APPLICATION OF COMPUTER TO PHOTOGRAMMETRY AND MAPPING (A CASE STUDY OF MAPPING UNIT OF THE DEPT. OF LAND, PLANNING AND SURVEY FCDA ABUJA)

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CERTIFICATION

I certify that this project was carried out by Mallam ABDULLAHI SARKI in the Department of Mathematics and computer science, federal university of technology Minna.

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DEDICATION

TO ALLAH FOR HIS MERCIES

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All those whose names have not been mentioned here are also remembered and I am most grateful to all. May Allah bless and reward them all.

ABSTRACT

The study identifies some computer hardwares and software, and skilled manpower necessary for application of computer in conjunction with the available photogrammetric equipment in the Mapping Unit.

The Lower Usman Dam mapping data was utilised as a test data for the development of a program for internal use with the target of producing in house maps.

The study also enumerates other hardware and software already existing for use in other areas of plotting, digital mapping, strip and block adjustment.

Recommendation are made on the need for every mapping and survey sections to computerise.

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CHAPTER ONE

1.0 INTRODUCTION

The mapping section of the Federal Capital Development Authority has the responsibility to provide all maps and other survey information and records needed for constructions and other development activities in the Federal Capital Territory. This role is indeed very important as the city and every part of the Territory is being developed in accordance with plans already laid down on paper. Maps are therefore needed from the very inception upto the final execution of the master plan of the Capital City.

The production of maps could be very demanding in human, and material resources. Compilation could be very slow and error prone. Maps are however, always urgently needed and this calls for fast map production in house especially when limited area of land is involved. The problem arises from the cumbersome mathematical computation involved in map computation. Therefore introduction of computers to the subject of photogrammetry which is the background science of mapping could make life very easy. The fast computational capabilities of the computer eases the application of least square solution to the problem of photogrammetry and surveying. It is also now possible to manage huge amount of data using sophisticated programs.

There are also computer interfaces to capture digital and graphical data for map compilation. The age of total automation of photogrammetry is already here.

1.1 RESEARCH OBJECTIVES

The main objective of this project is to survey the various ways in which computer is applied to mapping and photogrammetry, and to use aerial triangulation in three dimensional conformal transformation programs for mapping lower Usma Dam as a test. The program will be written in Turbo Basic.

1.2 SCOPE AND LIMITATION

In this study emphasis will be laid on in-house mapping. In house mapping are for limited or small expanse of land for which maps are needed for urgent Planning or Engineering works. This is because in-house mapping can be carried out fast and with less cost and can be made available when required. The need for such maps arises more frequently than the bigger mapping projects. The latter is usually given out on contract due to its size.

The program will cater for aerial triangulation to provide control for in-house mapping.

1.3 JUSTIFICATION FOR THE STUDY

i. To reduce to the bearest minimum the time and labour involved in map production.

ii. To reduce the cost of providing ground control, and labour cost in plotting

iii. To make the maximum utilization of stereo restitution equipment.

iv. Further more, to find a way of updating the equipment by configuring it with computer systems eventually.

This will further enhance the serviceability of the plotting equipment which has become obsolete due to fast changing technology.

In a nutshell the justification of this study is to cut down on cost of in-house map production; improve on time of delivery accuracy of finished maps; make optimum utilization of equipment and personnel and to guide against obsolescence.

1.4 RESEARCH METHODOLOGY

In studying, developing any system the following points should be taken into consideration:-

i. Problem definition:- The issue involved should be well studied and defined in all of its ramification. Failure of such system could always be as a result of lack of all encompassing problem definition.

ii. Feasibility study:- In this study having defined what problems to be solved the next stage will be to identify what are the equipment (s) that is, hardware, software material and even personnel needed for the execution of the system.

iii. Analysis, Design and Acquisition: Having undertaken a feasibility study of available hardware, software and personnel, it will now be necessary to see how all these could work to achieve the set objectives. All the minor design considerations would have to be looked into. Here all possible alternatives would have to considered.

iv. Programming, implementation, acquisition and maintenance: All these aspect of system development will be considered.

With the above points in view the various computer facilities that can be applied to the job will be studied in order to draw some information that will help in this project. To put it in clearer terms, source of information will be from:-

i. Manuals from various mapping and survey equipment manufactures on computer facilities.

ii. Journals on Survey and mapping concerning computer applications

iii. Lecture notes from seminars, workshops, dealing with the subject.

iv. Submissions by survey companies of mapping projects carried out for FCDA especially the Lower Usma Dam Mapping.

v. Data on aerial triangulation carried out for mapping of Lower Usma Dam will be used to implement the developed program.

vi. Programs will be written in Quick Basic language since many of the personnel in the Department are more familiar with basic programming including the author. However, it should be pointed out that FORTRAN is more appropriate for subjects such as photogrammetric and mapping.

vii. The available computer hardware and software system, and skilled personnel needed for implementation of this program will be reviewed.

viii.The Aerial Triangulation will be based on the three Dimensional conformal Transformation. However, other methods will be listed briefly.

