

COMPUTER APPLICATIONS TO AEROTRIANGULATION

IN PHOTOGRAMETRY,

BY

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P.GD/M.CS/97/402.

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of the requirements for the award of post-graduate Diploma in
Computer Science.

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Finally, I express my gratitude to Almighty Allah for providing my needs and sparing my life throughout my stay in the University.

DEDICATION

This project work is dedicated to Almighty Allah, my late mother Mrs Moriatsu Yusuf (may your gentle soul rest in peace. Amen) and to my children Sekinat and Latifat Yusuf.

CERTIFICATION

This project work by Yusuf T. Hassan entitled "Computer Applications to Aerotriangulation in photogrammetry", meets the requirements for the award of Post-Graduate Diploma in Computer Science of the Federal University of Technology, Minna.

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ABSTRACT

This project is based on computerizing aerotriangulation in Photogrammetry, Photogrammetry is simple the production of maps and plans from aerial photographs. It has been used so many times and found to be as accurate as the land surveying methods of getting more horizontal control points.

Aerotriangulation is a method of getting more horizontal control points using the Photogrammetric instruments (ie stereoplotters), (for this project, wild A-8 was used). The method of carrying out the aerotriangulation is the independent method in which no model is dependent on any other model. After selecting your aerial photographs, and the inner, relative and absolute orientation has correctly performed, you will now set-up the 1st model and compute the machine values (ie XYZ-Values) of the ground controls.

The computation was carried out by using designed form that enable you to transform the machine values (autograph readings) to terrain co-ordinates that will serve as new control points.

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CHAPTER ONE

1.1 DEFINITION OF COMPUTER:-

Computer can be defined as an electronic machine that accept data/information, (ie stored program) process it and comes out with an output. In other words," computer is a machine that receives or stores or processes data very quickly according to a stored program" (Collins S.M.H, 1988, Comprehensive Dictionary of computing, Evans Brothers Limited, London. P.42)

1.2 BACKGROUND HISTORY OF COMPUTER

The history of Computer will be uncomplete without mentioning the first counting pebbles by herds men who use it to count their animals when leaving for grazing in the morning and recounting the pebbles when they come back in the evening.

The first mechanical and calculating machine was invented in 450 BC known as the Abacus. The Abacus was a mechanical pebbles counting machine invented in china. For a long period nothing was on record to show any other computing method not until the year 1617 when John Napper invented the use of logarithm for multiplication and division of large numbers. This was a land mark in the history of computing. Later on in the year 1642, a French mathematician Blaise Pascal devised the first true

adding and subtracting machine named Pascal Arithmetic Machine. His aim of doing this, was to count-down on his father's labour as a revenue collector. And in 1671, Goufried Von Leibnitz invented a calculator that could do the multiplication and division in addition to Pascal's adding and subtracting machine.

But the modern calculator was the handy work of French man named Charles Xerier Thomas in 1920. In the year 1822, Charles Babbage invented an Analytical Engine, a machine that embodied the principles and capabilities of the modern automatic computer this together with some of his other works earns him the father of "computers".

The first commercially practical adding machine was invented in 1884 by William Burroughs. Also in 1887, Herman Hollerith, (an employee of U.S. Bureau of the Census), used punched card equipment to process the U.S. 1890 Census card system to process the 1910 census.

These machines were the for runners of electromechanical data processing systems. Between 1937-1944, Howard Aiken of Hoard University, designed the automatic sequence controlled calculator (ASCC) known as mark 1. Also, during this period, (1942) John V. Atanasoff and Clifford Beery devised the 1st digital computer to work by electronic means called COLOSSUS. Another name for it is Atansoff-Beery computer(ABC).

The first large scale general purpose electronic digital computer called ENIAC (ie Electronic Numeric Integrator and computer) was invented in the year 1946- by John Mauchly and J. Prosper Eckert. In 1949, the first stored program computers known as EDSAC (ie Electronic Delay Storage Automatic Calculator) was constructed at Cambridge University in England by Maurice V. Wilkes. Later on BINAC (Binary Automatic Computer) was invented by Eckert and John Mauchly. This was followed by EDVAC (Electronic Discrete variable Automatic Computer) which was smaller, more versatile and more flexible machine than ENIAC was designed and it become a true stored program binary machine using numbers for instructions. Later, the 1st business data processing system known as UNIVAC I was developed by John Mauchly and prosper Eckert. This machine make use of 500 vacuum tubes and it could read computer and write information simultaneously.

Finally, the generation of computer can be summarized as follows:-

1st Generation (1951-1959). It uses the vacuum tube.

2nd Generation (1959-1963) It uses the transistors.

3rd Generation (1964-1970) It uses the Integrated circuit.

4th Generation (1971-1990) It uses the microminiaturized circuit.

5th Generation (1990-present day).major advances is currently going on.

(Lecture note (CPD711) Introduction to Computer)

1.3 DEFINITION OF BASIC TERMS IN COMPUTER

- i. **ALU:-** This is an acronym for Arithmetic and Logical Unit. This is the unit where the arithmetic and Logical operations are performed.
- ii. **ASSEMBLER:-** A language translator that translate assembly language programs to machine code.
- iii. **ASSEMBLY LANGUAGE:-** Is a low-level programming language in which each statement corresponds directly to a single machine instruction.
- iv. **ANALOG COMPUTER:-** A computer that represents data in continuously variable such as voltage fluctuations rather than digitally encoded information.
- v. **BIOS:-** An acronym for basic input/output system. It is a set of routines that work closely with the hardware to support information transfer between the elements of the computer system such as disks, memory and monitor.
- vi. **BOOT:-** To start a computer
- vii. **BOOT STRAP:-** The ability of the computer to test its various units, load its operating system and prepare itself for use.

- viii. BUG:- An error in hardware or software
- ix. CACHO:- Is a special memory where data are stored for quick access, when working with the computer.
- x. COLD-BOOT:- A start-up process that begins with turning on the computers power switch.
- xi. DEBUG:- It means to detect, locate and correct errors in a program.
- xii. DOS:- (Disk Operating System): A term used to describe any operating system that is loaded from a start up from disk devices.
- xiii. INPUT:- Means of passing data/information into a computer.
Eg. Keyboard, Punch Card, Punch tape, joy stick etc.
- xiv. OUTPUT:- A Processed data/information being printed out or shown on the monitor.

(REMY N. Onyewuenyi, (1994) Micro Computer studies for beginners)

(Lecture note (CPD711) Introduction to Computer)

4.1 BRIEF DESCRIPTION OF PHOTOGRAMMETRY AND AEROTIANGULATION.

What is Photogrammetry (PGMMY)

Photogrammetry derived its name from three Greek words (ie Photo, grammar and metron). Photo in Greek means light, grammar means something drawn or written while metron means to measure. Thus, the 1st definition of Photogrammetry is graphical measurement by means of light. But, with the development in science and technology, Photogrammetry can now be defined as the art, science and technology of obtaining reliable information from aerial photos about the physical objects and its environment for the purpose of recording, measuring and interpretation of photographic images and patterns of electromagnetic radiant energy.

To a lay man, Photogrammetry is that branch of surveying where maps and plans are prepared from aerial photographs. (Manual of Photogrammetry, Fourth Edition)

We can make use of Photogrammetry for:

1. Production of conventional maps using conventional signs and symbols.
2. Production of photo-maps

3. Production of numeric data
4. Production of data from remote sensing.

Photogrammetry, can be applied to other areas of engineering apart from surveying. Such areas are: geology, forestry, agriculture, medicine and surgery, planning of cities and highways and also in military intelligence.

AEROTRIANGULATION:- This is a process used for the extension of horizontal and vertical control points where the measurement of angles and distances on overlapping Photographs are related into a spatial solution using the principles of perspective photographs. In other words, aerotriangulation is a method of establishing supplementary, planimetric and height controls using the geometric relationships between successive aerial photographs.

These supplementary controls must tied to ground controls so as to give its geodetic significance. Thus ground control points are still needed but the number of these points can be greatly reduced.

The method of carrying out the extension of controls depends on the available plotter (instrument). The base-in base-out method can be carried out on WILD A7, multi-projector (eg multiplex) and Belplex, whereas the dependent and independent methods can be

carried out on Wild-A8, Kern PG-2 and other instruments that are having two-projectors.

