APPLICATION OF CLOSE RANGE PHOTOGRAMMETRY IN ARCHITECTURAL DOCUMENTATION

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF ARCHITECTURE

by

ANIL DIKSHIT

DEPARTMENT OF ARCHITECTURE AND PL
UNIVERSITY OF ROORKEE
ROORKEE-24 7667 (INDIA)

February, 1986

To

My

Parents

CERTIFICATE

CERTIFIED that the dissertation entitled, "APPLICATION OF CLOSE RANGE PHOTOGRAMMETRY IN ARCHITECTURAL DOCUMENTATION", which is being submitted by **Mr ANIL DIKSHIT**, in partial fulfilment of the requirement for the award of Degree of Master of Architecture in Architectural Design of University of Roorkee, is a record of student's own work carried out by him, under our supervision and guidance. The results embodied in this dissertation have not been submitted for the award of any other Degree or Diploma.

This is further to certify that he has worked for a period of 9 months from June 1985 to February 1986 for preparing this Dissertation for Master of Architecture Degree at this University.

(R.C. BADJATIA)
PROFESSOR
DEPTT. OF CIVIL ENGG.
UNIVERSITY OF ROORKEE
ROORKEE-247 667

(K.C. KAMBO)
PROFESSOR
DEPTT. OF ARCHITECTURE & PLANNING
UNIVERSITY OF ROORKEE
ROORKEE-247 667

Dated 10 th day of February - One thousand Nine hundred and Eighty-Six.

दिनांक 24 माघ 2042 शके

ABSTRACT

Photogrammetry is the science in which the geometrical properties of an object are analysed in quantitative terms from their images recorded on photographs. Though the application fields of Close Range Photogrammetry are numerous and quite diversified. The work in this dissertation is confined to photogrammetric applications in architectural documentation. The purpose is to acquaint the Architects and Archaeologists of the photogrammetric techniques and infuse in them interest for adopting these in their own interest and in national interest.

The Architect has to design and foresee the construction of objects and spaces. He is also required to maintain a record of the architectural excellence of the past. There are multiplicity of agencies looking after the monuments of national heritage and architectural excellence in India. The various methods used by these agencies does not cope with the magnitude of the documentation requirements in the country. The CRP technique recording is fast, accurate, condensed. The problems occuring due to inaccessibility of the objects can be easily over come by this technique.

The various steps in the photogrammetric recording of these monuments has been taken up in detail. The methodology derived was carried out on experimental basis, on the St. John's Church, University of Roorkee Campus, itself. The results obtained are quite remarkable. They can be furtrher refined by the introduction of suitable, sophisticated instrumentation.

It is also suggested that this technique should be utilised by various agencies responsible for preserving, maintaining and documentation of the structures of national and architectural excellence on routine basis.

ACKNOWLEDGEMENTS

I acknowledge my deepest sense of gratitudes to my supervisors for this dissertation, Prof. K.C. Kambo, Faculty of Architecture and Planning and Prof. R.C. Badjatia, Faculty of Civil Engineering. Their was an impeccable team of inter-disciplinary professionals in the truest sense of the term, at whose hand it was a shear joy to listen, and learn.

I must express my thanks to Dr. R.S. Tiwari, Professor, Faculty of Civil Engineering, Department, for his guidance. Patient and determined he was a devoted companion on the long voyage of this work.

Many have contributed to the making of this dissertation, mainly, Major General G.C. Agarwal, the Surveyor General of India and Col. B.B.S. Karki, Deputy Surveyor General of India, without their help it would not have taken the shape as it is now.

It would be proper to acknowledge the zest of two people who has contributed to this dissertation indirectly. Prof. M. Carbonell, President,International Committee of Architectural Photogrammetry, Saint Mande, France and Dr. Ross. W. Dallas, Chief Surveyor, Photogrammetry Unit, Institute of Advanced Architectural studies, University of York, Great Britain, has been supplying all the necessary and relevant literature, and informations well in time. Also, their keen interest in success of this work is greatfully acknowledge.

Special thanks are due to International Committee of Architectural Photogrammetry (C.I.P.A.) for registering this work as the recognised research work in hand, in India.

Nor must I omit to place on record my sincere thanks to Mr. Kamal Jain, Mr. K.S. Baliyan, Mr. Vinod Bansal, Mr. Mohammed Nazim, Mr. Desh Deepak, Mr. Lokesh Sharma, Mr. Ram Nivas for the time, energies and skills which they have placed at my disposal liberally.

I acknowledge at last, the facilities and help provided by following agencies. Needless to mention that failing this, it would not be possible to accomplish this work. They are, Roorkee University, RURCC, Survey of India, Dehradun, Department of Science and Technology (Government of India) New Delhi, British Council, London, Institute of Advanced Architectural Studies, University of York, Great Britain and International Committee of Architectural Photogrammetry, Saint Mande. France.

My warmest thanks are also due to Mr. N.K. Tiwari, New Delhi for the converting the manuscript into this immaculate dissertation.

ROORKEE

DATED: FEBRUARY, 1986 **(ANIL DIKSHIT)**

LIST OF FIGURES/PLATES

o o o

CONTENTS

CHAPTER 1 INTRODUCTION

CHAPTER 1 INTRODUCTION

"Everything around us has an age of its own and every instant it undergoes a transitory state of destruction. Photogrammetry represents a most powerful tool, not to prevent destruction, but to permit an accurate, nearly ageless reconstruction. No other tool is yet to challenge the efficiency of or replace fittingly this photogrammetry, in this sphere."

Hallert, 1953.[28]

Photogrammetry is the science in which the geometrical properties of an object are analysed in quantitative terms from their images recorded on photographs. The technique of making precise measurements from photographs taken from close-ranges is known as Close Range Photogrammetry.[2] Though the application fields of Close Range Photogrammetry are numerous and quite diversified, these have been grouped into three major categories namely Architectural, Biosteremetic and Industrial including engineering, by the commission V of the International Society of Photogrammetry.[2]

A review of literature will show that a lot of work has already been done in these areas and that a variety of techniques have been put forward for such applications from time to time. The work reported in this dissertation is confined to photogrammetric applications in architectural documentation only. The purpose is to acquaint the Architects and Archaeologists of the photogrammetric techniques and infuse in them interest for adopting these in their own interest and in the national interest of maintaining the record of important structures.

It is noteworthy that the very first measurements ever carried out using photogrammetry were on the monuments.[3] Interestingly, it is also a fact that the term photogrammetry was introduced by an Architect Al'brecht Meydenbauer of Germany, who made the first photogrammetric survey in 1867. For over a century thereafter, photogrammetric methods and equipments have continued to be developed and refined. In recent years the architectural application of photogrammetry have undergone considerable expansion both in scope and diversity.[5]

1.1 THE PROBLEM

The professional demand of an Architect is to design and foresee the construction of objects in 3-D space. He is also required to maintain a record of the architectural excellence of the past for the purposes of restoration and reconstruction of national heritage.

Our country has the proud heritage of multitude of monuments which reflects, not only, the culture of various epochs but also the type of architecture prevalent in ancient days. Hundreds of shrines, temples, monastries, mosques, churches, forts, tanks, pagodas, palaces, towers and other historical buildings speak of the architectural enrichment of physical environment and testimoney to the architectural wisdom of our predecessors. An urgent need at the present time is to preserve this valuable heritage, for which we have to give special attention to have proper documentation of these structures of excellence. A documentation at the level of elevational details of architectural components of these artifacts is desirable to have precise records.

In this dissertation it is proposed to establish a methodology to carry out Photogrammetric Surveys of monuments and to show the merits of the technique of Close Range Photogrammetry (C.R.P.) over the conventional approach. Close Range Photogrammetry goes a long way in helping Architects to develop a study of information on documentation and record of structures in concise manner. With the help of stereo-pair of photographs of an object, three dimensional model of the object is obtained, which can be measured to record the desired data. The ultimate utilisation of this could be towards the establishment of

National Library of Data Records (N.L.D.R.), which subsequently may be published. This will also serve as a valuable reference for Architects, Archaeologists, Historians, and students in these fields. For the experimental studies the St. John's Church at University of Roorkee campus is selected.

1.2 DOCUMENTATION OF HISTORIC STRUCTURES

There are multiplicity of agencies looking after the monuments of National Heritage in India, resulted in poor maintenance. Many of these monuments are unattended and left in wilderness.

As per the records, there are 10,584 monuments only in Union Territory of Delhi, which are listed with various agencies as the monuments of national heritage or architectural excellence. Unfortunately, only 4,213 of these structures are properly documented while remaining 6,361 have been left unattended. Notwithstanding the large amount of task for documenting these monuments various agencies like Archaeological Survey of India, Delhi Development Authority are contemplating strong steps to cover up the gap. Similarly, millions of other such important structures in the country have been left out unrecorded. This situation of improper documentation of monuments is mainly because of lack of proper documentation techniques.

The traditional method of recording by taking actual measurements at site, which still is being used by Archaeological survey of India and other organisations does not cope up with the magnitude and need of the problem. Hence, there is a need to substitute this method, by some faster methods such as photogrammetry. The techniques of C.R.P. for architectural documentation envisaged here can easily replace the traditional methods, since it has some intrinsic advantages over earlier methods as discussed in detail in Chapter-3.

1.3 PRESENT TECHNIQUES

The Archaeological Survey of India is responsible for the documentation of historical structures in the country. It would involves tremendous amount of work to be carried out, if we consider the size of country and our rich past both qualitative and quantitative. The Archaeological Survey of India has often been expressing its inability to take care of all the listed structures in the country. This may be primarily due to lack of techniques and funds. The techniques used by Archaeological Survey of India is time-consuming, uneconomical, lengthy and bulky. Even the accuracy of recording is far away from accuracy desired by the Architects, Engineers for restoration and reconstruction.

The present method of recording of these monuments, used by Archaeological Survey of India can be divided into two parts first the graphical documentation and secondly the pictorial documentation.

The term graphical documentation has been taken by "Graphic unit" of Archaeological Survey of India. The recording is done by traditional method of sketching and hand measurements of the various details. The data recorded at the field is brought back to the studios and subsequently drafting of the monuments takes place to finally get the end results.