CHAPTER TWO

2.0 ORGANISATIONAL STRUCTURE OF THE FEDERAL CAPITAL DEVELOPMENT AUTHORITY [FCDA].

The Federal Capital Development Authority [FCDA] was created in 1976 under Decree 2 of the Federal Republic of Nigeria of 1976 by the Federal Military Government. The then head of state acted on the report submitted by the Aguda Commission for the relocation of the Nation's Capital City. The decision that prompted this relation was informed by the need to among other things:-

i. The need to centralise the Capital City to make for easy access to all parts of the country.

ii. For our Natural Security and to guard our Natural Sovereingnity.

iii. Administrative convenience and availability of large Land mass and so on.

The Federal Capital Development Authority was therefore created to monitor the development of the Capital Territory.

The Federal Capital Territory function presently with mine departments and some Parastatals as listed below:-

i. Department of Personnel [Administration]

ii. Department of Education

iii. Department of Health Services

iv. Department of Maintenance

v. Department of Public Works

vi. Department of Engineering Service

vii. Department of Finance & Economic Development

viii. Department of Lands, Planning & Survey

The parastatals under FCDA are:-

i. Water Resource Agency

ii. Mass Literacy Education Agency

iii. Area Council Service Board

iv. Urban Mass Transit Transportation Board

The main objective of setting up the FCDA is to monitor, manage all kinds of Development/infrastructure in the Capital Territory Abuja. For sustainable and habitable living in the Capital City of Nigeria. In an attempt to achieve these objectives, the Federal Capital Development Authority uses various consultants in many fields and professions to carry out its tasks through the Departments: the Department of Planning, Land & Survey does the aspect concerned with Planning and Control of Development and also Resettlement of displaced persons due to Developmental activities.

The Department of Land, Planning and Survey are further broken down to Divisions as listed below for the performance of its functions are:-

[here we shall only list the Divisions and go ahead to the Land Survey Division where specifically our study is located].

i. Regional Planning Division

ii. Directorate Division

iii. Urban Planning Division

iv. Development Control/Resettlement Division

v. Land Survey Division

Land Survey Division is in-charge of all Land Surveying, Aerial Photography, Mapping, Satellite Mapping, Cartography and Boundary matters.

2.1 BASIC CONCEPTS AND DEFINITIONS

2.1.1 PHOTOGRAMMETRY

Photogrammetry can be defined as the science of determining the shapes, sizes, positions of objects in relation to one another using photographs. It is an indirect way of measuring and representing the objects without physical contact with the said object. This is because only the photograph of the object would be scrutinised.

There are three major branches of photogrammetry in terms of method of acquiring the photographs, and method of measurement. These are Ground or Terrestrial Photogrammetry, Stereo photogrammetry, Aerial photogrammetry.

The initial development were in ground photography. The French man Lausesdat prepared a survey in 19961, and during the nineteen century the method was used in Canada and Switzerland among other countries particularly for plotting of mountainous terrain which could have been very difficult for normal ground survey. The ground photography is carried out using photo theodolite which consists basically of a camera of known total length together with a theodolite.

In stereophotogrammetry pairs of photographs are taken from stations at each end of a line with the instrument set up normally so that the image planes are in the same vertical plane and parallel to the line joining the stations. The pair of photographs taken at stations could be viewed stereoscopically subject to certain conditions so that plotting can be effected by machines.

There was further development in the field of photogrammetry which brought about the emergence of Aerial photogrammetry. A survey plotted from photographs taken from above the ground was again made by Laussedat in 1858, and by the end of the century other works on these lines had been carried out. A great deal of photographic surveying and reconnaissance was carried out during the World war, 1914 - 18, and from that time onward progressive steps have occurred in the technics of flying by aircraft to cover the aerial photography and also many sophisticated plotting or mapping equipment have been developed.

Photographs from the air or (aerial photographs) may be used for both surveying and compilation of topographical maps, but for the photograph to give a true plan certain conditions must be met, namely: (i) the ground on the photo must be horizontal (ii) the camera must not be tilted from the vertical when the exposure is made (iii) the camera lens and the photographic material should be as perfect as possible and there should be no atmospheric refraction. In addition when flying at high altitude, the curvature of the earth is of some account.