The main purpose of aerotriangulation is to reduce the number of both horizontal and vertical control points determined by land surveying methods, thus reducing the high-cost of field work, time spent on the field and also for Photogrammetric mapping to be achieved without actually setting foot on the property being mapped. This is an important point of property owners refused surveyors access to their land. The classified into one or two broad categories that is analogical and analytical. Analogical involves manual relative orientation and measurement of model co-ordinates using stereoscopic plotting instrument while the analytical methods consist of photo-coordinate measurements followed by numerical relative orientation and computation of model coordinates using an electronic computer. (Paul R. Wolf. Elementary Photogrammetry).

1.4 DEFINITION OF TERMS IN PHOTOGRAMMETRY

(AS USED IN THIS PROJECT)

- i. DIAPOSITIVE:- a positive photograph on a transparent medium usually polyester or glass. It is also a term used to refer to a

transparency used in a plotting instrument, a projector or a comparator.

- ii. **MODEL DATUM:-** that surface in a stereoscopic model conceived as having been reconstructed as part of the model representing the sea-level of nature.
- iii. **MOSAIC:** an assembly of aerial photographs whose edges have been trimmed-off or out and matched to form a continuous representation of a portion of the earth's surface.
- iv. **PRINCIPAL POINT:** this is the foot to the perpendicular from the interior perspective center to the plane of a photograph.
- v. **CONJUGATE PRINCIPAL POINT:** a principal point that is transferred from one photograph to the other. They must be of overlapping photographs
- vi. **OVERLAP:** the amount of which one photograph covers the same area as covered by another usually represented in percentage.
- vii. **OVERLAPPING PAIR:** two photographs taken at different exposure in such a manner that a portion of one photograph shows the same terrain as shown on a portion of the other photograph.
- viii. **TEMPLET:** a graphical representation of a photograph. A templet records the directions or radial taken from the photograph.

- ix. **HAND TEMPLET**: a templet made by tracing the radial lines from a photograph onto a transparent medium eg. Plastic sheet. Hand templets are laid out and adjusted by hand to form the radial triangulation.
- x. **SLOTTED TEMPLET ASSEMBLY (STA)**: a templet on which the radial lines are represented as slots cut in a sheet of cardboard.
- xi. **TIE POINTS**: image point identified on photographs in the side lap (ie lateral overlap) area between two or more adjacent strips of photographs. They serve to tie the individual sets of photographs into a single flight unit and to tie adjacent flights into a common network.
- xii. **MINOR CONTROL POINT (MCP)**: these are points chosen on the photograph by the Photogrammetrist whose co-ordinates are to be determined.

CHAPTER TWO

LITERATURE REVIEW

2.1 WHY PHOTOGRAMMETRIC METHOD OF EXTENSION OF CONTROLS:

In the past, getting of control points has kept the land surveyors in the field for many days and nights. For this reason, other means of speeding up the idea of getting more controls without spending many nights in the field has been devised. In short Photogrammetry came into being as a substitute to land surveying method of producing plans and maps. Thus, in order to save a lot of time which is cost effective in return, aerotriangulation was devised to get more horizontal and vertical controls for mapping purpose.

Moreover, many Photogrammetric projects require an extensive amount of horizontal and vertical photo control. For example, in compiling topographic maps with stereoplotters, the absolute minimum number of control points necessary in each stereomode is two horizontal and three vertical points. For large mapping projects, therefore, the number of control points needed is extensive and the cost of establishing them can be extremely high if done exclusively by field survey methods.

2.2 GRAPHICAL METHOD OF EXTENSION OF CONTROLS:

Initially, aerotriangulation was done using the graphical method. That is using Hand Templet, where a templet is placed over an aerial photograph and the ground control points (GCP) and minor control point (MCP) are transferring from the photograph onto the templet. After transferring of these points onto each templet, all the templets are gathered together and taken to an already plotted sheet (where the GCP are plotted using the X and Y co-ordinates supplied by the land surveyors). The pricked points on each templet and rays drawn are then transferred to this sheet where the intersection of rays indicate the position of each point on the sheet. From this, other MCP are then co-ordinated because the sheet has already been given their X and Y values. But due to the poor alignments, wrong transfer of points from one photograph to another photograph, paper shrinkage and a lot of time being spent, the expected results are not very satisfactory and as such a more accurate method that does not involve the use of paper was developed known as slotted Templet Assembly (STA). In the case of STA, a plastic material known as permatrace or cobex is been used in the place of paper in the Hand Templet method. Each point (ie GCP and MCP) is also been transferred onto this material and later on this material is been punched at the center (using a punch machine). This hole is then placed on a

slotting machine where each templet is rotated so that each point represent the rays that produced that image. After slotting, the unwanted part is been trimmed or cut off. The templet is then gathered together on an already plotted sheet where the GCP are already using the X and Y. Co-ordinates supplied by the land surveyor. With the use of stud and needle each templet is fastened together and MCPs are been coordinated. But, this also posses some inaccuracies as to the expected results, thus, the use of radial –line triangulation was devised.

Radial-line triangulation is the method for extending of supplementary horizontal controls. The techniques may be applied to planimetric map compilation. It is one of the earliest Photogrammetric mapping procedures done initially by graphical method called radial-line plotting. It is also used for providing controls for small scale mapping, for controlling mosaic construction and for planimetric map division. The principle upon which radial-line triangulation is based is that angles with their vertex at the principal point of a vertical photograph are true horizontal angles. The radial-line triangulation consist basically of two distinct operations i.e (1) Resection and (2) Intersection. This method of obtaining more horizontal controls and vertical controls also posses some errors among which are;

- i. Differential paper shrinkage.
- ii. Graphical or mechanical construction errors.
- iii. Faulty location of principal point.
- iv. Faulty transfer of conjugate principal points.
- v. Tilt is reckon to be on every photograph used.

2.3 PROBLEMS OF RADIAL-LINE METHOD

The radial-line triangulation is not used extensively today because it has given way to a more accurate and convenient method which is aerotriangulation. That is the use of stereoplotters to get more and vertical controls using the analog and analytical method. The analytical method which is a mathematical way of getting more horizontal controls has come to be the best method in terms of accuracy of the expected result. It was first established by Sebastian Finsterwalder in the beginning of this century. He applied vectors to investigate the problems of single and double points resection in space, topographic mapping from balloon photographs and the formulation of relative and absolute orientation. "Had Finsterwalder had the modern capacity for extensive computation, the entire development of Photogrammetry might have been different". After Finsterwalder works, a man named Carl Pulfrich (1901) of Zeiss developed the 1st stereo comparator designed for precise measurement of photograph image co-

ordinates. He was the antecedent (ancestor) of the modern instruments employed in analytical Photogrammetry. While Otto Von Grubber (1942) devised the protective equations and their differentials which are fundamental to the development of modern analytical methods.

In 1930, Earl Church (professor of applied mathematics) developed means of analytical solutions to space resection, intersection, orientation and extension of controls. Professor church devised the cosine notation. Although this method was cumbersome when compared to the modern day matrix notation but the cosine notation is ideal for organizing machines and calculation to be performed with a computer.

In 1959, Dr. Hellmut Schmid who came the united states from Germany (after world war11), developed the principles of modern multi-station analytical Photogrammetry. Although his work was directed to ballistic camera operation in which several camera may observe an invent simultaneously, but the application of these procedures to control extension by strips and blocks of aerial photos followed immediately. In his work, he introduced the correct least-squares solution, the simultaneous solution using of error propagation. He is the first Photogrammetrist to plan his solutions in anticipation of the use of high-speed electronic computer.

Another aspect of developing areotragulation was done by Dr Paul Hergert (1956) who devised a system of analytical control extension based upon minimizing the perpendicular distances between pairs of corresponding rays. Another formulation for aerotriangulation was developed by G.H. Schut (1955-1956) of National Research Council in Canada. He analyzed the existing methods of analytical triangulation, reduced them to a common notation and classified them according to three criteria:

- a. triangulation procedures
- b. type of condition equation
- c. Method of solving condition equations

This method was also cumbersome and time consuming.

Another major contributions to theory and practice of aerotriangulation was developed by Diane Brown (1957). His elegant and general treatment of least squares adjustment and error propagation, analytical formulation of internal and external perturbations of imaging systems, algorithm and logic for efficient solution of large systems of equations, close-range application and sensor calibration, including his computer programs for the reduction of data from extra terrestrial photographs represent some of the most elegant treatments in operational use today.