The pictorial documentation is done for detailing the architectural components and small portions of structures or pieces, exhibiting culture and traditions such as coins etc, Very rarely a pictorial documentation is done for a monument. However, they do possess a few records of monuments of national heritage. Although these do not furnish all the necessary information, as far the restoration and reconstruction is concerned, but they ideally supplement the graphical documentation.

Agencies such as Delhi Development Authority, National Association of Students of Architecture, which are also playing an important role in documentation of monuments of India, are still applying the above techniques of recording these structures and their environment.

1.4 EMERGING TECHNIQUES

The Close Range Photogrammetry (CRP) which was used for recording of historical monuments in early days was largely forgotten in the pre-world war period. In recent years, however, it has regained its utility.

The introduction of Close Range Photogrammetry, has opened a new avenue for the Architects and Archaeologists. This new technique, facilitates the research in the field of documentation. The process is quick, condensed and offers an easy straight forward approach to related measurement problems. The in-accessibility of object, which had the impact as limitation of traditional method of recording has been nicely overcome by this technique. The details of the techniques of Close Range Photogrammetry have been discussed in detail, in Chapter-3.

CHAPTER 2 DEVELOPMENT OF CRP

CHAPTER 2 DEVELOPMENT OF CRP

The origins of photogrammetry lies in mid 19th century. The subject has now reached a very advance developments. It would be interesting to take this transition step by step i.e. photogrammetry, Close-Range Photogrammetry and then Architectural photogrammetry respectively.

2.1 HISTORICAL DEVELOPMENT

A glance at the history of photogrammetry shows that it was the French army colonel Aime Laussedat, who in middle of nineteenth century, developed the photogrammetric methods for mapping, using photographs, taken with metric cameras. From these photographs horizontal pencils of rays were reconstructed. The plane table photogrammetry made it possible for the surveyors to compile a map, using point by point intersection technique.[15]

The initial problem of identifying homologous points on two photographs was solved by invention of the stereo comparator, which resulted from independent work in 1901 by Pulfrich in Germany and Fourcade in South Africa in 1903.[6,7] The stereoscope had already been invented between 1830 and 1832 and the floating mark principle in 1892 by Stolz. Steps towards part automation were taken in 1907 by Thompson and in 1908 Von Oreal's idea was developed by Zeiss in Jena into first stereo autograph. This, after further development, allowed continuous plotting of planimetery and contours, the result being presented graphically, directly on plotting table.

Thereafter, there has been a continuous allround development in Cameras, films, plotting instruments and automation techniques to establish photogrammetry as the best method for extension of control data and plotting of various objects.[14]

2.2 EVOLUTION OF CRP

Although air survey techniques received wide spread adoption in the years between two world wars and thereafter the development of Close Range Photogrammetry may be largely a phenomenon of last two decades. There are ofcourse, exception to this generalisation, amongst which the work of Meydenbaur is worth mentioning. Nevertheless 1960's and 1970's have seen a tremendous increase in the application of Close Range Photogrammetry in the field of Architecture and architectural documentation.

The application of Close Range Photogrammetry for recording can be traced back to Euclid (250 B.C.), Leonardo da Vinci (1452-1515)[12] and others who analysed the difference between two images seen by left and right eyes. In 1867, Meydenbaur drew plans of cathedral of witzler with the help of photographs.

In CRP also central Projection (boundles and pencil of rays) is used for image formation. In addition parallel projection for Scanner generated images (direction or distance) and others may also be used. Thus not only camera-film but also X-rays scanning and transmission electron microscopes, photodiode arrays with analogue or digital output can be used for photogrammetric measurements in Close Range Photogrammetry. The derived quantities which may result from these measurements are, for example Spatial data, area, volume, angles, and other digital or graphical data. Time is sometimes the fourth dimension in Close Range Photogrammetry which is utilised to yield speed, acceleration and deformation measurements.[13, 14]

It may be noted that almost any kind of object can be measured by photogrammetry, the only real condition being that it should be possible to obtain image of the object and area of interest.

Many of today's CRP applications uses principles of terriestial photogrammetry which was evolved during early years of science along with aerial photogrammetry.

Photogrammetric principles were applied very early in evaluation of medical X-ray images mainly by Davidson, 1898; Lambet, 1901; Druner, 1905/6; Pulrich designed first X-ray stereoplotter in 1918. Hasselwander may be called father of medical X-ray photogrammetry, because of his pioneer work done in first half of twentieth century.[20]

Among the early application of Close Range Photogrammetry is surveying of glaciers. Finsterwalder started to use plane table photogrammetry in 1889. The possibility of determining changes in size and velocity of glaciers by photogrammetry was soon recognised, and thus the fourth dimension of time included in the analysis of measurements.[28]

2.3 ARCHITECTURAL PHOTOGRAMMETRY TECHNIQUES

The many fold increase in the application of Close Range Photogrammetry in several fields may be attributed to allround development in photogrammetric instrumentation and computing facilities. This is also due to general growth in demands of science, engineering, architecture, medicine for quantitative information of all kinds and photogrammetry provides a novel way in which this data can be advantageously obtained.[23] The development of analytical, rather than graphical methods, has also provided a flexibility which is attractive for disciplines, of architectural application as well as in other fields.

Of the various methods reported, the following have been utilized specifically in the field of architecture, and are of interest to this dissertation.

2.3.1 Magnification of Drawings

Drawings at the scales of 1:10 and larger, present slightly different problems and while the equipment used may be the same. Much larger photoscales are needed for plotting at these scales. A number of metric camera either do not focus down to the required distance or require special adopters to reduce the focussing distance. The officine Galileo Veroplast for example, can have one or two spacers inserted between lens assembly and the camera body in order to allow focussing in the ranges of 4.5 M to 2.4 M and 2.3 M to 1.6 M. The closest focussing allows photoscales of approximately 1:10. A problem of camera alignment may occur when very short base lengths are involved and in such cases a stereometric camera is useful.

2.3.2 Orthophotography

Many orthophotographs of architectural features have been produced in recent years. Seeger (1976) and International Committee for Architectural Photogrammetry (CIPA, 1977) have given examples of a number of sources.[39]

The production of orthophotographs, from suitable photographs of elevations of buildings is technically quite feasible. This method provides a photographic image free of perspective errors of the single photograph and is produced far more cheaply than the line drawing and with the benefit of showing far more details than is possible in a line drawing.

The photographic image is very useful, particularly for facades, which consists of brickwork, rubble work or with features such as painted ceilings. This is partly due to consideration, such as planning law, but is also due to the simplification which the line drawing gives. It removes the excess details which often make a facade or its photographs too complex to analyse. It is possible to trace a line drawing directly from orthophotographs.

There seems, no doubt that orthophotograph has a very valuable part to play in the contribution of photogrammetry to architectural documentation. Orthophotography is not yet in general use in the architectural field but its use is very likely to grow. The future of orthophotography in architecture may be closely tied to its development in cartographic work. In particular, the trend towards complete automation of the process, for example Keating and Boston (1970) could be particularly useful in architectural work.[12]

2.3.3 Deformation Measurements

Deformation measurements may be considered in two categories: firstly a measurement of the existing deformation of an architectural feature, and secondly, as a method of monitoring movement in a structure.[20,21] The first application is fairly straight forward, as the normal occuracy tolerances applicable to architectural work usually provide satisfactory results. The second consideration i.e. the monitoring of movement in a building structure usually demands the highest standards of accuracy which photogrammetric process can provide. This is because movement of structure over a short time scale is usually very small and it may be necessary to detect changes as small as 1 mm or 2 mm. In first case of detecting and measuring deformation in a static mode, results up to ±10 mm accuracy are usually quite adequate and these can be measured directly on 1:50 scale elevation drawing.

Monitoring of deformation, however, present quite different problems. In order to produce an accuracy of ±1 mm or ±2 mm in a large structures, the photogrammetrist has to consider all the various possible sources of error. Very thorough control, based on stable points, has to be established and possibly adjusted using microgeodetic processes before utilising the same for photogrammetric operations. Evidently there must be special reasons for undertaking such work photogrammetrically and indeed this is a field where, despite the thoroughness of technique required, photogrammetry can provide the architect or building surveyor with probably an unique service. Photogrammetry allows any number of precise three dimensional measurements to be taken as well as the possibilities of taking new measurements from photography if the analysis of the problem should change.

2.3.4 Inverse Photogrammetry

A problem frequently encountered by architects and planners is to show the effect of new building or other structure in relation to an existing landscape or townscape. The usual solutions are to produce perspective drawing or to draw the new structure on conventional photographs.[26] The first process lacks realism and second accuracy. Using the photogrammetric process in reverse, it is possible to take photographs of the site with a metric camera and with a plan of the site and co-ordinates of new structures, re-produce these co-ordinates in their precise positions on the metric photography. The photographs can then be examined in the sure knowledge that the view is exactly as if the structure was already existing. It can be seen that, while the process is technically correct, the result may be no less ambivalent than that obtained with conventional perspective drawing or photographs. Nevertheless, the process can give a much more accurate indication of the visual intrusion and mass of a new structure than conventional processes.

2.3.5 Infra-Red and X-Ray Photogrammetry

These methods depart considerably from conventional photogrammetry. All surfaces emit thermal radiation, the amount of which varies with the material.[10] This heat emission can be detected in infrared wavelength band and equipments such as, Aga Thermovision 750 enables this heat emission to be monitored on a Television Screen or recorded on a photograph. The process can be used to detect any form of heat variation, such as the presence of water or electrical services or the heat loss from the surface of the building. The process which is of most interest in the context of architectural photogrammetry is that of detecting hidden structural features within a facade. This process promises to be of considerable value but it should be noted that it cannot provide the accuracy of conventional photogrammetric drawings.[26]

Portable X-ray machines enable specific areas of structures to be examined internally. The process is similar to that used with static X-ray cameras. The X-ray machine is placed on one side of the feature and an X-ray film behind it. The results are satisfactory but the process suffers two disadvantages. Firstly, only a very small area may be examined at one time, secondly the process is limited by the thickness of the object under examination.

Unfortunately, not enough work has been done in either of these areas, to enable them to be evaluated in economic terms, but there is undoubtly considerable potential, particularly for infra-red process.

