peripheral of a large computing system (eg. 3D digitizer) and with the price drop this might become by definition the low cost system in the near future. Thank you

A. Gruen: A clear rectification of opinions expressed before. The issue of a low cost digital system as being a suitable method or product has to be answered by architects really !! Are there any comments?

R. Letellier: There is a little problem as in this room there are very few clients, just like doctors talking to doctors about medical things. I am an architect responsible for a recording service in Canada.

According to my experience there are two levels of recording, the accurate one, which you use if you are rich enough to have access to Photogrammetry, but I'd say that there are hundreds if not thousands of Architects, like Mr. Cocke, who was supposed to give a paper (Mr Jachimski gave his paper two days ago) who don't have access to such equipment. By that I mean they only have paper and pencils on their desks. They have told me that they cannot even afford to buy a 35mm lens for their cameras. They see me as a person who does recording, using high and low end techniques and they would like to have an answer as to how can they improve their effectiveness with the means they have. Naturally my only answer is rectified photography, pen recording and simple photography. Representing them here, please tell me what should I recommend to them as an alternative low cost recording system

A. Gruen: Any answers from the panel or from the floor?

P. Patias: One thing is certain, With a pen you cannot solve the problem. The other thing, now it is not a big deal to own a PC. If you don't have money you should skip all the rest of Photogrammetry and go to digital Photogrammetry. Unless you want to buy a photogrammetric instrument. These instruments are expensive, even the small ones. The only future would be to work with a computer and have means to scan an image. It could be a scanner, a CCD camera. Both of them are getting better and better in terms of resolution and cost. So the only thing remaining is software, the only thing photogrammetry can offer now. Rectification has been in use for many years, whether graphical, analytical or digital. Hence what I would recommend is work with a PC, a scanner and software that will soon be available in the market and cheap.

A. Gruen: Any more comments? One additional remark: If you cannot afford a PC, buy an analogue rectifier, they don't cost anything nowadays !!

P. Waldhausl: A rich man's photogrammetry may be a poor man's profit. In other words the production method should not be changed too quickly, because the personnel has to be trained for the new instruments, which may be changed quickly. Getting things to work productively might take a lot of time. Hence I would recommend to the users to keep the old traditional method if it is sufficient for the task.

A. Gruen: This production aspect is not normally considered by university people, any comments??

W. Wester-Ebbinghaus: Some presentations described the possibilities of using just one photograph. This is a problem, because you don't record all three dimensions. Even if you process it digitally the problem remains, a single perspective and the result is not geometrically better. I would like to say that the principles of analytical photogrammetry should be the base for all recording.

A. Gruen: Any more comments: If not, I would like to remind you that during the Symposium we heard of other recording application novelties, about which the panel members did not comment, but we should keep in mind. They were on-line display/processing/plotting used in conjunction with photogrammetry. For example Dr. J. Peipe mentioned the measurement macros, a very interesting approach indeed. The other aspect of using multispectral images or the integrated survey aspect are all worth following up. Finally I would like to have a comment from M. Carbonnell, who probably has more experience in architectural Photgrammetry than any of the rest of us. He will comment on the current state-of-the-art of Architectural Photogrammetry, comment on collaboration with the architects and all these things.

M. Carbonnel: I only wish to draw your attention on an important point. As you probably know the CIPA Committee was set up in 1969 jointly by ISP (now ISPRS) and ICOMOS. The main aim of CIPA was to be a forum of the specialists for conserving monuments and the specialists of Photogrammetry. However during this Symposium we can show the big evolution of Photogrammetric techniques and the multiplication of the technical means that can be devoted to this purpose. But except a few papers, I think another dimension was absent. The architectural - cultural dimension. I think that Architectural Photogrammetry is not only made for the pleasure of the Photogrammetrists, but mainly to give replies and solutions to the requirements and needs of the conservationists. We should review the present statute of Architectural Photogrammetry in this way in order to have better relationships and co-operation between these two categories of specialists. After a quarter of a century of work with Architectural Photogrammetry within ICOMOS, we should plan for the next CIPA Symposium in 1993, to devote it to this problem to review the problems of the specialist in heritage recording and the reply of the photogrammetrist, because photogrammetric techniques are quickly evolving, but also the needs of the conservationist are also evolving. A good opportunity would be to establish a new working statute, a new state-of-the-art of Architectural Photogrammetry. Concluding, I would like to express my pleasure to see the new generation in this room, but they have to cultivate better relations with the people responsible for the conservation of our heritage.