CHAPTER THREE

SYSTEM DESIGN

3.1 FEASIBILITY STUDY

In any survey work, feasibility study plays an important role in the overall accuracy of the job and as such we need to undertake a feasibility study of the project area known as Recce (Recognizance survey) in surveying generally. Recce in surveying means going to the field to take a look at the area under consideration, walk round it and make a rough plan of how you go about selecting your points. In this manner, on getting to the field, I made some rough sketch of the points I felt should be co-ordinated. Points selected are points that cannot easily be removed (ie points like intersection of roads, edges of buildings and points very close to power line etc). The points chosen are known as Ground Control Points (GCP).

In getting our controls for any Photogrammetric work, we need aerial photographs. So the 1st thing was the planning for the photographs. Before taking the photos, a lot of factors must be taken into consideration because the quality of the photo has an effect on the clarity of the images and accuracy of the job to be carried out. Among such factors are the equipment's to be used, optical axis of the taken camera, flying height and full coverage. The equipments are the type of air-craft and air-camera to be

used. One must make use of an air-craft that should be stable at the required flying height and must be able to go more than required flying height. The air-camera must be fixed to the air-craft in a gimbal mounting position (ie ability to rotate both horizontally and vertically relative to the axis of the air-craft). The weather must be carefully studied before the take off of the air-craft so as to ensure that the intensity of the sun must not be too high so that the shadow of an object will not be mistaken for the object itself. The optical axis of the taken camera determines the type of aerial photos needed. In this project, vertical photos are needed and as such, the optical axis of the taken camera was kept vertical. In getting full-coverage, the 1st and last exposure must be outside the board lines. After taken all these factors into consideration, photography can now be undertaken.

I must mention here that for this project work, the photos are already available.

After the production of the photos, the next thing I did was to select my points as control points. My points are selected using the aerial photos and a mirror stereoscope on the field. This was done by identifying the points already marked on the ground from the aerial photos and using a fine needle, I pricked the center of these points. This was done for all the points needed. The number of points selected are six control points as horizontal

control points and 10 vertical control points. These points were given to a land surveyor who co-ordinated them (ie providing the X,Y and Z values. The Z-values are the heights of each points. It is worth mentioning that the points selected are well identifiable points, very sharp and they are also appearing on at least 3 successive aerial photos. These are also been transferred to other photos where they are appearing. After the selection of the GCP, the next thing I did was to choose minor control points (MCP). These are points chosen in the office with the use of aerial photos and a mirror stereoscope. They are minor because the co-ordinates of these points are not supplied by the land surveyors rather they are points chosen as an extension of controls, whose co-ordinates are to be determined using the plotting instruments. The MCP are distinguished from the GCP by making a circle round the MCP while a triangular sign is used for GCP. The MCP are also transferred to all relevant photographs.

3.2 Another Feasibility study that was undertaken was the choice of an instrument (i.e stereoplotter). In choosing this instrument (i.e wild A8), I took into consideration the C-factor of the instrument, the available photo (i.e the type of photos which are vertical photos) and the accuracy of the instrument. This is determined from the classification of Wild-A8 which is a 3rd - order instrument the accuracy of which is acceptable to this project

work. Also on the instrument, I did carried out a test on the instrument (wild -A8) so as to determine its accuracy. In other words, I need to ensure that the assembling of the parts was done correctly. (Although, not all the parts can be tested for, because of its complications e.g. the arrangement of the optics which was the work of these who install the instrument). The areas tested for are the suitability of the instrument, ie how leveled is the instrument on the ground and to check if there has been any change in its position on the ground as a result of the earth problems, the camera body, the kappa obliquity and width error.

Testing for leveling:- Get a spirit level and place it on the glass-plate first on the X-guide rail and use the three foot-screws until the deflection amounts to one division when the level with its glass plate is reversed. Do the same operation on the Y-guide rail. (These rails are part of the wild-A8 instrument attached to the plotting table. Care should be taken to see that the fingers of the hand do not touch the bubble-tube because of the warmth of the hand.

Levelling the Camera Body:- (The camera body is where the two-projectors are on the instrument. In other words, where we place our diapositives). Get a spirit level and place it on the grid-plate in both X and Y-directions and do the leveling by using Phi and Omega (these are

elements of orientation). The deflection when reversed should not be more than one division.

Rectifying Kappa (X) Obliquity and Width Error:- This is checking of the floating mark (floating mark is an indicator to your movements in the instrument, just like the cursor in a computer) because a deviation of the floating mark in Y-direction has the effect of wrong measurement of distances. This can be determined as follows:-

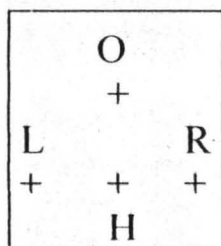
At the back of the grid plate, I mark the following points ie L,R,O,U and H. Set your focal length at 150mm set your projection distance (Z) at 300mm and photo-base at 80mm. Then place the floating mark on points O and U and at each time I record their values on the Y-drum. Placing the floating mark again on points L,H, and R and at each time I read the X and Y values.

Calculate the difference as follows:-

$$YR - YL \triangleq Y$$

$$(XR - XL) (YU - YO) \triangleq X$$

From the above equations, I computed my X and Y



As:-

$$X = X_H - 1.5 \Delta Y$$

$$Y = Y_H + 1.5 \Delta X$$

Note:- The residual errors ΔX and ΔY should be equal to zero. (this is stated in the instrument manual). The above readings was done with the left eye for the left plate and the right eye for the right plate.

Having satisfied myself that the instrument was still in its rightful position and all the parts tested were still in good condition, I now went ahead to the working procedures.

3.3 WORKING PROCEDURES:-

It must be stated here, that the aerial photos for this project area was already available long time ago (because this country has been covered with aerial photos and the expenses involved in taking new photos cannot be undertaken by an individual). Despite the availability of the photographs, I still went ahead to compute for the number of photos, the photo-scale and the flying height of the taken air-craft. This is just to ensure that all necessary data are available for my work.

3.4 The photo-scale was calculated using the formula;

$S = F/H - h$, Where 'S' is the photo-scale, 'F' is the focal length of the taken camera. 'H' is the flying height of air-craft, and 'h' is the mean height of the area (Kwoi town-ship in Kaduna State).

$$F = 150\text{mm}, \quad H = 4,000\text{m} \text{ and } h = 250\text{m}.$$

$$\therefore S = 150/4000 - 250$$

$$= 150/3750 \times 1000$$

$$= 1:25,000$$

The number of photographs was calculated using the gathered data:-

Area of photography was 15km by 10km (including outside Kwoi town-ship), format size is 230mm by 230mm, forward overlap 60%, lateral overlap 25% and the photo-scale is 1:25,000.

Calculation for number of aerial photographs:-

Gain percent of forward overlap = 40%

\therefore 40% of format size

$$= 40/100 \times 230/1$$

$$= 92\text{mm}$$

Number of photos per strip:-

Length of the area x 1000,000

92 x photo-scale.

i.e 15km x 1000,000 (we multiply by 1000,000 to convert the km to mm)

$$92 \times 25,000$$

$$= 600/92$$

$$= 6.5$$

$$= 7.$$

But we need to add 2 extra photos because the 1st and last exposure on each strip must be outside the border line.

Thus the number of photos per strip $= 7 + 2 = 9$ Photos

Gain % of lateral overlap = 75%

\therefore 75% of format size.

$$= 75/100 * 230$$

$$= 172.5 \text{ mm.}$$

Number of strips

Breadth of the area x 1,000,000

172.5 x photo-scale

$$= \frac{10 \times 1,000,000}{172.5 \times 25,000} = \frac{400}{172.5}$$

$$= 2.3 = 3 \text{ strips.}$$

\therefore total number of photos:-

$$= 9 \times 3 = 27 \text{ photographs.}$$

Thus, for this project work, the total number of photos needed is 27.

3.5 Having confirmed that the needed photos were available, I went ahead to start aerotriangulation. In preparation for the aerotriangulation (extension of control points) the following steps was undertaken.

1. Preparation of the diapositives
2. Identification of control points
3. Selection of the points
4. Plotting of Ground control points on a grided sheet
5. Preparation of observation and transformation forms.