2.3.6 Rectified Photography

As an alternative to conventional hand measurement or stereophotogrammetric methods, considerable use may be made of rectified photography to provide a quick and cheap method of recording facades. This process is known by various names, such as photomosaics, photomontage and photodrawings, but the term rectified photography is most convenient.[4]

The process consists of taking photographs in a plane which is exactly nearly parallel to a facade and printing them, true to scale. This product provides the architect with a useful working document, which shows for more details than would be available on a conventional line drawing. The process however does not provide the accuracy of true photogrammetric work or orthophotography.

Rectified photography is a very useful technique for the architects. It has the advantages of simplicity and economy. The disadvantage is that it is not reliable as a measured drawing and no depth information is available. The photographic form of representation is very useful as a great deal of details, particularly of the condition of a facade can be easily seen. Rectified photography may be a useful first product in introducing the architect to photogrammetric techniques.

2.4 RELEVANCE IN ARCHITECTURE

Photogrammetric techniques are continually been refined as practical measurement tool. The above review has concentrated on standard techniques in use at present and these methods may be expected to be of the use for some years to come.

However, the techniques described in chapter 2.3 are particularly useful in Architectural photogrammetry and discipline of Architecture itself. It has been found from the various applications that adoption of these techniques may provide a very useful documentation technique for the working of an architect. It is expected that it will enhance the glory of the profession itself and introduce a new era of documentation and maintenance as well as the design and reconstruction of structure and environment of national heritags.

CHAPTER 3 CRP TECHNIQUES V/S TRADITIONAL METHODS

CHAPTER 3 CRP TECHNIQUES VS TRADITIONAL METHODS

As mentioned earlier the recording of monuments and structures of national importance have been carried out by means of hand measurement and sketches from ancient times. Recently the technique of Close Range Photogrrammetry has been utilised for documentation of historic structures. In the following a comparative study of these two methods has been done to bring out the potential and merit of CRP approach.

3.1 TRADITIONAL METHODS

Department of Archaeology has been recording monuments of national and historical importance by means of free-hand sketching by experts and measurements at site. This approach is not only time consuming but sometimes incomplete due to physical in-accessibility of structures which render accurate measurements impossible.. Moreover the work involved at site becomes too voluminous and turns to be expensive in terms of time and money. The difficulties of measurement of structure at site are well known, to be discussed here further.

3.2 POTENTIALS OF CRP

In Close Range Photogrammetry (CRP) since the measurements are made on photographs taken from some distance from the object, these difficulties are easily overcome.

The potentials of CRP which are of immense help to Architects and photogrammetrist, in the field of Architectural photogrammetry, may be listed as follows:[2,5]

(1) The object (or building) is not touched during CRP measurement process.

(2) Data capture (or acquisition) is quick and condensed in nature.

(3) The photographs store both Sementic and metric data with high density.

(4) The deformation and movements in structure can also be measured and monitored.

(5) Evaluation of metric photographs can be done at anytime in office a laboratories any number of times at later stages and by different experts of different fields.

(6) Invisible part of spectrum can be used for creating images like X-rays, infra-red rays etc. for capturing some esoteric details.

(7) Complicated shapes and movements can be measured comparatively with much ease.

(8) Employing the stereo photogrammetric procedure continuous contouring of irregular objects can be done easily resulting in better overall accuracy.

3.3 COMPARATIVE ANALYSIS

It has oftenbeen suggested that most valuable use of photogrammetry in architecture would be in creating archieves of metric photography and related survey control data in order to preserve records of an architectural heritage against the likelihood of some individuals or multiple catastrophe. This objective has unfortunately rarely been realised, apart from such notable exceptions as Maydenbauer's recording.[5]

From this point of view, photogrammetry seems well suited for this task since the survey photographs and control measurements can be obtained quickly in comparison with hand measurements. The photographs contain a great deal of data can be stored indefintely for preparation of drawings only when needed. This advantages prompt that photogrammetristic's and architect's should work to get such archives established in the national interest.

The adoption of photogrammetric methods may provide solution to several specific documentation problems, arising during the restoration and study of classical antiquity and national heritage. What makes photogrammetric methods indespensible is the scale of optical refinement, accuracy, speed,time, reliability and economy compared to traditional methods.

Depicting large areas of irregular masonary of highly complex Hindu Temple Architectune and gothic Architecture of west which earlier was not possible, is now feasible by employing Close Range Photogrammetric techniques. The plasticity of flowing forms can not be fully explored by drawing methods, but can be done easily by photogrammetric methods.

3.4 INFERENCES

Photogrammetry has wide range of application in architectural recording. It may be principally used for preparation of drawings of facades though there are number of other areas where it can be applied.

Photogrammetry offers several advantages over the conventional measurement processes, which makes its use worthwhile. The accuracy, speed, safety, ease of recording details and archival value of the photogrammetric process given the architect a valuable technique for the study and restoration of building.

Recently a Indian National Trust for Art and culture Heritage (INTACH) has been found, which is also been entrusted with the conservation of these monements. At present the trust is employing traditional method of recording, and documentation. However, application of photogrammetic Technique for this will be not only time saving and fast but accurate also.

CHAPTER 4 CASE STUDIES

CHAPTER 4 CASE STUDIES

As per records no work has so far been done in the field of Architectural Photogrammetry, in our country. Thus the case studies reviewed by the author are from England and U.S.A. are given below:

(1) Restoration of Castle Howard, Yorkshire, England (U.K.)[25]

(2) Statue of Liberty Restoration, New York (U.S.A.)[28]

The selection of this case studies has been done by keeping in view that they must cover up both the eras of Close Range Photogrammetry. The first case studies is based on the work done by Mr. E.F.Thompson in the year 1960 while the other one is a current example of restoration of status of Liberty at in 1985-86. Although, the principle of photography in both cases are the same large variation in the analysis and processing can be noted.

4.1 RESTORATION OF CASTLE HOWARD, YORKSHIRE, ENGLAND (U.K.)

Case Study - I.

The importance of use of Photogrammetry in reconstructional survey of important monuments damaged due to some reason on the other may be appreciated by this example.[25]

The author has personally visited this building at England and can rightfully say that it has been restored back to its glory. It is difficult to define the castle and one must see the entire complex of which castle is part to appreciate it. The following passage aptly describes the glory of this castle.

"Nobody had informed method at one view I should see a palace,a town, a fortified city, temples on high palaces, woods worthy of being each a metropolis of Druids, the noblest Lawn in the world fenced by half of horizon, and a mausoleum that would tempt one to be buried alive, is short, I have been gigantic palaces before, but never a sublime one."

- WALPOLE.

Castle Howard stretches over the ground where for several hundred years had stood a Henderskelf castle. This had been rebuilt in 1683, but was gutted by fire only ten years later the method used for restoration of two damaged parts i.e. the main cupola and the hall ceiling are based on two different approaches. The recording of main cupola was done by using stereophotographs and employing the conventional usual photogrammetric survey technique. The approach was not same in the case of ceiling. There was not a single photograph available of Pellegrim's fresco taken centrally and vertically upwards. Only an oblique photograph of the painting was available. Hence, the researchers made some simplifying assumptions that the central vertical view was truely central and truely vertical and the camera position was at the geometrical centre of the rectangle formed by the columns of the hall. They also assumed that columns are vertical and nadir point of the oblique photograph was accurately given on the photograph by the intersection of images of these columns. The results were obtained on this basis.

4.2 STATUE OF LIBERTY RESTORATION NEWYORK (U.S.A.)

The statue of liberty commemorates more than American's independence or their alliance with the French. It stands as a memorial to 19th century technology. At the time of completion in 1886, it held the record of being largest concrete pour and the tallest iron structure. Soon after its completion, it received one of the first passenger elevators and indoor lighting systems.[28]

The current restoration shows every sign of carrying on that tradition. Not only does it utilize the newest technology, but some which was never before used in a building.

Some of the technology used in the statue's restoration is new only in the sense of its having been largely forgotten. The National park service, who look after it, has taken seemingly opposite approach with the statue's flame. Originally an all copper clad form, the flame soon after its erection, had glass panes cut into it in an effort to convert the statue into a light beacon. Unfortunately, only a few good photographs exist of the flame as finally installed. The restoration team has matched, the flame in that one photo using digitised, photogrammetric images of current flame, and plaster models photographed at the same angle at the same angle as the original.

Diagnostic techniques have played a crucial role else where in the restoration. Ultrasonic calipers to gauge the thickness of the copper skin by measuring the rate at which sound passes through the material and convering that time-lag into lenear dimension; X-ray equipment to locate cracks or voids in the iron structures by recording the passing of X-rays through the material, anemometer to measure wind forces, and stress guage to detect overstressed members. Not only every old building requires such diagnostic, but should the need arise, many of these techniques are available in better equipped testing laboratories.

When the statue of liberty recopens on July 4, 1986, its reconstruction technology may not concern many people. The statue's symbolism has always overshadowed the structure itself, even though the technology advanced by its construction has certainly contributed as much as its symbolism to their actual freedom.

4.3 *FINDINGS*

No doubt all restoration of ancient buildings raises problems but when there is no accurate record of what has been destroyed, the difficulties are magnified. In case of Castle Howard, accurate drawings did not exist. But for photogrammetry the restoration of these building would not be possible and it could never regain its glorious past.

Statue of Liberty restoration explores the highly advanced and sophisticated techniques, in restoration of historical monuments. Some may find this a little surprising in such an important building and it makes one wonder to how many other monuments this applies at the present time. But it won't be improper to state that these techniques, will receive a widespread welcome in the field of architectural documentation in near future.

CHAPTER 5 METHODOLOGY OF CRP

CHAPTER 5 METHODOLOGY OF CRP

The term "Close Range Photogrammetry" has come to be used in photogrammetric literature more predominantly than the traditional non-topographic photogrammetry. Although the principal use of photogrammetry, since inception, has been in the field of topographic mapping, its applications in various other fields and development of new techniques to solve the diverse requirements of these new fields, gave rise to the term, non-topographic photogrammetry. Close Range means that the object to camera distance is limited. Some advocates 300 m as a maximum limit, while the minimum distance may be fraction of a millimeter where macro and microscopic photographs are used for measurements. These both are regarded as falling within the scope of Close Range Photogrammetry.

The Close Range Photogrammetry system includes three sub-systems:

(1) Data Acquisition

(2) Data Reduction

(3) Data Presentation

All of these are discussed in detail later in this chapter.