A. Gruen: Thank you Maurice, this was a most valuable comment. We should try to attract them back to our Symposia. Any suggestions on how are we going to do it?

R. Letellier: How could we approach our clients?? One idea would be for the CIPA Symposia to address the ICOMOS Meetings on several issues. One year you should listen to their problems, next year you discuss it among yourselves and then the year after you come up with the answers.

In National Park Service we need good documentation. A relational data base that we use is ILORS. It will allow for everyone involved to access the information they need based on the geocode of the monument. Perhaps I should also mention a Congress that is going to take place next year, where people from all disciplines (conservationists, environmentalists etc.) will meet, state their problems and exchange views in trying to find a common solution. If anybody is interested I could give more details. Thank you.

A. Gruen: This brings the Symposium and the panel discussion to a close. Perhaps I should mention another important event, before the next CIPA Symposium, at least for those interested in Photogrammetry. It is the ISPRS Washington Congress next year (2-14/08/92). Two technical sessions will be devoted to Architectural Photogrammetry plus a few additional sessions of interest to Architectural Photogrammetry. In addition we will have a Special session titled "Photogrammetry records the world's heritage". Finally a Tutorial on fundamentals of digital Close range Photogrammetry will also take place.

This concludes my talk. Many thanks to everybody - Organizers panel members, speakers and all of you, wishing that we will soon meet in another place. I hand you over now to Prof. J. Badekas for some Rèsolutions and other business matters.

J. Badekas: I thought that I would be the last member of the panel and I had prepared myself to make some contributions!! But since everything I had in mind has already been so elegantly presented by the previous speakers I was ready to quit. I am, however, a rather persistent person, I still have found six topics on which I would like to comment !!

I would like first to remind you that a similar Symposium of CIPA took place in Athens in 1974. The closing session of that Symposium also took place here in Delphi.

I would like next to make a remark on GIS and monuments. GIS is useful for a lot of things. Architectural and archaeological documentation is one field that will benefit from GIS technology. Users of this documentation are not familiar of what they may expect from this technology and GIS experts have not been seriously concerned with this kind of approach at all, as GIS are in their infancy. Armin Gruen is correct in not characterizing what we are at the moment building as Geographic Information System, because what we are building is just a Data Base. However, it posesses all the characteristics to be developed to a GIS in the future. For this completion knowledge, money and time should be invested. But it is important to start. According to a Chinese proverb "even the longer travel starts with a single step".

Then I would like to stress the importance of having architects and archaeologists in these meetings. Close co-operation with these experts is of utmost importance and CIPA is well aware of this.

Next, I would like to propose a resolution of the CIPA Symposium

RESOLUTION

The Symposium,

recognising that in international and civil wars so many valuable monuments have been destroyed during recent years, and noting that photogrammetric documentation is progressing too slowly

recommends that all national correspondents of CIPA as well as the CIPA Committee itself approach national and international institutions and organisations in order to express the deep concern and disappointment that mankind and his heritage is not sufficiently respected nor protected and it

further recommends that all measures should be undertaken to complete proper photogrammetric documentation in all countries and civilisations around the world as soon as possible and by international co-operation with CIPA, ISPRS, ICOMOS and all other organisations and institutions concerned

Delphi, October 4th, 1991

If everybody agrees this will be approved. If this is the case we have the approval for the resolution.