In preparing the diapositives (that is glass-plate with images of ground objects engraved on it). The ground objects are buildings, foot-path, major and minor roads, streams, rivers etc). the first thing I did was to mark all the relevant control points (ie GCP and MCP) using the snap marker on all relevant diapositives after identifying these points from the aerial photographs. After doing that, I selected some very sharp and well identifiable points as tie-points. Tie-points are used in joining one model to the next one. The points selected as tip points are points that appears on at least three successive photographs or diapositives and they are been transferred to all relevant diapositives. Before doing all this, on a sheet of stable material the ground control points was plotted using the coordinates

given by the land surveyors at a scale which is $\frac{1}{4}$ that of the photo-scale. (i.e 1:6,000).

Having marked all the necessary GCP and MCP on the diapositives, I started by carrying out the orientations of model zero (ie the 1st model). The orientations include inner, relative and absolute orientations.

3.6 Inner orientation is the process of restoring back the original rays that produce the images and getting the exact position of the air-craft as at the time of exposure. It is also the means of centering the diapositives in the projectors including setting the correct principal distance onto the projectors. The procedures of carrying out inner orientation are as follows:

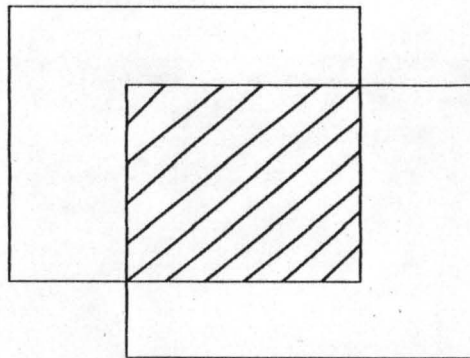
1. Setting the correct principal distance onto the projectors. This was done by setting the exact value of the focal length (150mm) of the taken camera onto the projectors by using a crank. Fix the crank in the correct position and wind up or down to get the exact value of the focal length. The body of the projectors are calibrated in millimeter.
2. Centering of the diapositives. This was done by placing the diapositive into the photo-carrier and with the use of the light-box (provided by the manufacturer of the instrument) and the four

magnifiers. I make sure that the fiducial marks on the diapositive coincide exactly with that of the photo-carrier.

The reason for doing this, is to ensure that the principal point is on the optical axis of the projector lens.

On completion of the above two steps, the first and second diapositives with the emulsion side downward is taken back to the projectors. We must ensure that the overlapping areas is in between the two projectors.

Diagram: showing overlapping areas.



3.7 The next stage of orientation is the Relative orientation. Relative orientation is the procedure of making the stereomodel to be very clear. In other words, it is a procedure of removing Y-PARALLAX. (parallax is the apparent displacement of an image point due to a change in the position of observation). But you cannot start relative orientation directly without introducing an approximate model base (ie bx) so that subsequent model

scale connection is kept at a minimum. My model-base was computed using the formulas

$$bx = (\text{photo-scale} \times \text{photo-base}) / \text{model scale}$$

$$\text{i.e } bx = (Sp * b) / Sm$$

My approximate model-base was calculated as 184mm because my $Sp = 1:10,000$, $Sm = 1:5000$ and $b = 92\text{mm}$.

The photo-base (b) was calculated by finding the gain percent of the format size. (For this project, the forward overlap is 60% and the format size is 230mm by 230mm.

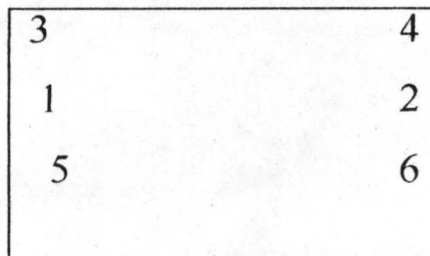
Thus, my photo-base is equal to

40% of 230

=92mm.

After calculating my bx, the value was set onto the bx-dial.

(ie 184mm was used as an approximate model base). To begin relative orientation proper, you need to know the six-standard points in the model.



See the above diagram:-

With these points identified in the stereomodel, you either use the empirical method or the numerical method of relative orientation. For this

projects work, the empirical method was undertaken because it is faster than the numerical method. The empirical method which is the trial and error method was carried out as follows:-

Step 1 Remove Y-parallax at point 1 using x' (kappa II)

Step 2 Remove Y-parallax at point 2 using x' (kappa I)

Step 3 Remove Y-parallax at point 3 using ϕ'' (phi II)

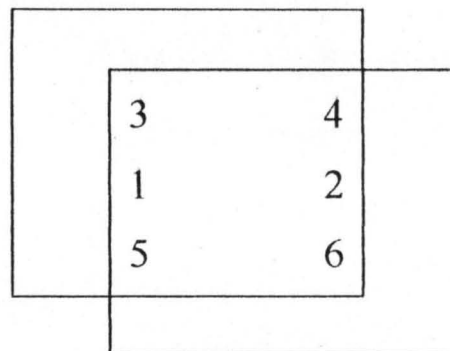
Step 4 Remove Y-parallax at point 4 using ϕ' (phi I)

Step 5 Remove over correct $1\frac{1}{2}$ times using either WI or WII (Omega I or Omega II) at point 5.

Step 6 Repeat steps 1 to 5

Step 7 check point 6 and if there is any parallel repeat steps 1-5

Diagram showing the overlapping areas and the conventional six-standard points.



3.8 Having completed the relative orientation, a three dimensional model has been established but the model has known scale and is yet to be leveled with respect to a datum. To know the scale and to level the model with

respect to a datum, I therefore, carried out what is known as absolute orientation. But before you can start absolute orientation, you need to calculate what would be your model scale by using the scale of the photograph, the focal length (f) of the taken camera and the type of camera whether it is a wide-angle camera (70-degrees) or a super wide angle camera (above 100 degrees). This is to enable me to find the ratio between the photo-scale and the model-scale. Using the formula (Z-MAXIMUM) /f, I calculated my model scale as

$$Z\text{-maximum}/f$$

$$= 350/152$$

$$= 2.3\text{mm.}$$

(Z-maximum is the maximum projection distance of the stereoplotter). Thus the required model scale was calculated using this formula: $S_m = S_p/2.3 = 10,000/2.3 = 4,348$. From the manual of wild-A8, the largest possible model scale with the available transmission for direct height reading is 1:5,000 into the glass-scale position on the instrument and introduced my gear ration which was also calculated using the relation sheet. The sheet was plotted at 1:2,500 and the model scale as 1:5,000, thus the gear ratio is 1:2. The placing of the gear ratio into the gear box was done

by un-tying two nuts from its cover and placing the bigger gear to the left-hand side and the smaller one to the right.

On completion of choosing the model-scale, absolute orientation was carried out. Absolute orientation is a way of scaling and leveling to ground controls in a photogrammetric instrument of a relatively oriented stereoscopic model (4th Edition of manual photogrammetry). It involves two main stages that is scaling and leveling of the stereomodel. In absolute orientation we normally start with the scaling which can be done using the empirical method or the numerical method. The empirical method was adopted for this project work because it is faster than the numeric method. But in either method, the stereomodel must contain two horizontal control points with their co-ordinates well plotted on the grid-sheet. These points must be in diagonal position to each other.

Empirical method:- This is the trial and error method of scaling. The gridded sheet was placed on the plotting table and the X and Y hand wheels was moved to one of the control point in the model. Put the floating mark onto the ground using the foot-disk. During this movement, the pencil chuck moves relatively with the hand-wheels. The sheet was moved so that the plotted point is directly beneath the pencil point. Then move the hand-wheels to the other diagonal point in the model (see diagonal below) and

bring the floating mark onto the ground using the foot-disk and check whether the pencil point is directly beneath the second plotted point on the sheet. If the point falls short of the second plotted point on the sheet, the base of the instrument must be increased by separating the cameras (ie projectors) in X-direction with the use of the bx-screw. But if the pencil point falls beyond the second plotted point, the base of the instrument must be decreased using the bx-screw.

Before increasing or decreasing the base of the instrument, you have to note the distance between the pencil point and the second plotted point, divide this distance into two and use your hand to correct one half by shifting the sheet and the other half is corrected using the bx-screw. This procedure is repeated until the two plotted points are in the same scale as that of the model.

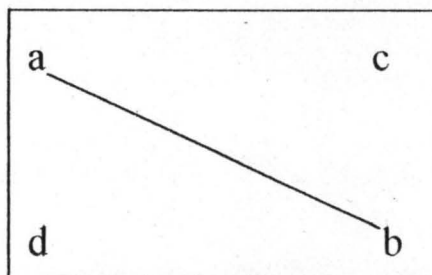


Diagram showing the plotted ground control point for scaling the model.