5.1 DATA ACQUISITION

Data acquisition system generally refer to the mode of acquiring photographs or imageries of the objects of interest on which measurements could be carried out.[9] A broad classification of the acquisition system, is the conventional and non-conventional imageries which can be easily distinguished.

By conventional imagery is meant the photographic image based on the central projection of the object on to an image plane through a lens system, as in a photographic camera. Imagery acquired by any other means or using special devices such as various types of sensors or other electro-optical techniques, is generally called the non-conventional imagery.

5.1.1 Conventional Imagery

By conventional imagery is meant the imaging system that have a lens and an image plane, such as photographs based on the central projection of object on to an image plane. These can be obtained by using both metric and non-metric cameras.[1]

Simplest way to classify the cameras in metric category is by the existance of fiducial marks and knowledge of focal length. A dominant feature of metric cameras is that the radial distortion is negligibly small for most practical applications. Generally the glass plates are prefouned as emulsion base, since this prooves the best solution possible from the point of view of stability.

Non-metric cameras are defined as those which do not have fiducial marks and for which interior orientation elements are unstable and partially unknown. However due to number of advantages which non metric cameras offer over the metric cameras, particularly the cost and easy availability the use of these cameras is increasing day by day.

The correct use of non metric cameras, however, can help tremendously in documenting the immense amount of data related to monuments and sites. With proper processing non--metric camera can furnish impressive results.

These cameras (non-metric) are specially useful for taking photographs of inner side of an object like chimney, dome, tower, arches and plastic decorations of the vaults at very oblique angle to preclude gaps.

5.1.2 Non-Conventional Imagery

An image system which does not, use a lens and image plane is called is the non-conventional system.[1] To this group belong X-rays, T.V.system, digital images etc. Scanning electron microscopes (SEM), Holograms, Moire topography, solid state Imagery devices (SSID), (thermal or Emitted.)

5.1.3 Ground Control Acquisition

All photogrammetric procedure requires ground object/ Space Conrol data for correlating the photographic measurements to the measurements on the object.

The most thorough and accurate methods of control involves the provision of at least four premarked points, co-ordinated by geodetic methods using precise theodolite intersection method. This method is very accurate and reliable, but it is time consuming and expensive. It can often take longer time to achieve controls than to take the photography. The minimum acceptable control is to have taped distances and points of known height in each model. This method though, quick and cheap is not so accurate as it provides no control in depth, if cross section is required. The use of targets is recommended wherever possible. The extra time taken in attaching them to the facade is more than compensated by the speed and reliability of point identification which they provide, during both field work and photogrammetric plotting.[3]

5.2 DATA REDUCTION

After the imagery, in the form of suitable stereo or convergent photographs has been acquired, the next phase of the photogrammetric system is the reduction of data. The basic principle of data reduction system is the reconstruction, at a certain known scale, of a well defined and geometrically precise model of the photographed object, which is subsequently submitted to precise measurements and further processing. The reconstruction of model can be accomplished by employing either an analoge approach or on analytical approach or a semi-analytical approach. The choice of a method depends largely on the form and accuracy of the desired final output, the data acquisition system chosen and the avilability of plotter and computer facilities.[11]

5.2.1 . *Analog Approach*

In this approach normal or near normal stereophotographs of the object are used to create a three-dimentional model on a photogrammetric plotter by physical means, either optically or mechanically. The final output is in the form of graphical plotting including controuring of the objects.[10,15] Analogue approach lacks flexibility and versatility because of the fact that most of the photogrammetric stereoplotters designed originally for vertical aerial photography, do not have sufficient photographic distance and orientation angle ranges to accomodate photography taken with stereometric camera and many of the metric and non-metric cameras.

5.2.2 Analytical Approach

In this approach a mathematical model, rather than the physical model of the object space is created from the measurements of a number of image points common to two photographs of an overlapping.[11] In other words a mathematical model is constructed to represent the relation between the points in the object space, the perspective centre of the lens and corresponding points on the image space. The application of numerical analysis to this model results in the solutions of problems of camera calibration, space resection and orientation, space intersection of photographs.

This approach is particularly suitable for details of monuments, and in checking on their stability through the use of digital models, by forming digital models encompassing the monuments fundamental points as the skeleton of its structure. One can study the proportions defining the volume and compare the forms. The approach offer greater degree of accuracy and flexibility than analog approach.

5.2.3 Semi-Analytical Approach

This approach results from the combination of analog and analytical approaches, by interfacing a conventional plotter with digital computer. The stereomodel of the object is formed on the plotter by a suitable relative orientation procedure (i.e.the two projectors are manipulated relative to each other in such a way that all corresponding rays intersect in space. This condition can be achieved if it is ensured that at least 5 corresponding rays intersect in space.) and is measured with the help of encoders and automatic recorders attached to plotters. The computations are subsequently carried out on the digital computer using analytical methods.[9]

This method is useful when the amount of data to be recorded is much larger and is required in graphical as well as in digital form.

5.3 DATA PRESENTATION

The output form of photogrammetric processing can be presented in number of ways. The data presentation, depending upon the requirements, can be obtained in three ways.[13,14]

- Digital Presentation
- Graphical Presentation
- Pictorial Presentation

5.3.1 Digital Presentation

With the development of digital electronic computer it has been found useful to represent the data in the form of digital model. Numerical parameters, such as Area, volumes which are generally required in the surveys of historical monuments and sites, can be easily computed from digital model with the help of electronic computer.

Graphic products, such as contoured maps and perspective views from various angles can also be generated provided suitable software are prepared. These graphic products are generally very useful in architectural documentation, because these documents can be more easily interpreted by those who have to make decisions and need to judge the proposed transformation of the traditional aspects of historic centres.

5.3.2 Graphical Presentation

This presentation is very common and popular. The example of the presentation are contours, maps, cross-sections and profiles. Architects responsible for the conservation and development of monuments and historical sites, have found it useful to adopt the normal plan-section and elevation presentation used for buildings, to express the volumes of an historic sector or even an entire town.

5.3.3 Pictorial Presentation

Pictorial presentation of objects in the form of photographs or sketches is very useful in architectural applications, because it gives an overall view of the various surroundings, landscapes and environmental setting of the monument.

Many of times it avoids an actual site visit by all the personnel as well as save field time if suitable pictures are obtained. It also serves as a document for future reference and as will be seen in the next chapter, this can be used for photogrammetric measurements, under special circumstances.

CHAPTER 6 EXPERIMENTAL PROGRAMME

CHAPTER 6 EXPERIMENTAL PROGRAMME

The application of Close Range Photogrammetric technique for architectural documentation, involves detailed planning at the various stages of work. The overriding concern is to procure complete photographic coverage of the object of interest along with suitable control data. In cases where geometrical similarity is not maintained in objects, extra care needs to be given in selection of camera stations and subsequent processing.

6.1 ST. JOHN's CHURCH, ROORKEE

On the basis of these considerations and also considering limitations due to accessibility of structure and availability of suitable camera system etc., St. John's Church situated in the University of Roorkee campus itself, was selected for the application of photogrammetric technique for documentation.

This church has a long relation with the University, having been built and designed byPhilip George, Assistant Engineer, Ganga Canal, back in 1862, along with the main building of University of Roorkee, earlier the Thomason College of Civil Engineering.

The easy proximity and convenient location of church, has been a major factor for its selection. From the point of view of antiquity and old architectural practices churches represent particularly important group of buildings. In these the construction technology and aesthetics appears to be fundamentally different from those of classical antiquity. Churches retain the harmonious proportions and the sensitive layout of the classical structures. The intentional refinement, applied to churches may introduce indifference towards regularity and structural accuracy, due to inherent artistic tendencies of culture, as this depicts, the individual character of churches and contributes to its morphological diversity. The asymmetry observed in the layout of facades, the irregular shape of walls, the uneven slope of roofs and relatively unconditioned arrangement of building material, reflect some of the traits prevalent in ancient days. Further, the treatment of interior space also reveals irregularities, particularly the Domes and Vaults. These very irregularities are homogenously distributed and contribute to an identity and charm of this church.

6.2 PLANNING FOR EXPERIMENT

An Architectural Photogrammetric survey needs a careful study of monument or building and involves detailed planning of work at the various steps. Due consideration has to be given to the availability of facilities, need and requirements of output on the basis of which techniques for data presentation and reduction have to be chosen.

For planning the experiment presented here not much choice was available with regard to data acquisition and reduction instrumentation. For data acquisition, three types of cameras were available in the photogrammetry laboratory of the Civil Engineering Department viz., aerial camera wild RC5A, an ordinary amature camera and Zeiss stereometric camera SMK 120. Out of these the stereometric camera was selected on the basis of following considerations:

(a) Its a metric camera, with known interior orientation characteristics.

(b) Stereophotographs are obtained simultaneously from one camera station.

(c) Shooting parameters (e.g. focal length, coverage etc) were in accordance with the monument selected.

The front face of the selected monument, namely the St. John Church, could be covered fully from one set up of the camera nearly 10 meters away from the monument which distance is close to the optimum photographic distance advocated by the manufactures.

For data reduction the availability of plotting instrument was limited to WILD A8 plotter, available in the Photogrammetry laboratory of the Civil Engineering Department and Planicomp C-100 plotter available with the Survey of India, Dehradun. The Planicomp C-100 plotter was preferred, because it can accomodate both terrestrial and aerial photographs as well as the negative/diapositives, obtained from Stereometric Cameras in terms of focal length. The WILD A8 plotter doesn't have the focal length range to accomodate the diapositives obtained from Setereometric camera and is essentially a topographic plotter for aerial photography. Planicomp C-100, which is a semi-analytical plotter, provides greater overall accuracy and flexibility and hence was selected for data-reduction.

For data presentation, the choice was between two modes namely the graphical or the digital output. As discussed earlier since the data documentation was to be limited to graphical form only, the graphical plotting mode was preferred in the present case.

For obtaining the desired ground control data, targets were planned to be fixed on the church building as well as outside of the building, to be determined by geodetic survey method. Two theodolite stations were selected such that for all the target points the intersection of rays from these stations form well conditioned triangles to define the targetted points properly.

6.3 INSTRUMENTS

As mentioned above, the Stereometeric Camera, SMK 120 was used for data acquisition purpose and planicomp C-100 was used for the plotting of the details in the present experiment. Some important characteristics of these instruments are given below.