The last part of my talk is the most pleasant one. I would like to thank:

- The CIPA Committee members for agreeing to hold the Symposium in Greece. Also with their presence they have honoured and supported us
- All Institutions and Societies in Greece that have financed and supported this Symposium in many ways
- My colleagues and collaborators in the Laboratory of Photogrammetry in NTUA, who actually carried the burden of the organisation of the Symposium
- The Session Chairmen, the panellists and the speakers, who with their interesting contributions and stimulating presentations have made this Symposium so lively.
- All of you who have come here to attend the Symposium and have participated in the discussions.
- The administration and the people of the European Cultural Centre in Delphi for facilitating our work.
-Our photographer, Mr. Chliveros and Christos for operating these complicated audio machines
- I wish you a pleasant time for the rest of the programme and a nice trip back home.

Finally, I ask Prof. Mario Fondelli to close the Symposium

M. Fondelli: This CIPA Symposium is over. The balance was very good. We should all thank Prof. Badekas and his collaborators for the work they have done. The CIPA Committe thanks also all Session Chairmen and speakers for their contributions of such a high scientific level. The next Symposium will take place in Romania in 1993. According to the decision of the Committee the Symposium will take place every two years from now on. The topic of the next Symposium will be:
Cultural Heritage, Conservation and Photogrammetry.

Thank you, Good Bye!

Papers submitted but not presented to the Symposium

Photogrammetric study of curved surfaces of monuments

Examples of the historical center of Mystra.

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1. Introduction

The preservation of the cultural inheritance of every country is its very first obligation. On this purpose a multiple study of monuments and historical centers is entirely necessary. To attempt this the methods of Photogrammetry and Photointerpretation are of great importance.

Photointerpretation and photogrammetric exploitation of air-photographs, terrestrial takings for general presentation, takings from near places (external, internal) and several kinds of restitution (graphical, analytical, rectification, orthophotography) were the subjects of our study of various monuments and historical centers of Greece (1-11).

Particular interest for photogrammetric study is put on the architectural parts of monuments, which include curved surfaces, especially when they have paintings and/or they present several kinds of damages (crevices, deformations etc.).

We usually meet these curved surfaces, except other cases, in the internal areas of churches, their study of which is especially important for Greece.

In this paper we attempt a preliminary study on the internal areas of the Cathedral at the historical center of Mystra (Peloponnesus, Greece).

2. Study of the curved surfaces.

From the two barrel-vauts, the eastern one was covered by painting destroyed at great extent.

The paintings are completely destroyed at the central barrel-vault, which presents serious crevices.

At both cases with geometric dimensions drove to the use of stereocamera with which the takings were successively done. (Fig.1-3).

Suitable targets, four at each case, were placed at the corners of the subject, the coordinates of which were reported at trisorthogonal system, beginning with one of them and horizontal axis, x,ψ (indicative dimensions are presented at Fig. 1 (1-2 2,77 m), Fig. 4 (1-2 2,80 m).

The restitution of the eastern barrel-vault was considered purposeful to be done with orthophotography. The orthophotography at scale 1:20, Fig. 2 was done with Topocart orthophot Iena.

At the case of the central barrel-vault, a graphical restitution was done at scale 1:20. Characteristic architectural details and crevices were restitued in alignment Fig. 4, I-II, a, b, c, and contour lines were been drawn, Fig. 4, 0-56 cm.

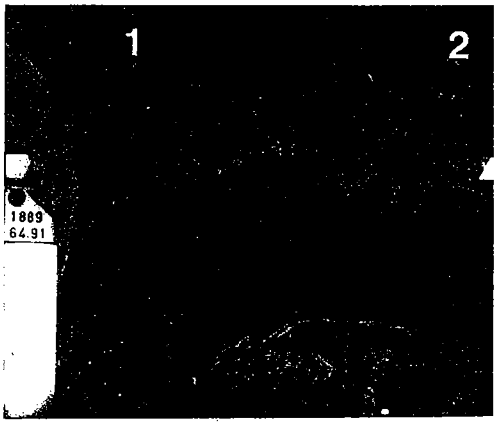

Fig. 1. One photograph of the stereoscopic pair of the southern barrel-vault.

Fig. 2. Orthophotograph at scale 1:20 from the pair of Fig. 1 (Reduction).