Note: You can either scale through A and B and check on C and D, or you scale through C and D and check on A and B. when the model is well

scaled, points A,B,C and D must be well fitted without any problem. After scaling the model, the next thing I did was to level the model.

Levelling: This is a way of making the given control points to read their true heights which was supplied by the land surveyors. This operation involves the use of common Phi and common Omega. But on wild-A8, there is no common omega, so I make use of the two omega. Levelling can be done in either empirical or numerical method. We need the heights of four points out of which three are used for leveling and the fourth one as a check point.

Empirical method of leveling: In this method, two corner points along the phi-axis are chosen (see diagram below). Move the instrument with the use of the "gun" to point D and put the floating mark on the ground. Set the given height with the hand onto the glass-scale. After this was done, I move the instrument to point C and put the floating mark on the ground using the foot-disc, read its height and find the difference between the read its height and the given height of point C. the difference is divided into two, one-half is set on the glass-scale with the foot-disc and the floating mark is placed on the ground with the foot-disc. The second half is set on the glass-scale with the hand. The instrument is moved back to point D and the above operation is repeated until points D and C are reading their given heights.

After this was completed, another two points were chosen along the common omega axis (see diagram below). The points are point C and point A. Since point C has been levelled using the common phi axis, the instrument was moved to point A. put the floating mark on the ground and find the difference the difference between this height and that of the given height for point A and divide this difference into two. One-half was set onto the glass-scale with the foot-disc and put the floating mark on the ground using the two-omega. The other half was set onto the glass-scale with the hand. The instrument was then moved to point C and height was taken which will not change unless the previous setting with the use of common-phi is not property done.

When these two points (ie points C and point A) are reading the correct given heights, then check on point D to see if the height has changed. If it has changed, repeat the whole procedure again until points D, C and A are reading their given heights. Then check on point Band if there is any difference between the read height and the given height of point B, then the whole procedure is repeated until point B is reading its given height. In the exercise I carried out, after the second trial all the points were reading their given heights.

Diagram showing points for levelling.

A	B
+	+
D+	+C

3.9 AEROTRIANGULATION USING THE INDEPENDENT METHOD:

Having confirmed that the scaling and leveling of the model has been properly carried-out, I went ahead to start the extension of controls using the independent method. (Because we have also the dependent method of extension of controls). The independent method is a process where-by individuals model is having different scale and different angular position. Therefore, the initial model is used as reference to other models. Moreover, all other models in a strip (ie photos on a straight line) are then brought to the same scale and the same angular orientation of the initial model (ie model zero). Like wise, in independent method, each element of absolute orientation is transferred from model to model up to the last model in a strip. It is worth mentioning that wild-A8 is having only two projectors, thus, we start our model zero by placing the first diapositive on projector 2. (Note: the two first diapositives must be the overlapping type and the area of overlap must be in-between the two projectors). Thus, the principle of aerotriangulation comes into use when we are trying to have model 2 and model 3 in which there are no addition control points and since in model 1,

plates 1 and 2 are having the same position relative to each other at the time of exposure. In order to introduce plate 3, plate 1 is removed and plate 2 is placed in the position of plate 1 (that is in projector 1) and the value of omega right is transferred to the omega left, then plate 3 is placed in projector 2. The problem now is to bring model 2 to the same scale as model 1 having successfully oriented model 2 with the use of elements of orientation of the new plate. We don't have to touch the left omega when orienting model 2 but it can be achieved by comparing a distance common to both model, then making these distances equal.

After placing diapositives in their respective projectors, I now prepare my recording (observation) forms. We have two types of forms, one is used for the recording X and Y co-ordinates from the autograph and the values of elements of orientation must be recorded on it.

The second form is known as the transformation form where the autograph readings are transformed into the terrain co-ordinates. With these forms ready, I now get the autograph readings of my points to be used for transformation.

Autograph readings:

POINTS NUMBER	X CO ORD	Y CO ORD
8A	447.365	326.757
8B	447.584	277.097
8C	447.122	301.669
9A	447.437	326.990
9B	447.693	276.935
9C	476.627	302.336

Terrain co-ordinates:-

POINTS NUMBER	X CO-ORD	Y CO-ORD
8A	9011.31	6402.70
8B	9002.70	5111.82
8C	8999.90	5902.21

Note: The 3-terrain co-ordinates above are the only co-ordinates given by the land surveyors.

Using the above data, the first thing I did was to calculate my δT (ie the difference in the terrain co-ordinates) and δA (ie the difference in the autograph co-ordinate).

δT was calculated using the formula:

$$\delta T = \sqrt{(X_3 - X_5)^2 + (Y_3 - Y_5)^2}$$

$$\text{ie } (9011.31 - 9002.7)^2 + (6402.7 - 5411.82)^2$$

$$= (8.61)^2 + (990.88)^2$$

$$= 74.132 + 981843.174$$

$$= 981917.3065$$

$$= \underline{990.917}$$

and δA was calculated using the formula:

$$\delta A = (X3 - X5)^2 + (Y3 - Y5)^2$$

$$\text{ie } (447.365 - 447.584)^2 + (326.757 - 277.077)^2$$

$$= (0.219)^2 + (49.66)^2$$

$$= 4.796 + 2466.165$$

$$= 2470.961$$

$$= \underline{49.7}$$

After computing my δA and δT , I now calculated my K(constant)

using the formulas

$$K = \delta T / \delta A$$

$$= 990.917 / 49.7$$

$$= 19.9379 = \underline{20}$$

The value of K was then used to multiply the autograph readings. The reason for doing this, is to bring the autograph readings into the same unit as that of the terrain co-ordinates (ie into meters). The new values of the autograph reading after multiplying with the value of K. are as follows:

POINTS NUMBER	X CO ORD	Y CO ORD
8A	8947.30	6535.11
8B	8951.68	5511.93
8C	8842.44	6033.38
9A	9518.73	6535.30
9B	9553.86	5538.69
9C	9532.58	6046.72

The above data was record into the observation form (see appendix) and the mean of points 8A, 8B, and 8C was calculated as follows:

For X co-ordinate $(8974.30 + 8951.93 + 8942.44)/3$

$$= 26868.67/3$$

$$= \underline{8956.22}$$

For Y co-ordinate $(6535.14 + 5541.93 + 6033.38)/3$

$$= 18110.45/3$$

$$= \underline{6036.82}$$

I choose these points because these are the only points with terrain co-ordinate. Also, the mean of the terrain co-ordinate was also computed as follows:

For X co-ordinate

$$= (9011.31 + 9002.7 + 8999.90)/3$$

$$= 27013.91/3$$

$$= \underline{9004.64}$$

For Y co-ordinate

$$= (6402.90 + 5411.82 + 5902.21)/3$$

$$= 17716.93/3$$

$$= \underline{5905.64}$$

Having computed the mean for the autograph and the terrain co-ordinates, I now find the difference between the autograph readings and the mean (e.g. $8947.30 - 8947.14 = 10.16$) for both X and Y and the values was recorded in column 2 and column 3 of the transformation form (see appendix). That of the terrain co-ordinate was also done in the same way and the difference was recorded into column 6 and column 7 (e.g. $9011.31 - 9004.64 = 16.67$) of the transformation and transferred the record values of column 2 and column 3 to columns +a and +b on the transformation form and that of columns 6th and 7th was transferred to column -C on the same form. The values in column a, b, and -c was used to get my aa, bc and ac (see appendix...).

The result of aa is 493293.4953, that of bc is -6446.4788 and that of ac is -492107.8552.

The next thing I did was to calculate for $K \cos \alpha_0$ and $K \sin \alpha_0$ using the following formulas

$$K \cos \alpha_0 = -ac/aa$$

$$K \sin \alpha_0 = -bc/aa$$

$$\text{thus } K \cos \alpha_0 = 492,107.8552/493293.4953$$

$$= 0.9975$$

$$\text{and } K \sin \alpha_0 = 6446.4788/493293.4953$$

$$= 0.01307.$$

After this, I now transformed the analog readings to that of the terrain using the formulas stated below so as to get my terrain co-ordinates for points 8A, 8B, 8C, 9A, 9B and 9C.