6.3.1 Camera

For data acquisition, it was planned to have the conventional method of photography for which the Stereometric Camera (SMK-120) was used. The Stereometric camera consists of two matched camera units having focal length 60 mm mounted on each end of a base bar, such that the relative orientation of cameras with respect to each other is known. The camera axes are set at right angles to the bar and are parallel. Both cameras can be rotated about the base bar axis so as to cover the objects in height dimensions if so desired.

The use of Stereometric camera has several advantages, the important one being that as axes are at right angles to the plane through the objects being photographed produced, and if a proper Base/Distance is achieved, the analysis becomes comparatively simpler. Since relative orientation of photographs is known, the creation of the Stereomodel is simplified. With base accurately known scaling can be done easily or the absolute orientation can be achieved by using ground control points. The possibility of synchronised exposures allows each pair of photographs to be obtained under same condition of illumination. For camera film, cut film was used. Traditionally, glass plates are used for such photography and infact are to be preferred but since these have become difficult to obtain and are expensive cut films may be used. Cut films offer advantages in as much as these are light, relatively stable and easy to handle.

6.3.2 Plotting Instrument

The instrument selected for plotting is the semi-analytical plotter, Planicomp C-100, manufactured by Carl Zeiss, West Germany. It can accomodate different types of photography viz aerial terrestrial and even oblique. The data can be recorded in the disc computer (HP 1000) attached to it, and the output can be obtained either in digital form or graphical form. Other characteristics of this instrument are that it can take as input the following types of data products:

(a) Paper prints.

(b) Diapositives/Negatives

(c) Colour/black and white image size upto 240 x 240 mm.

(d) Any focal length can be accomodated.

Besides, the following corrections may be applied to the images:

(a) Affine film shrinkage

(b) Radial symmetric distortion refraction

(c) Earth curvature

(d) Affine map shrinkage

(e) Instrument irregularities

The output can be obtained in two forms i.e. numerical and graphical forms. In numerical output the main feature is single point coordinate recording. The facility of automatic point positioning also exists. The graphical output may consist of planimetry and/or elevation drawings of the features. The drawings may be in pencil or pen as convenient. The instrument has got the capability to draw straight lines, circles and curves and other symbols automatically on the DZ-6 digital tracing table.

The computer (HP 1000) attached to planicomp C-100 is easily distinguished because of its efficiency and capability of handling the data. It has a memory of 64 K-bytes, 16 bit word length extendable to 256 K-bytes. The operating system is RTE IV B. The HP 1000 disc drive is a single unit that contains two disc plotters, one permanently mounted and other housed in removable cartridge. The compiler has also a proven track RTE FORTRAN IV program written in basic language and executed under control of basic interpreter.

The graphics terminal uses an 8 bit microprocessor to control most of the operations. The display can be in either form i.e. alphanumeric display and/or graphics display.

6.3.3 Accuracy

In general, if proper stereophotographs are employed in universal stereoplotting instruments accuracy of adequate standards for architectural work can be easily obtained. In those works where drawings at 1.50 or 1:100 are required, with standard 0.2 mm line thickness, an accuracy equivalent to ± 10 mm on ground can be obtained.

For high accuracy in the results it is of utmost importance that control points are fixed properly and precisely. For the present work the controls were fixed on the church building and these were simultaneously recorded both by the photography and ground surveys. For ground survey a WILDT2 theodolite, which has the least count of 1", was used for angle observations and a steel tape was used for measurements of base between the theodolite stations. A subtense bar was kept in front of the building during photography to serve as a check for scale of the photogrammetric model.

6.4 FIELD WORK

In a standard photogrammetric survey work a line drawing of a facade at 1.50 or 1:100 scale is generally produced by using photographs obtained from metric cameras and employing a stereoplotting instrument for plotting the details.

As discussed earlier, a precise photogrammetric model must be obtained for achieving desired accuracy in the documentation work.For this it is necessary that the control points fixed over the building are designed properly so that these are well defined for recording by photography and theodolite field measurements. The targets used were of size 4 cm x 3 cm made of black and white painted cards. While putting the targets to serve as control points care was taken that difference in depth dimensions in facades, was uniformally achieved. This facilitated the plotting of model at later stage, with proper accuracy in depth dimension. For checking the scale of photography a subtense bar was kept in front of the building before photography. This bar has got two targets excatly 2 meters apart, which is subsequently interpreted on photographs to obtain the scale of photograph (APPENDIX I).

The Stereopair of photographs the front face of the church was obtained by stereometric camera SMK 120 with camera fixed on tripod at ground level and with the axis of the camera horizontal and at right angles to the facades. At the same times, the theodolite stations were fixed and readings of various targetted points on facades were obtained using WILD T2 theodolite. Two set of readings each of the face left and right were taken and later averaged out to take care of instrumental error if any. The theodolite station were planned such that angle of intersection at any single point is more that 30^{o} and less than 120^{o}. The horizontal measurements were made by the help of steel tape with an accuracy of .001 meters. In all observations were obtained for 17 targetted points so that some of these could be used for checking the accuracy of the photogrammetric work.

The photography was carried out in a conventional manner. During photography care was taken the illumination is uniformed at the facade and bright sunlight did not produce shadows on the features as it might result in consequent loss of details.

6.5 LABORATORY PROCESSING

The field observation and negatives were brought to the laboratory for subsequent processing. The exposed film was developed using conventional approach and diapositives as well as contact prints were obtained. The diapositives, obtained were checked for necessary information like fiducial marks, control points etc. (PAGE 47-A).

The ground survey data was processed analytically on digital computer DEC 2050 system, (APPENDIX II) and photocordinates (XP, YP, ZP) of the targetted points were obtained (PAGE 47-B & 47-C).

The processed data both photographic and field survey was utilised in planicomp C-100 semi-analytical plotter at Survey of India Dehra Dun. For setting the model control point no 1, 2, 3, 4 and 15 were used. Rest of the points were used in checking the accuracy of the photogrammetric work. Thus, a solid model was obtained and the plotting was done from this at the scale of 1:50.

The plotting thus obtained provided the architectural drawing of the front face of the facades from which measurements could be obtained (PAGE 47-D).

LEFT DIAPOSITIVE

RIGHT DIAPOSITIVE

GROUND CONTROL CORDINATES

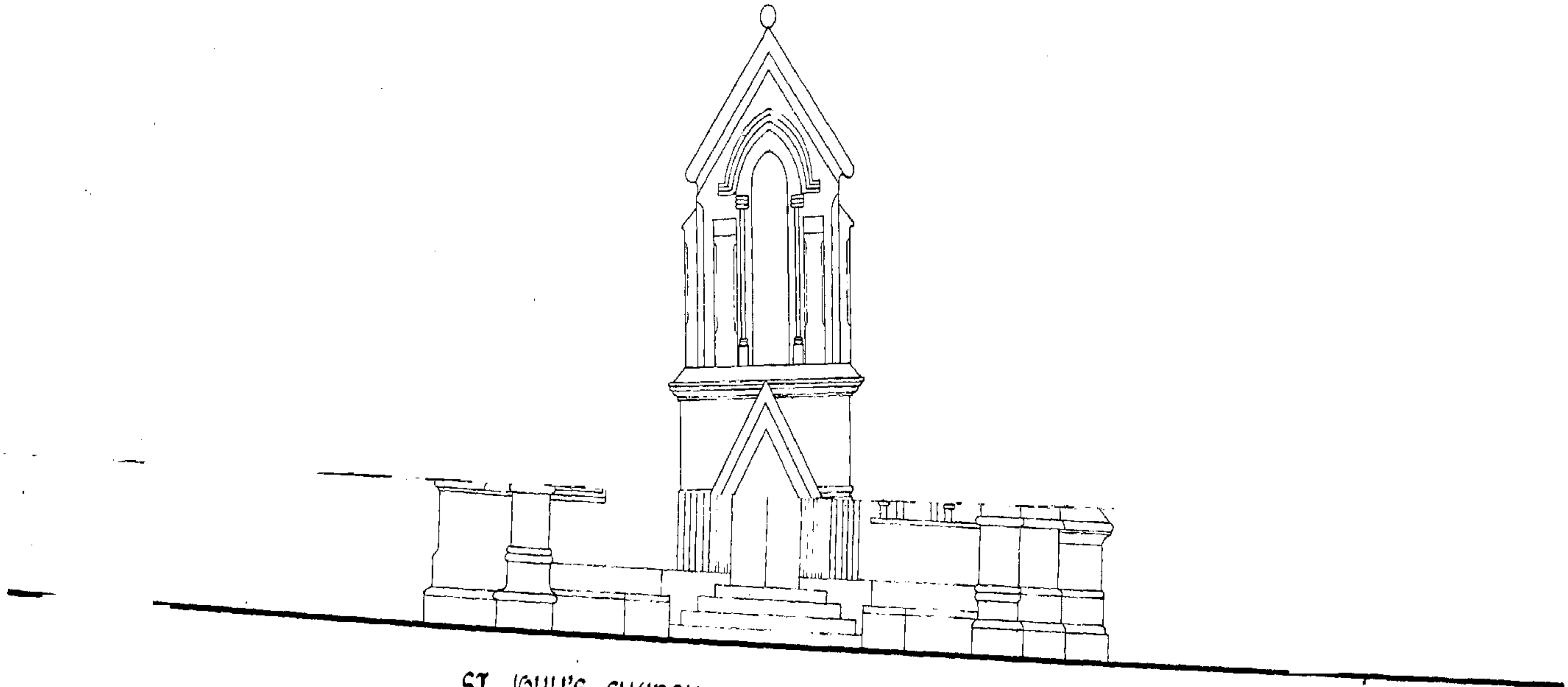
LEFT INST. X= 100.0000000M Y= 100.0000000Z= 100.0000000M
RIGHT INST.X= 119.6280000M Y= 100.0000000 M Z= 100.0780400 M
CHECK -COMPUTED Z FOR LEFT INST STATION= 99.9995670 METERS.