The considerations about digital models in the photogrammetric research and practice present contineous interest. Terrain-geomorphology and various kinds of technical works consist the main directions for relevant studies. However, we consider that the study of architectural parts may be also multiply served with digitals.

On this purpose, a satisfactory research and facing of all the particularities, which are presented at the study of the architectural parts, can be obtained with a systematic approach of the problem, with evaluation and exploitation of the existing experience about digitals.

The use of a square grid of sampling points was considered useful in the present paper for the beginning of such a study.

The sampling points, at which we measured altitudes, were taken at the grid sections every 2 cm at the scale of the drawing.

Of course, the density of the sampling points can vary according to the case for all the net or locally for a more detailed description.

Furthermore other kinds of digitals can be searched through.

Using the suitable program we can have various products as contour, curves, sections, perspectives etc.

Parts of contours, which were drawn on base of the program that was edited for this reason, are presented at Fig. 4, 1-8. A satisfactory at principal corresponding with the curves of the graphical restitution is confirmed.

The program for digital models, as it was used at this preliminary form, included the study of the surface of the model on every square-cell at the center of which the altitude was corresponded to the average of the altitudes of the four apexes of the square.

Fig. 3. One photograph of the stereoscopic pair of the western barrel-vault.

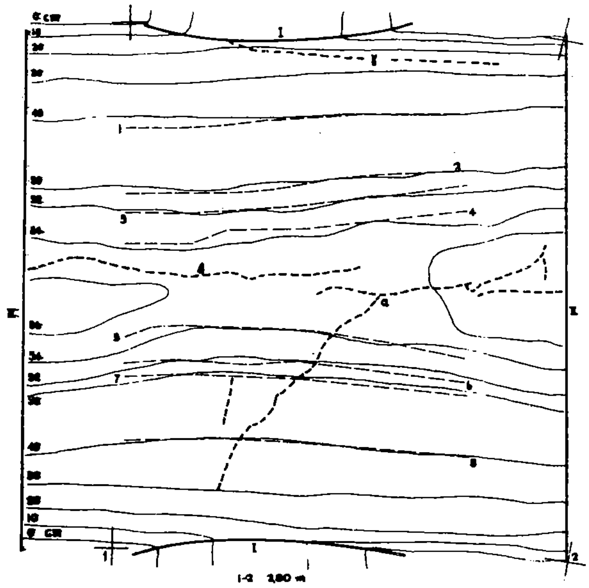

Fig. 4. Photogrammetric restitution at scale 1:20 from the pair of Fig. 3 (Reduction).

The course of every contour was searched through in each cell with the possibility of smoothing of its parts.

3. Conclusions - Discussion.

Curved surfaces, among the various architectural parts of a church, are of particular interest and they present increasing requirements at the photogrammetric survey.

The interest is growing because these areas are usually covered by paintings. Then, the photographic images present deformations because the taken photograph is central projection of a curved surface. Various methods (developments etc.) can principally be used for the photogrammetric survey - restitution at similar cases. However, orthophotograph, which is reseased of the above deformations, offers at principal some advantages because it is a photographic metric document at orthogonal projection, including much information.

The study of damages and of deformations of architectural parts because of various reasons, their attendance, our interference and their restoration is an extremely interesting direction of the study of monuments. Especially taken care of topographic and photogrammetric works are being required in order to have results of increasing accuracy. At the case of this study, the plotting of the crevices and the study of the relevant curves give first interesting information about the damages and the relevant deformation of the surfaces.

Taking and suitable elaboration of digitals seem that they may serve the study of the curved surfaces of the architectural parts (basic form and partial deformations) and give multiple useful results from the aspect of automatism (curves, profiles, perspectives etc.), storage, filing, etc.

This study is a preliminary facing of the problem of the photogrammetric study on curved surfaces of the architectural part of monuments. It took place with the means of the existing equipment of which the suitable evaluation and the use of its possibilities are realistic and positive consideration which offer experience for further research of the subject and serve better the whole problem of the study of monuments and historical centers.

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