The formulas are these:-

$$X = X_{TM} + aK \cos \alpha_0 + bK \sin \alpha_0$$

$$Y = X_{TM} - aK \sin \alpha_0 + bK \cos \alpha_0.$$

For example, the terrain co-ordinates for points 8A was obtained as follows:-

$$\text{For } X = 8947.14 + (-4.7 \times 0.9975) + (-3.44 \times 0.01307)$$

$$= 8942.4068$$

$$\text{For } Y = 6036.82 - (-4.7 \times 0.01307) + (-3.44 \times 0.9975)$$

$$= \underline{\underline{6033.45}}$$

The results from these two equations for each point was recorded in column 9 of the transformation form. (see appendix...). The values obtained was compared to that of column 4 and column 5 and I found that the

transformation was correctly done because my errors was below the given limits that is 0.03.

Having completed my model zero; to carryout the next model or rather to connect model zero to model 1, the diapositive in projector I was removed and in its place diapositive no. 2 was place and diapositive no. 3 was placed on projector 2. The relative orientation of the 2nd model was performed in the same manner as model zero and the height of P (N) (which was a point chosen in model zero) was set at 100 grade using the foot-disc. When this is done, the floating mark will no longer be on the "ground" and as such I have to bring the floating mark to the "ground" using the bX-screw. Then, I now check the scaling on the principal points in this model. From here, I now calculated my common-phi for the new model using the formulas $P(N) - Z'P$ (ie $150.46 - 110.54 = 39.92$). this result was set on to the common-phi dial. The next thing I did was to check the leveling of w (ie omega) by putting the floating mark on P(N) onto the "ground" using the foot-disc. After this, I now went ahead to read the co-ordinates (ie 10A, 10B and 10C).

Using the transformed values of points 9A, 9B and 9C as my terrain co-ordinates, I now transformed the autograph readings of points 10A, 10B and 10C into terrain co-ordinates as it was done for model zero.

Thus, points 9A, 9B, 9C, 10A, 10B, and 10C whose terrain coordinates were not supplied by the land surveyors are appendix...). In this way, the chosen pass-points are now used as control points having determined their terrain co-ordinates.

CHAPTER FOUR

SOFTWARE DEVELOPMENT AND IMPLEMENTATION

4.1 In development my software, the following steps was taken:

- i. **Problem Definition:-** This is the process of determining the nature and scope of the project work. In this project work or program development, the definition of the problem has to do with limiting the tedious task the surveyors has to go through in getting horizontal controls from the field. The problem is how to get more horizontal control from the few ones supplied by the land surveyors using the Photogrammetry stereoplotters.
- ii. **Feasibility Study:** The feasibility study in this case has to do with carrying out an indepth research and study of what the possible problems might be and also embarking on a careful analysis of each necessary parameter that would be needed for the development of the program.

In the development of this program, the parameters that needs to be considered are:-

- a. **Aerial photograph,** we need a stable and a specially designed air-craft that will carry the aerial camera. We also need a clear weather free

from snow, cloud, dust, smoke etc so that very sharp pictures can be obtained.

- b. Diapositives: It is necessary that the diapositives should have ground features like buildings, trees, streams etc on the area you are working upon. This is to enable us to prick our points whose co-ordinates are needed. Also, on the diapositives we need to prick our points using either the pre-marking or post-marking method.
 - c. Choosing a reasonable scale: A reasonable scale is necessary for the plotting of ground controls supplied by the land surveyors.
 - d. Marking of the diapositives: In choosing our points, we need to mark them using either the triangular symbols for the ground control points and a circular symbol for the minor control points.
- iii. System Analysis: After the system has being approved for further study, the next step is to perform a detailed analysis of the existing system. The overall emphasis is to uncover some of the limitations of the existing system. Also to determine the extent to which the system can help to achieve the much needed goals and objectives in the following order:-
- a. Getting all the needed aerial photographs for which the extension is to be carried out.

- b. Carrying out all the three orientations to get a good stereoscopic view of the stereomodel.
 - c. Recording of all the elements of orientation, that is getting the values of elements of orientation like kappa (κ), Phi (ϕ) and omega (ω). Also to read and record all the autograph co-ordinates for each chosen and given points in the model.
 - d. Transforming the autograph readings into terrain co-ordinates using all the mathematical formulas.
- iv. Coding: Coding has to do with first designing an algorithm for the program, then after which a preferred and a suitable programming language is chosen that can meet the overall requirements of the system in terms of performance, codes are developed in a step by step sequence until all the stages of the program are codes.

In this project, all the parameters needed for the effective performance of the program are coded into the computer using the Basic language. To develop Basic codes, the syntax and semantics of this language was carefully studied. The program was divided into modules and each module as a sub-program to the main program.

- v. Debugging: This has to do with removing the bugs or errors which might be either logical error or syntax error of the program. The

essence of removing bugs if at all it exist, is to make for attaining the designed performance or the result of the developed program. Unchecked and undebugged programs will bring about a malfunction of the program.

- vi. Test Running: This is the process of testing the program with sample data so as to see if it will produce the desired result. It is necessary here to test all the modules of the program individually to ensure their work ability. In test running the program, sample co-ordinates of points like points 8A, 8B and 8C for both autograph and terrain co-ordinates was keyed into the computer to see if it would get the desired transformation.
- vii. Implementation: Implementation is the process of installing the program where it is to be used. The program was installed on 326 computer and there is a provision for any user on how to use the program so as to achieve the desired aims and objectives in any Photogrammetric exercise that requires extension of controls.
- viii. Maintenance: After the program has being installed and found to achieve its aim,
there is the need for a period maintenance which could be quarterly, every six months or yearly or as often as the end user deem it necessary to alter a

sequence. The essence of maintenance is to make the program meet up with changes by the surveying profession or personal changes by the surveyor which makes for effectiveness.

(Lecture note (CPD728). System Analysis and Design)

CHPATER FIVE

5.1 RECOMMENDATION:

The department should try to organize seminars for P.GD. students even if it is once in a semester. This will allow the students to read more books on computer science as relative to their individual areas of specialization.

The department should enforced the students to attend practicals and it is to carry two-credit load. A lecturer should be attached to this program so that the students should be able to operate on one or two different applications (like word perfect and Dbase packages) during their stay in the department.

I will also recommend the department to give out the project topics to students or the students should submit their project topics at the beginning of every second semester. This will enhance the performance of the students in project writing because both the human and material resources are available while in school.

CONCLUSION:

- 5.2 In conclusion, computerization in any organization is a function of the volume of activities on the ground for processing. In other words, the use of computer should take over the manual way of getting more controls and the staff involve should be highly proficient in the field of computer.

APPENDICES

REFERENCES:

REMY N. Onyewuenyi, (1994) Micro Computer Studies for Beginners

Lecture Note CPD 711, Introduction to Computer

Lecture Note CPD 711, Computer Programming made Easy

American Society of Photogrammetrist, Manual of Photogrammetry Fourth edition

Paul R. Wolf, Elements of Photogrammetry

Lecture Note CPD 728, System Analysis and Design

Kenneth Agbasi, Introduction to Computer Science and Basic Programming

Holmes, Basic Programming

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CLS
SCREEN 12
LINE (0, 50)-(639, 310), 2, B
LINE (75, 50)-(75, 310), 2
LINE (75, 110)-(639, 110), 2
LINE (0, 140)-(639, 140), 2
LINE (0, 170)-(639, 170), 2
LINE (175, 110)-(175, 310), 2
LINE (275, 50)-(275, 310), 2
LINE (375, 110)-(375, 310), 2
LINE (472, 50)-(472, 310), 2
LINE (560, 110)-(560, 310), 2
LINE (0, 280)-(639, 280), 2
LINE (75, 110)-(639, 110), 2
LOCATE 2, 25: PRINT "TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COOR
LOCATE 5, 12: PRINT "A COORDINATE IN"
LOCATE 6, 12: PRINT "TERRAIN SYSTEM"
LOCATE 6, 38: PRINT "+a                +b                -c"
LOCATE 8, 10: PRINT " Xa                Xb                "
LOCATE 10, 4: PRINT " 1                8                9"
LOCATE 7, 2: PRINT "point No"
LOCATE 12, 2: PRINT "1/8A"
LOCATE 13, 2: PRINT "2/8A"
LOCATE 14, 2: PRINT "3/8C"
LOCATE 15, 2: PRINT "4/9A"
LOCATE 16, 2: PRINT "5/9B"
LOCATE 17, 2: PRINT "6/9C"
DIM ARG(12)
DIM TER(6)
DIM AR(8)
DIM B(6)
DIM C(6)
FOR I = 1 TO 12
LOCATE 1, 1: INPUT "INPUT ARG:"; ARG(I)
NEXT I
FOR I = 1 TO 6
LOCATE 1, 1: INPUT "INPUT TER:"; TER(I)
NEXT I
DT = ((TER(1) - TER(3)) ^ 2 + (TER(4) - TER(6)) ^ 2) ^ .5
DA = ((ARG(1) - ARG(3)) ^ 2 + (ARG(7) - ARG(9)) ^ 2) ^ .5
REM K = (DT / DA)
FOR I = 1 TO 12
ARGZ = ARG(I) * K
ARG(I) = ARGZ
NEXT I
ARGXI = (ARG(1) + ARG(2) + ARG(3)) / 3
ARGY1 = (ARG(7) + ARG(8) + ARG(9)) / 3
TERXI = (TER(1) + TER(2) + TER(3)) / 3
TERY1 = (TER(1) + TER(2) + TER(3)) / 3
FOR I = 1 TO 6
ARGX2 = ARG(I) - ARGX1
LOCATE I + 11, 11: PRINT ARGX2
AGR(I) = ARGX2
NEXT I
FOR I = 1 TO 7
ARGY2 = ARG(I) - ARGY1
LOCATE I + 15, 25: PRINT ARGY2
ARG(I) = ARGY2

```

```

NEXT I
FOR I = 1 TO 3
TERX2 = TER(I) - TERX1
LOCATE I + 11, 61: PRINT TERX2
LOCATE I + 11, 40: PRINT TER(I)
C(I) = -1 * TERX2
NEXT I
FOR I = 4 TO 6
TERY2 = TER(I) - TERY1
LOCATE I + 8, 71: PRINT TERY2
LOCATE I + 8, 50: PRINT TER(I)
C(I) = TERY2
NEXT I
LOCATE 19, 38: PRINT TERX1
LOCATE 19, 50: PRINT TERY1
J = 0
FOR I = 1 TO 3: J = J + 1
AR(J) = ARG(I): NEXT I
FOR I = 7 TO 9: J = J + 1
AR(J) = ARG(I): NEXT I
J = 0
FOR I = 4 TO 6: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 3: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 6
LOCATE I + 11, 35: PRINT AR(I)
LOCATE I + 11, 48: PRINT B(I)
LOCATE I + 11, 60: PRINT C(I)
NEXT I
END

```

SUB box2

```

LOCATE 2, 25: PRINT "TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COORDINA
LOCATE 5, 12: PRINT "A COORDINATE IN"
LOCATE 6, 12: PRINT "TERRAIN SYSTEM"
LOCATE 6, 38: PRINT "+a"
LOCATE 8, 10: PRINT " Xa"
LOCATE 10, 4: PRINT " 1"

```

+b	-c"
xb	"
8	9"

END SUB

```

CLS
DIM ARG(12)
DIM TER(10)
FOR I = 1 TO 12
INPUT "INPUT ARG:"; ARG(I)
NEXT I
FOR I = 1 TO 6
LOCATE 1, 1: INPUT "INPUT TER:"; TER(I)
NEXT I

ARGX1 = (ARG(1) + ARG(2) + ARG(3)) / 3
ARGY1 = (ARG(7) + ARG(8) + ARG(9)) / 3
TERX1 = (TER(1) + TER(2) + TER(3)) / 3
TERY1 = (TER(1) + TER(2) + TER(3)) / 3
FOR I = 1 TO 6
ARGX2 = ARG(I) - ARGX1
LOCATE I + 11, 11: PRINT ARGX2
AGR(I) = ARGX2
NEXT I
FOR I = 1 TO 7
ARGY2 = ARG(I) - ARGY1
LOCATE I + 15, 25: PRINT ARGY2
ARG(I) = ARGY2
NEXT I
FOR I = 1 TO 3
TERX2 = TER(I) - TERX1
LOCATE I + 11, 61: PRINT TERX2
LOCATE I + 11, 40: PRINT TER(I)
C(I) = -1 * TERX2
NEXT I
FOR I = 4 TO 6
TERY2 = TER(I) - TERY1
LOCATE I + 8, 71: PRINT TERY2
LOCATE I + 8, 50: PRINT TER(I)
C(I) = TERY2
NEXT I
LOCATE 19, 38: PRINT TERX1
LOCATE 19, 50: PRINT TERY1
J = 0
FOR I = 1 TO 3: J = J + 1
AR(J) = ARG(I): NEXT I
FOR I = 7 TO 9: J = J + 1
AR(J) = ARG(I): NEXT I
J = 0
FOR I = 4 TO 6: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 3: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 6
LOCATE I + 11, 35: PRINT AR(I)
LOCATE I + 11, 48: PRINT B(I)
LOCATE I + 11, 60: PRINT C(I)
NEXT I

FOR I = 1 TO 6
ARGX2 = ARG(I) - ARGX1
LOCATE I + 11, 11: PRINT ARGX2
AGR(I) = ARGX2
NEXT I
FOR I = 1 TO 7

```



```

JJ = JJ, + 1:
IF JJ > 6 THEN JJ = 6
YYA = TER(JJ) - YA
IF J = 6 THEN YYA = 0
  PRINT YYA
NEXT I
SUM = 0
FOR I = 1 TO 3
SUM = SUM + C(I)
NEXT I
LOCATE 19, 35: PRINT SUM
SUM1 = 0
FOR I = 4 TO 6
SUM11 = SUM1 + C(I)
NEXT I
LOCATE 19, 47: PRINT SUM1

```

```
CLS
```

```
SCREEN 12
```

```

LINE (0, 50)-(639, 310), 2, B
LINE (75, 50)-(75, 310), 2
LINE (75, 110)-(639, 110), 2
LINE (0, 140)-(639, 140), 2
LINE (0, 170)-(639, 170), 2
LINE (175, 110)-(175, 310), 2
LINE (275, 50)-(275, 310), 2
LINE (375, 110)-(375, 310), 2
LINE (472, 50)-(472, 310), 2
LINE (560, 110)-(560, 310), 2
LINE (0, 280)-(639, 280), 2
LINE (75, 110)-(639, 110), 2

```

```
LOCATE 2, 25: PRINT "TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COORDINATE"
```

```
LOCATE 5, 12: PRINT "A COORDINATE IN"
```

```
LOCATE 6, 12: PRINT "TERRAIN SYSTEM"
```

```
LOCATE 6, 38: PRINT "+a" +b -c"
```

```
LOCATE 8, 10: PRINT " Xa" Xb "
```

```
LOCATE 10, 4: PRINT " 1" 8 9"
```

```
LOCATE 7, 2: PRINT "point No"
```

```
LOCATE 12, 2: PRINT "1/8A"
```

```
LOCATE 13, 2: PRINT "2/8A"
```

```
LOCATE 14, 2: PRINT "3/8C"
```

```
LOCATE 15, 2: PRINT "4/9A"
```

```
LOCATE 16, 2: PRINT "5/9B"
```

```
LOCATE 17, 2: PRINT "6/9C"
```

```
DIM ARG(12)
```

```
DIM TER(6)
```

```
DIM AR(8)
```

```
DIM B(6)
```

```
DIM C(6)
```

```
FOR I = 1 TO 12
```

```
LOCATE 1, 1: INPUT "INPUT ARG:"; ARG(I)
```

```
NEXT I
```

```
FOR I = 1 TO 6
```

```
LOCATE 1, 1: INPUT "INPUT TER:"; TER(I)
```

```
NEXT I
```

```
DT = ((TER(1) - TER(3)) ^ 2 + (TER(4) - TER(6)) ^ 2) ^ .5
```

```
DA = ((ARG(1) - ARG(3)) ^ 2 + (ARG(7) - ARG(9)) ^ 2) ^ .5
```

```
REM K = (DT / DA)
```

```

ARGY2 = ARG(I) - ARGY1
LOCATE I + 15, 25: PRINT ARGY2
ARG(I) = ARGY2
NEXT I
FOR I = 1 TO 3
TERX2 = TER(I) - TERX1
LOCATE I + 11, 61: PRINT TERX2
LOCATE I + 11, 40: PRINT TER(I)
C(I) = -1 * TERX2
NEXT I
FOR I = 4 TO 6
TERY2 = TER(I) - TERY1
LOCATE I + 8, 71: PRINT TERY2
LOCATE I + 8, 50: PRINT TER(I)
C(I) = TERY2
NEXT I
LOCATE 19, 38: PRINT TERX1
LOCATE 19, 50: PRINT TERY1
J = 0
FOR I = 1 TO 3: J = J + 1
AR(J) = ARG(I): NEXT I
FOR I = 7 TO 9: J = J + 1
AR(J) = ARG(I): NEXT I
J = 0
FOR I = 4 TO 6: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 3: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 6
LOCATE I + 11, 35: PRINT AR(I)
LOCATE I + 11, 48: PRINT B(I)
LOCATE I + 11, 60: PRINT C(I)
NEXT I