PIONTS		DISTANCES	XP	YP	ZP
1	D1=	19.180091METERS	103.9743900	118.7638000	101.4383400
	D2=	24.435946METERS	103.9744	118.7638	101.4340
2	D1=	18.875344METERS	104.4636400	118.3399700	107.0637800
	D2=	23.797314METERS	104.4636	118.3400	106.9770
3	D1=	19.667309METERS	106.0777100	118.7046600	105.1140000
	D2=	23.097072METERS	106.0777	118.7047	105.0973
4	D1=	19.433466METERS	107.8706400	117.7683100	100.2992200
	D2=	21.306064METERS	107.8706	117.7683	100.2961
5	D1=	20.475406METERS	107.1841200	119.1737000	101.8849800
	D2=	22.857841METERS	107.1841	119.1737	101.4930
6	D1=	20.432107METERS	107.1118500	119.1544400	108.3261100
	D2=	22.881143METERS	107.1118	119.1544	108.3537
7	D1=	22.157129METERS	109.6601000	119.9404300	100.7584000
	D2=	22.293043METERS	109.6601	119.9404	100.7553
8	D1=	21.334697METERS	109.8194200	118.9406500	105.4663500
	D2=	21.329713METERS	109.8194	118.9407	105.4674
9	D1=	21.325527METERS	109.8025300	118.9390800	110.1409600
	D2=	21.336084METERS	109.8025	118.9391	110.1666
10	D1=	21.179415METERS	109.8028700	118.7742200	114.3697600
	D2=	21.189724METERS	109.8029	118.7742	114.3578
11	D1=	21.285645METERS	109.7895100	118.9009000	118.0450800
	D2=	21.308216METERS	109.7895	118.9009	118.0310
12	D1=	21.619691METERS	111.8382400	118.0905300	100.2991400
	D2=	19.696387METERS	111.8382	118.0905	100.2954
13	D1=	22.690070METERS	112.1283000	119.1766400	104.4409000
	D2=	20.590992METERS	112.1283	119.1766	104.4311
14	D1=	22.768514METERS	112.2458900	119.1948800	108.1792000
	D2=	20.565476METERS	112.2459	119.1949	108.1694
15	D1=	23.220082METERS	113.6100500	118.8132600	105.0447800
	D2=	19.752327METERS	113.6101	118.8133	105.0000
16	D1=	25.025767METERS	115.4616500	119.6780700	101.4493700
	D2=	20.114298METERS	115.4616	119.6781	101.4459
17	D1=	24.476448METERS	115.1228200	119.2456900	101.3500000
	D2=	19.765965METERS	115.1228	119.2457	101.3551

COMPUTATION OF CONTROL POINT COORDINATES

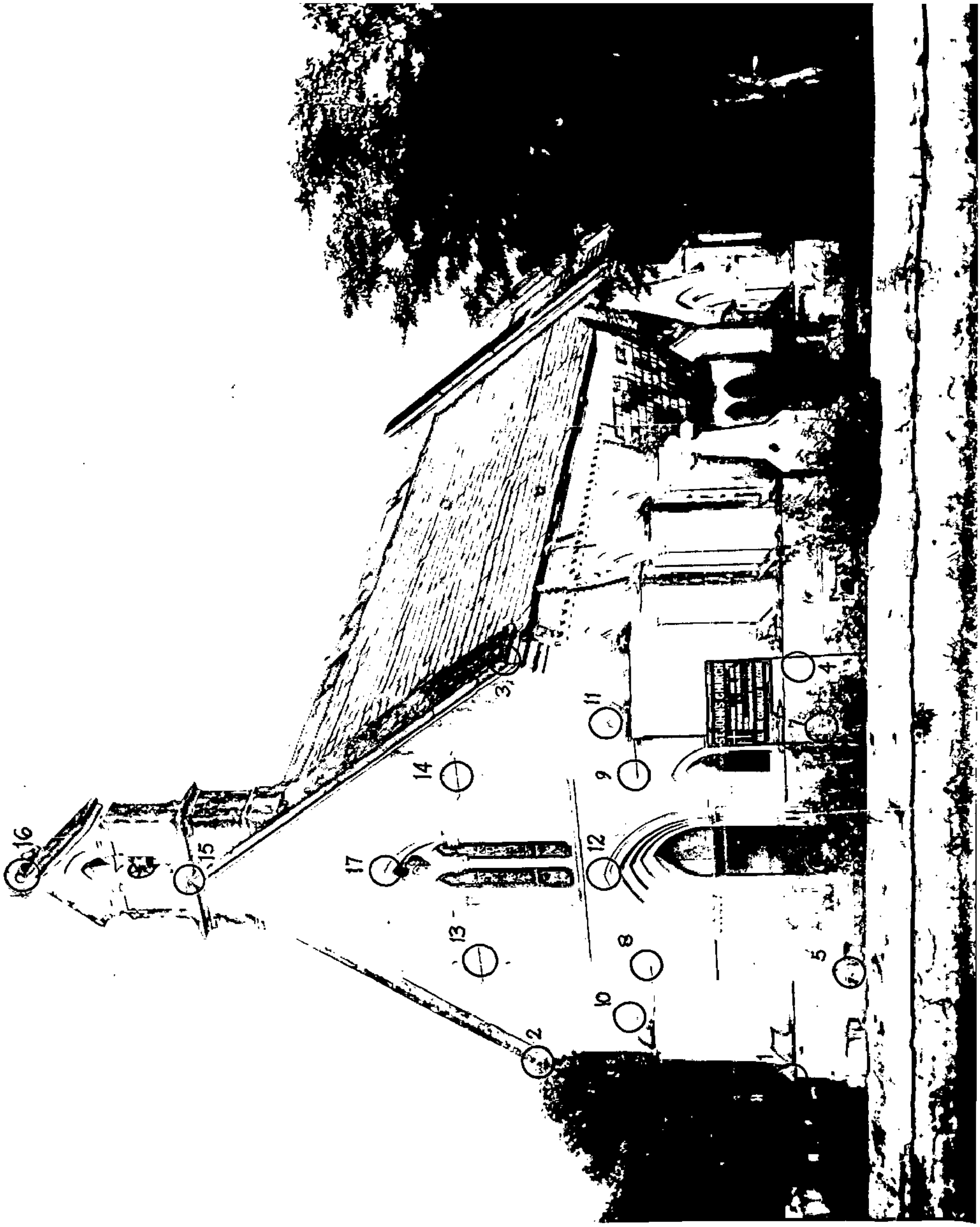
(YP AND ZP HAVE BEEN INTERCHANGE TO CONFORM TO ADOPT ED OBJECT SPACE COORDINATES SYSTEM)

POINT NO.	CONTROL NO.	COORDINATES IN METRES XP	YP	ZP
1	1	103.974390	118.763800	101.436150
2	2	104.463640	118.339970	107.020410
3	10	106.077710	118.704660	105.105640
4	5	107.870640	117.768310	100.297670
5	8	107.184120	119.173700	103.189010
6	13	107.111850	119.154440	108.339910
7	6	109.660100	119.940430	100.756830
8	12	109.819420	118.940650	105.466900
9	17	109.802530	118.939080	110.153800
10	15	109.802870	118.774220	114.363780
11	16	109.789510	118.900900	118.038030
12	7	111.838240	118.090530	100.297280
13	9	112.128300	119.176640	104.436010
14	14	112.245890	119.194880	108.174310
15	11	113.610050	118.813260	105.022410
16	4	115.461650	119.678070	101.447630
17	3	115.122820	119.245690	104.152530



ST. JOHN'S CHURCH, UNIVERSITY OF ROORKEE, 1:50

STRI.. 380597 - DATED 986 ; PLANICOMP - C100. 26(PHOTO) PARTY, NORTHERN CIRCLE, SURVEY OF INDIA, DEHRADUN, (U.P.)


ST. JOHN'S CHURCH

6.6 RESULTS

The results of the experiment were found to be extremely good as themean errorin the plot is .0239 meters. (APPENDIX III).

As discussed earlier, a graphical output was obtained for presentation and recording. Further a pictorial documentation was also prepared to supplement the graphical plotting. (PAGE 47-E).

CHAPTER 7 CONCLUSIONS & RECOMMENDATIONS

CHAPTER 7 CONCLUSIONS AND RECOMMENDATION

On the basis of the study and experiment carried out in this dissertation, following conclusions may be derived:

a. The photogrammetric approach for documentation of monuments is rapid with high degree of accuracy.

b. The data obtained is concise and semantic and may be stored in different formats for further use.

c. Since the field work is minimised the documentation by this process of recording is economical.

The results of the documentation of church have shown the above merits clearly. In this case the total time taken can be divided in the following phases.

a.	Photography	2 Hrs.	Simultaneously
b.	Control survey	6 Hrs.	
c.	Processing	2 Hrs.	
d.	Plotting	12 Hrs.	
e.	Field check	3 Hrs.	
		25 Hrs.	

Also, overall accuracy estimated on the basis of random field measurement of distances on church and that of photogrammetric model has been found to be

$$\sigma_x = \sigma_y = .024\ m.$$

$$\sigma_z = .043\ m.$$

These results canbe refined further by using more appropriate and sophisticated instruments and the new methods likely to be introduce in the field of Architectural documentation. Notwithstanding, the various limitations of funds etc., it may be concluded that this technique can easily substitute the traditional method of documentation of structures of national importance.

It is strongly recommended that photogrammetric techniques should be further improved and utilised on routine basis by the various agencies like, Archaeological survey of India, Indian National Trust for Art and Culture Heritage and others, who have the responsibility of preserving and maintaining these historic monuments of national improtance and for which properly recorded and documented data is urgently needed.