SUM1 = 0: SUM2 = 0: SUM3 = 0
FOR I = 1 TO 6
SUM1 = SUM1 + (AR(I) * AR(I))
SUM2 = SUM2 + (AR(I) * C(I))
SUM3 = SUM3 + (B(I) * C(I))
NEXT I
LOCATE 21, 20: PRINT "[AXA]="; SUM1
LOCATE 22, 20: PRINT "[AXC]="; SUM2
LOCATE 23, 20: PRINT "[BXA]="; SUM3
DIM KC(30)
DIM KS(30)

KC = -(SUM2 / SUM1)
KS = -(SUM3 / SUM1)
LOCATE 24, 20: PRINT "KCOSA="; KC
LOCATE 25, 20: PRINT "KSINA="; KS
JJ = 3
FOR I = 1 TO 6
Z = TERX1 + (AR(I) * KC) + (B(I) * KS)
LOCATE I + 11, 11: PRINT Z
XXA = TER(I) - Z
IF I > 3 THEN XXA = 0
LOCATE 22 + 1, 46: PRINT XXA
YA = TERY1 - (AR(I) * KS) + (B(I) * KC)
LOCATE 1 + 11, 25: PRINT YA

```

```

FOR I = 1 TO 12
ARGZ = ARG(I) * K
ARG(I) = ARGZ
NEXT I
ARGXI = (ARG(1) + ARG(2) + ARG(3)) / 3
ARGY1 = (ARG(7) + ARG(8) + ARG(9)) / 3
TERXI = (TER(1) + TER(2) + TER(3)) / 3
TERY1 = (TER(1) + TER(2) + TER(3)) / 3
FOR I = 1 TO 6
ARGX2 = ARG(I) - ARGX1
LOCATE I + 11, 11: PRINT ARGX2
AGR(I) = ARGX2
NEXT I
FOR I = 1 TO 7
ARGY2 = ARG(I) - ARGY1
LOCATE I + 15, 25: PRINT ARGY2
ARG(I) = ARGY2
NEXT I
FOR I = 1 TO 3
TERX2 = TER(I) - TERX1
LOCATE I + 11, 61: PRINT TERX2
LOCATE I + 11, 40: PRINT TER(I)
C(I) = -1 * TERX2
NEXT I
FOR I = 4 TO 6
TERY2 = TER(I) - TERY1
LOCATE I + 8, 71: PRINT TERY2
LOCATE I + 8, 50: PRINT TER(I)
C(I) = TERY2
NEXT I
LOCATE 19, 38: PRINT TERX1
LOCATE 19, 50: PRINT TERY1
J = 0
FOR I = 1 TO 3: J = J + 1
AR(J) = ARG(I): NEXT I
FOR I = 7 TO 9: J = J + 1
AR(J) = ARG(I): NEXT I
J = 0
FOR I = 4 TO 6: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 3: J = J + 1
B(J) = AR(I): NEXT I
FOR I = 1 TO 6
LOCATE I + 11, 35: PRINT AR(I)
LOCATE I + 11, 48: PRINT B(I)
LOCATE I + 11, 60: PRINT C(I)
NEXT I

```

SUB box2

```

LOCATE 2, 25: PRINT "TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COORDINATI
LOCATE 5, 12: PRINT "A COORDINATE IN"
LOCATE 6, 12: PRINT "TERRAIN SYSTEM"
LOCATE 6, 38: PRINT "+a"
LOCATE 8, 10: PRINT " Xa"
LOCATE 10, 4: PRINT " 1"

```

+b	-c"
Xb	"
8	9"

END SUB

TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COORDINATES

POINT NO	A-COORDINATES REDUCED TO THE CENTER OF GRAVITY		TERRAIN COORDINATES		T-COORDINATES REDUCED TO THE CENTER OF GRAVITY	
	X	Y	XT	YT	xt	yt
1	2	3	4	5	6	7
1/8A	-156.32	-276.97	9011.31	6402.7	-9011.31	-6402.7
2/8B	-156.1		9002.07	5411.82	-9002.07	5411.82
3/8C	-156.16	301.67	8999.9	5902.21	-8999.9	5902.21
4/9A	-276.92	-156.32				
5/9B	277.69	-156.1				
6/9C	301.67	-156.56				
			9004.427	5905.577		

TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COORDINATES

POINT NO	A-COORDINATES IN TERRAIN SYSTEM		+a	+b	-c
	XA	YA			
1	8	9			
1/8A	447.36	326.76	-156.32	-276.97	-9011.31
2/8B	447.58	277.09	-156.1	277.09	-9002.7
3/8C	447.12	301.67	-156.16	301.67	-8999.9
4/9A	447.44	326.99	-276.92	-156.32	6402.7
5/9B	447.69	276.94	277.69	-156.1	5111.82
6/9C	476.63	304.33	301.67	-156.56	5902.21
			0	0	


```

CLS
SCREEN 12
LINE (0, 50)-(639, 310), 2, B
LINE (75, 50)-(75, 310), 2
LINE (75, 110)-(639, 110), 2
LINE (0, 140)-(639, 140), 2
LINE (0, 170)-(639, 170), 2
LINE (175, 110)-(175, 310), 2
LINE (275, 50)-(275, 310), 2
LINE (375, 110)-(375, 310), 2
LINE (472, 50)-(472, 310), 2
LINE (560, 110)-(560, 310), 2
LINE (0, 280)-(639, 280), 2
LINE (75, 110)-(639, 110), 2
LOCATE 2, 25: PRINT "TRANSFORMATION AND ADJUSTMENT OF AUTOGRAMETRIC COORI
LOCATE 5, 12: PRINT "A COORDINATE IN"
LOCATE 6, 12: PRINT "TERRAIN SYSTEM"
LOCATE 6, 38: PRINT "+a           +b           -c"
LOCATE 8, 10: PRINT " Xa           Xb           "
LOCATE 10, 4: PRINT " 1           8           9"
LOCATE 7, 2: PRINT "point No"
LOCATE 12, 2: PRINT "1/8A"
LOCATE 13, 2: PRINT "2/8A"
LOCATE 14, 2: PRINT "3/8C"
LOCATE 15, 2: PRINT "4/9A"
LOCATE 16, 2: PRINT "5/9B"
LOCATE 17, 2: PRINT "6/9C"
DIM ARG(12)
DIM TER(6)
DIM AR(8)
DIM B(6)
DIM C(6)
FOR I = 1 TO 12
LOCATE 1, 1: INPUT "INPUT ARG:"; ARG(I)
NEXT I
FOR I = 1 TO 6
LOCATE 1, 1: INPUT "INPUT TER:"; TER(I)
NEXT I
DT = ((TER(1) - TER(3)) ^ 2 + (TER(4) - TER(6)) ^ 2) ^ .5
DA = ((ARG(1) - ARG(3)) ^ 2 + (ARG(7) - ARG(9)) ^ 2) ^ .5
REM K = (DT / DA)
FOR I = 1 TO 12
ARGZ = ARG(I) * K
ARG(I) = ARGZ
NEXT I
ARGX1 = (ARG(1) + ARG(2) + ARG(3)) / 3
ARGY1 = (ARG(7) + ARG(8) + ARG(9)) / 3
TERX1 = (TER(1) + TER(2) + TER(3)) / 3
TERY1 = (TER(1) + TER(2) + TER(3)) / 3
FOR I = 1 TO 6
ARGX2 = ARG(I) - ARGX1
LOCATE I + 11, 11: PRINT ARGX2
AGR(I) = ARGX2
NEXT I
FOR I = 1 TO 7
ARGY2 = ARG(I) - ARGY1
LOCATE I + 15, 25: PRINT ARGY2
ARG(I) = ARGY2

```