APPENDIX I

THEODOLITE STATION 1

S. No.	POINT	HORIZONTAL FACE LEFT ° ' "	HORIZONTAL FACE RIGHT ° ' "	HORIZONTAL MEAN ° ' "	VERTICAL FACE LEFT ° ' "	VERTICAL FACE RIGHT ° ' "	VERTICAL MEAN ° ' "
1.	2nd Thed. station	00 02 00	180 02 18	179 58 04	93 42 50	266 16 57	93 42 56.5
2.	1	281 59 34	101 59 26	101 59 30	89 44 00	270 15 40	89 44 10
3.	2	283 42 50	103 42 32	103 42 41	73 08 34	286 49 35	73 09 29.5
4.	10	288 02 08	108 01 50	108 01 59	79 10 00	280 50 08	79 09 56
5.	5	293 55 30	113 55 23	113 55 26	93 05 23	266 54 10	93 05 36.5
6.	8	291 34 40	111 34 04	111 34 22	81 18 16	278 41 53	81 18 11.5
7.	13	291 24 24	111 23 50	111 24 07	71 09 00	288 51 10	71 08 55
8.	6	295 52 52	115 52 46	115 52 49	91 31 40	268 28 08	91 31 46
9.	12	297 26 27	117 25 53	117 26 10	79 04 35	280 55 02	79 04 46.5
10.	17	297 24 35	117 23 10	117 23 52	67 35 40	292 24 00	67 35 50
11.	15	297 36 36	117 35 40	117 36 13	58 25 00	301 34 40	58 25 10
12.	16	297 25 15	117 24 26	117 24 50	51 53 15	308 06 16	51 53 29.5
13.	7	303 14 00	123 13 56	123 13 57	92 46 50	267 12 54	92 46 58
14.	9	302 20 45	122 20 31	122 20 38	82 14 13	277 45 05	85 44 34
15.	14	302 34 25	122 33 54	122 34 10	73 17 43	286 41 35	73 18 04
16.	11	305 55 00	124 54 52	125 24 56	80 57 14	279 02 13	80 57 30.5
17.	4	308 10 30	128 12 20	128 11 25	89 46 15	283 08 44	83 18 56
18.	3	308 12 43	128 10 19	128 11 31	76 15 02	270 13 33	78 30 44.5
19.	Theo.Stn.2	00 01 56	179 59 04	--	180 01 33	00 01 00	--

HEIGHT OF INSTRUMENT 1.35 METERS

DISTANCE BETWEEN THEODOLITE STATION (1) AND (2) = 19.682 METERS

THEODOLITE STATION (2)

S. No.	POINT	HORIZONTAL FACE LEFT ° ' "	HORIZONTAL FACE RIGHT ° ' "	HORIZONTAL MEAN ° ' "	VERTICAL FACE LEFT ° ' "	VERTICAL FACE RIGHT ° ' "	VERTICAL MEAN ° ' "
1.	THEO.STN.	00 03 52	180 03 50		94 09 10	265 49 40	94 09 45
2.	1	50 13 42	230 13 43	50 13 42.5	89 59 03	270 00 44	89 59 09.
3.	2	50 28 50	230 28 40	50 28 45	76 52 23	283 07 27	76 52 28
4.	10	54 04 29	234 05 01	54 04 45	80 58 15	279 01 27	80 58 24
5.	5	56 30 21	236 30 34	56 30 27.5	93 02 20	266 57 23	93 02 28.
6.	8	57 01 10	237 00 45	57 00 57	82 21 53	277 38 20	82 21 46.
7.	13	56 50 24	236 50 10	56 50 16	73 09 21	286 50 08	73 09 36.
8.	6	63 26 20	243 26 30	63 26 25	91 43 33	268 16 07	91 43 43
9.	12	62 36 50	242 37 50	62 37 20	79 16 50	280 43 40	79 16 35
10.	17	62 35 00	242 34 35	62 34 47.5	67 43 23	292 16 05	67 43 39
11.	15	62 22 35	242 23 00	62 22 47.5	58 36 33	301 23 28	58 36 32.
12.	16	62 30 26	242 29 45	62 30 05	52 04 30	307 55 30	52 04 30
13.	7	66 42 13	246 42 05	66 42 11.5	93 17 27	266 42 30	93 17 28.
14.	9	68 38 30	248 38 20	68 38 25	81 42 00	278 17 45	81 42 07.
15.	14	68 58 05	248 57 35	68 57 50	71 50 56	288 08 50	71 51 03
16.	11	72 15 30	252 15 55	72 15 42.5	79 44 51	280 14 56	79 44 57.
17.	3	76 49 30	256 49 31	76 49 16.5	74 22 38	285 37 17	74 22 40.
18.	4	78 02 52	258 02 37	78 02 44.5	89 56 55	270 03 01	89 56 57
	Theo.Stn.1	00 03 50			180 04 01		

HEIGHT OF INSTRUMENT 1.35 METERS

DISTANCE BETWEEN THEODOLITE STATION (1) AND (2) = 19.682 METERS

APPENDIX II

APPENDIX II MAIN PROGRAMME

```
C       GROUND CONTROL COPUTATION FROM THEDOLITE MEASURMENTS ******
C       FOR BIOPHOTO LABORATORY *************BY ANIL DIKSHIT M.ARCH.

        DIMENSION RAD(10),VR2(95),
        1HD1(95),HM1(95),HS1(95),HD2(95),HM2(95),HS2(95),D1(95),
        1VD1(95),VM1(95),VS1(95),VD2(95),VM2(95),VS2(95),D2(95),
        1HR1(95),HR2(95),VR1(95),HR3(95),Z11(50),Z21(50),ZH1(50),Z
        1CCC(50),XP1(95),YP1(95),ZP1(95),XP2(95),YP2(95),ZP2(95),HRC(90),
        1XPM(95),YPM(95),ZPM(95),A(6),D(3),Z(3,3),WK(14),IPQ(90)

        OPEN(UNIT=5,DEVICE='DSK',DIALOG)
        OPEN(UNIT=6,DEVICE='DSK',DIALOG)
        PI=ACOS(-1.)
        RHO=PI/180.
1       CONTINUE
        READ (5,*) NP,BASE
    **********************************************************************
C**18   FORMAT (I2,F10.3)
C       LEFT STATION DATA HAVE SUFFIX 1 ,RIGHT STATION DATA HAVE SUFFIX 2
        READ (5,*) XC1,YC1,ZC1
C***19  FORMAT (3F15.5)
    **********************************************************************
        READ (5,*)HI1,HI2
C***20  FORMAT(2F10.3)
    **********************************************************************
        READ (5,*)VD12,VM12,VS12,VD21,VM21,VS21
        VR21=RHO*(VD21+VM21/60.+VS21/3600.)
        VR12=RHO*(VD12+VM12/60.+VS12/3600.)
        XC2=XC1+BASE
        YC2=YC1
C       ZC2=ZC1+HI1+BASE*TAN(VR12)
        ZH22=BASE*SIN(VR12)/COS(R12)
        ZC2=ZC1+HI1+ZH22

C       ZCC=ZC2+HI2+BASE*TAN(VR21)
        ZH11=BASE*SIN(VR21)/COS(VR21)
        ZCC=ZC2+HI2+ZH11
        WRITE (6,105),XC1,YC1,ZC1,XC2,YC2,ZC2,ZCC
105     FORMAT (1H1,40X,'GROUND CONTROL CORDINATES '/ /20X,'LEFT
        1INST. ','X=',F13.7,'M',2X,'Y=',F13.7,'Z=',F13.7,'M',/21X,'RIGHT
```

```
          1INST.','X=',F13.7,'M',2X,'Y=',F13.7,'
          1 M',2X,'Z=',F13.7,' M'/21X,'CHECK -COMPUTED Z FOR LEFT INST
          1STATION=',F13.7,' METERS.')
          WRITE (6,102)
    102   FORMAT(///,8X,'PIONTS',12X,'DISTANCES',20X,'COORDINATES IN METERS'
          1 /47X,'XP',15X,'YP',15X,'ZP')
          DO 50 I=1,NP
          READ (5,*) HD1(I),HM1(I),HS1(I),HD2(I),HM2(I),HS2(I)
          READ (5,*) VD1(I),VM1(I),VS1(I),VD2(I),VM2(I),VS2(I)
          HR1(I)=RHO*(HD1(I)+HM1(I)/60.+HS1(I)/3600.)
          HR2(I)=RHO*(HD2(I)+HM2(I)/60.+HS2(I)/3600.)
          VR1(I)=RHO*(VD1(I)+VM1(I)/60.+VS1(I)/3600.)
          VR2(I)=RHO*(VD2(I)+VM2(I)/60.+VS2(I)/3600.)
          HRC(I)=HR1(I)+HR2(I)
          D1(I)=BASE*SIN(HR2(I))/SIN(HRC(I))
          D2(I)=BASE*SIN(HR1(I))/SIN(HRC(I))
          XP1(I)=XC1+D1(I)*COS(HR1(I))
          YP1(I)=YC1+D1(I)*SIN(HR1(I))
C         ZP1(I)=ZC1+HI1+D1(I)*TAN(VR1(I))
          Z111=D1(I)*SIN(VR1(I))/COS(VR1(I))
          Z211=D2(I)*SIN(VR2(I))/COS(VR2(I))
          ZP1(I)=ZC1+HI1+D1(I)*SIN(VR1(I))/COS(VR1(I))
          XP2(I)=XC2-(D2(I)*COS(HR2(I)))
          YP2(I)=YC2+D2(I)*SIN(HR2(I))
C         ZP2(I)=ZC2+HI2+D2(I)*TAN(VR2(I))
          ZP2(I)=ZC2+HI2+D2(I)*SIN(VR2(I))/COS(VR2(I))
          WRITE (6,103)I,D1(I),XP1(I),YP1(I),ZP1(I)
    103   FORMAT(/,10X,I2,8X,'D1=',F16.6,'METERS',3F16.7)
          WRITE(6,104)D2(I),XP2(I),YP2(I),ZP2(I)
    104   FORMAT( 20X,'D2=',F16.6,'METERS',3F16.4)
          XPM(I)=(XP1(I)+XP2(I))/2.
          YPM(I)=(YP1(I)+YP2(I))/2.
          ZPM(I)=(ZP1(I)+ZP2(I))/2.
    50    CONTINUE

          READ (5,*) (IPQ(I),I=1,NP)
          WRITE(6,100)
```

```
100    FORMAT(1H1,35X,'COMPUTATION OF CONTROL POINT COORDINATES',
       1//35X,'(YP AND ZP HAVE BEEN INTERCHANGE TO CONFORM '/36X,
       1'TO ADOPT ED OBJECT SPACE COORDINATES SYSTEM )'///20X,'SERIAL
       1 NO.',10X,'CONTROL NO.',18X,'COORDINATES
       1 IN METRES'/58X,'XP',15X,'YP',15X,'ZP'/)
       DO 1111 I=1,NP
       WRITE(6,101) ((I,IPQ(I),XPM(I),YPM(I),ZPM(I)))
1111   CONTINUE
101    FORMAT(/,24X,I2,17X,I4,3X,3(F13.6,5X))
60     STOP
       END
```

APPENDIX III

```
RELATIVE ORIENTATION
   WITH LEFT  PHOTO FIX IN  ORTHO MODE
   MEASURED PY-POINTS
   USING 15 PARALLAXE POINTS

   COMPUTATION BY 1 ITERATIONS
   SIGMA 0 =   .007

   RESIDUAL PARALLAXES IN PHOTO
          POINT Y-PARALLAXE
           111       -.001
          1515       -.001
          1717        .000
          1414        .000
          1313        .000
           202        .001
           303        .001
           404       -.000
           505       -.000
           106        .003
           102       -.007
           104        .010
           103       -.020
           101        .021
           105       -.007
          MEAN        .008

** ACCEPTED ?
   YES

   NEW MODEL PARAMETERS :
             LEFT      RIGHT       MODEL BASE
   OMEGA    11.006    10.915     BX    24.540
   PHI     -12.605   -12.944     BY   -10.726
   KAPPA   -24.323   -24.393     BZ     3.113

   OK
END OF RELORIENT

ABSOLUTE ORIENTATION
   ALREADY MEASURED ORIENTATION POINTS
   I         POINT           XG              YG              ZG
              105   NOT IN GROUND MEMORY
              101   NOT IN GROUND MEMORY
              103   NOT IN GROUND MEMORY
              104   NOT IN GROUND MEMORY
              102   NOT IN GROUND MEMORY
              106   NOT IN GROUND MEMORY
              505   NOT IN GROUND MEMORY
   1          404         115.462        100.594         119.678   CONTROL POINT
              303   NOT IN GROUND MEMORY
   2          202         104.464        104.978         119.340   CONTROL POINT
   3         1313         107.112        106.298         119.154   CONTROL POINT
   4         1414         112.246        106.132         119.195   CONTROL POINT
   5         1717         109.802        108.112         118.939   CONTROL POINT
   6         1515         109.803        112.322         118.774   CONTROL POINT
   7          111         103.974        100.606         118.764   CONTROL POINT
   NEW MEASURED ORIENTATION POINTS
   NONE

   COMPUTATION WITH  7 CONTROL POINTS

   COMPUTATION BY  4 ITERATIONS
   SIGMA 0 =   .337

   RESIDUALS AT CONTROL POINTS AFTER ABSORIENT
   I         POINT         DXG           DYG          DZG
   1          404         -.368         -.497         .038
   2          202          .190          .388         .321 **
   3         1313          .223          .132        -.428 **
   4         1414         -.209          .346         .001
   5         1717         -.100          .209        -.008
   6         1515         -.135         -.062         .060
   7          111          .399         -.516         .016
             MEAN          .254          .348         .204
```

```
** ACCEPTED ?
   YES
   ABSOLUTE ORIENTATION EFFECTIVE AND THUS FIX PHOTO CORRECTED

   NEW MODEL PARAMETERS
                LEFT      RIGHT      MODEL BASE      MODEL CENTER
   OMEGA      11.006     10.915    BX     24.540  XG0     107.997
   PHI       -12.605    -12.943    BY    -10.726  YG0     102.087
   KAPPA     -24.323    -24.393    BZ      3.113  ZG0     130.500
   MODEL SWING      26.723

   OK
END OF ABSORIENT

LIST MODEL DATA E

 MODEL 555666                OPERATOR AKK            DATE 1986. 1.21.10.51
 ---------------------------------------------------------------------------

   MODEL SCALE 1:     40   TABLE SCALE 1:     50   PHOTO SCALE 1:     213

   ORIENTATION DATA  LEFT PHOTO  RIGHT PHOTO                         MODEL
   ----------------
                  F    56.750      56.750    FLIGHT HEIGHT            12
              OMEGA    11.006      10.915     ABOVE GROUND
                PHI   -12.605     -12.943
              KAPPA   -24.323     -24.393              AZIMUT      26.723
                 BX   -12.270      12.270    MODEL    ( XG0        108.00
                 BY     5.363      -5.363    CENTER   ( YG0        102.09
                 BZ    -1.557       1.557    POSITION( ZG0         130.50

   MODEL BASE: B =    26.962 (ORTHO)    EARTH CURV.CORR.: R = $$$$$$$$$

   ORIENTATION REPORT
   ------------------
   ABSOLUTE ORIENT.  USED CONTROL POINTS  PLANIMETRY  7 ELEVATION   7
                     POINT NO.               404        202          1313
                     POINT NO.              1414       1717          1515
                     POINT NO.               111
                     RESIDUAL COORDINATE ERRORS          MEAN          MAX
                                                  X      .254         .399
                                                  Y      .348        -.516
                                                  Z      .204        -.428

   RELATIVE ORIENT.  USED PARALLAX POINTS  15
                     RESIDUAL PARALLAXES        MEAN     .008  MAX    .021

   INTERIOR ORIENT.  USED FIDUCIALS  1234                 LEFT       RIGHT
                                         X-SHRINKAGE    .999574    .998029
                                         Y-SHRINKAGE    .999574   1.001826
                                         RECTANGUL.     0.00000   -.00024

   REMARKS:
   --------
```

** POINTS NOT USED IN STANDARD ERROR COMPUTATION.

```
END OF MODEL DATA E
```

REFERENCES :

R E F E R E N C E S

1 ASTORI, B and SENA, C (1972). "Consideration on Photogrammetric Survey of Castle of Vigenavo", Presented Papers of XIIth International Congress of Photogrammetry Ottawa, 1972, 13 Pages.*

2 CARBONNELL, M (1974). "Historic Centre Conservation" Photogrammetaric Engineering, 40(9), 1959-70.**

3 CHAMBERS, J.H. (1973). "Rectified Photography and Photo drawing for historic preservation". Office of Archaeology and Historic Preservation, Washington D.C. 38 Pages.**

4 DALLAS, R.W.A. (1975). "Direct ink draughting on Photogrammetric Plotting instrument". Photogrammatric Record 8(45), 326-9.*

5 DALLAS, R.W.A. (1977) "Architectural Photogrammetry", 2nd Edition tape/slide Presentation: 24 Slides with commentry and Script.**

6 FAIREY SURVEYS LTD. (1969). "Precision models direct from Maps and drawings". Fairey Survey News Letter 1,2.*

7 FERRI, W.S. and FOUNDELLI, M (1972). "Problems in Photogrammetric Surveying of domes". International Archives of Photogrammetry, 19(5). 16 pages.*

8 FORAMITTI, H (1966). "Photogrammetry in hands of building expert". Deutsche Bauzeitung, 9, 786-92 and 10, 874-80*

9 GRANSHAW, S.I. (1979). "Relative Orientation Problems". Photogrammetric Record 9(53), 669-75.*

10 HART, D.M. (1975) "X-ray examination of historic Structure". Office of Archaeology and Historic Preservation. Washington DC 24 pages.*

11 HOTTIER PH (1976). "Analytical Photogrammetry with homolog image curves". Presented Papers of XIIth International Congress of Photogrammetry Helsinki, Finland 1976, 6(519) 14 pages.*

12 International Committee for Architectural Photogrammetry (1972). Architectural Photogrammetry from 1968 to 1971, 45, 3-39.**

13 International Committee for Architectural Photogrmmetry (1974). Architectural Photogrammetry in 1973 and 1974. 56, 3-28**

14 International Committee for Architectural Photogrammetry (1977) Architectural Photogrammetry in 1975 and 1976, 67, 39 pages.**

15 JACHIMSKI, J.J. WEAVER, M.E. and LETELLIER, R. (1975). "The recording of Canadian historic monuments". Photogrammetria, 30(3-6), 147-61.*

16 KEATING, T.J. and BOSTON, D.R. (1979), "Digital Orthophoto production using Scanning microdensitometer". Photogrammetric Engg. and Remote Sensing, 45(6), 735-40*

17 Mc FADGEN, B.G. (1971) "An application of Stereophotogrammetry to archaeological recording". Archaeometry, 13(1), 71-81.*

18 MASRY, S.E. and FAIG, W (1977). "The analytical plotter in Close-range applications". Photogrammetric Engg. and Remote Sensing, 43(1), 89-94.*

19 MEYER, R (1968). "Modern methods of using Photogrammetric archieves of ancient architecture". Proceeding of the Conf. on the application of Photogrammetry to Historic monuments, Saint Mande, France 1968, ICOMOS Paris. 9 Pages.*

20 POLDERMAN, A.H. (1976). "Mapping of Shipwreks. Non-Topographic Photogrammetry at the Survey dept of Rijkswaterstaat."Presented Papers of XIII International Congress of Photogrammetry, Helsinki, 1976, 6(541) 4 pages.*

21 RIVETT, L.J. (1977). "The application of Photogrammetry to the recording of monuments and sites in Australia". Department of Surveying, University of Melborne, Australia Bulletin 42, pages.*

22 SEEGER, E (1976). "Orthophotography in architectural Photogrammetry". Photogrammetric Engg. and Remote Sensing, 42(5), 625-35.*

23 SENA, C. and ASTORI, B. (1976). "Contribution of Photogrammetry to Save the San Marco horses in Venice". Presented Papers of XIIIth International Congress of Photogrammetry, Helsinki, 1976, 6(542). 12 pages.*

24 SHMUTTER, B. and REDELIUS, G. (1970). "Architecture with analytics". Photogrammetric Engg. 36(10), 1073-8.

25 THOMPSON, E.H. (1962). "Photogrammetry in the restoration of Castle Howard". Photogrammetric Record, 4(20), 94-119.*

26 VARESS, S.A., LIPPERT, F.G. and TAKAMOTO, T. (1977). "An Analytical approach to X-ray Photogrammetry". Photogrammetry Engg. and Remote Sensing, 43(12), 1503-10.*

27 VON PRZYBILLA, H.J. and WESTER-RBBINGHAUS, W. (1979). "Bild flug mit Ferngelerkte Klinflugzeug". Bildmessung und Luftbildwesen, 47(5), 137-42.*

28 WHITTLESEY, J.H. (1975). "Elevated and airborne Photogrammetry and Stereo Photography". Photography in archaeological research. (Ed. E. Harp. Jr.) University of New Maxico Press, Albuquerque, pp. 223-57.*

29 WILLIAMS, A.R. (1976) "Orthographic Photography". British Journal of Photography, 123(6074), 1131-2.*

---

*Technical literature

**General literature