None of the above conditions can ever easily be met. Therefore, arose the need for photo grammetric equipment which can take care of the distortions occasioned by non achievement of the conditions. With the coming of the computer all the mathematical relations modeled for solving these problems have been made possible.

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2.1.2 MAPPING

This consist of all the activities involved in producing a map and could involve some or all of the following photogrammetry, surveying, cartography, hydrography satellite imagery and remote sensing and so on. The final product of all of the above is represented on a map.

Maps are plans in which scales and graticles or grid lines are provided and are drawn to represent objects of interest. Large scale maps (maps larger in scale than 1:5000) may be referred to as plans as all objects represented may be to scale or else they may be called cadestral maps. Not all details in a smaller scale maps are however, to scale. Some details such as roads, drainage, rivers and so on may be shown by conventional signs. Maps are made to represent as much as possible the metric nature of the object or place they represent.

There are various types of maps of which we have Topographical maps showing especially the relief of the earth surface and other features therein. Maps are of economic, political and security importance as they are needed for planning strategies and location of both human and material resources of the earth surface which are limited in nature.

2.1.3 COMPUTER

The computer can simply be defined as an electronic machine that follow instructions laid down for it to solve a particular problem and return a desired result. The computer therefore does three basic things:

1. It accepts data as input ~~as~~
2. Processes the data into desired information
3. Output the information.

The instructions that control the computer when it performs a task is known as a program. A collection of programs that are made to work together for a specific purpose is called software. There are system softwares which are concerned with directing the internal operations of the computer. They help set up the computer, and manage the memory space for incoming application program and data. The other type of software is known as the application software and these help the computer user define his problem and present the instructions in the form of language the computer understands. The languages may be BASIC, FORTRAN, COBOL, PASCAL and so on.

Computer systems may be said to comprise of the hardware, the human being that uses the computer, and the software that directs its operation.

The computer hardware are also categorised into

1. Microcomputers (small computers)
2. Minicomputers (medium sized computers)
3. Mainframe computers (large computers)
4. Super computers (very large computers)

The microcomputers are the commonest computers which can be seen in many offices and homes. Their performance in terms of memory capacity and speed are far slower than the other three categories. However, the mode of operation are virtually the same.

Computers may also be categorised as hybrid, analogue and digital.

2.2 IMPORTANCE OF THE COMPUTER IN PHOTOGRAMMETRY AND MAPPING

The importance of the computer in photogrammetry and mapping can be said to lie in its ability to process large data and also hold such data in memory for future reference. The other advantage is the speed with which it processes the data into desired information. It has therefore reduced the human labour involved in data processing in photogrammetry and mapping.

There exist computer software and auxiliary hardware for capturing data and processing same into final maps graphically or digitally.

Cost has also been lowered in the long run. The computer has widened the scope of the products of photogrammetry with the ability of the computer to marry information from many sources such as satellite imagery, remote sensing, surveying and planning.

<u>2.2 COMPUTER AIDED MAPPING</u>

There are several computer to carry out various stages of map compilation. These include:-

i. Data gathering from the field through land surveying to obtain ground control points. For this, there are computer interfaces which may be attached to the surveying theodolite or distance measuring device to capture and record data for office use. The data thus captured are recorded on CD-ROMs that reside in the computer interface during the surveying. A good example is the Geotracer system 2000 developed by Geotronics of Sweden.

ii. The next stage of Aerial Triangulation for central identification and analogue plotting of details are also supported by computer, hardware such encoders digitizers, video display unit, a central processing unit and application system software.

2.4 DIGITAL MAPPING

In digital mapping all the processing are heavily supported by computer facilities (hardware and software). All date is captured in digital format through analogue digital - converters (i.e. encoders) This is then processed and stored in the computer memory using appropriate software. As example of this is the CADMAP software.

2.5 LAND AND GEOGRAPHIC INFORMATION SYSTEM

Geographic information system is a computer - based system capturing, manipulating and displaying geographic related data in the computer with a specialised software. The software integrates map and its attribute information in a spatial database with powerful data management and modeling tools which allow users to retrieve data, perform sophisticated analysis and output the result as tabular reports or high quality maps. In Geographic / land information system data are gathered from various sources such as survey plans, Building Plans, Maps, Charts and so on through digital mapping to form topographical data base which can then be processed into Geographic information system.

2.6 SATELLITE IMAGERY

This is a method or technology involved in gathering photographic images of the Earth from far into space through the use of space satellites which are mounted with powerful electronic sensors.

Images so received are recorded on compact DISC ROM (CD ROM) which include software programs for use on personal computers. One example of such Image producing centre is Sport Image in Toulouse France.

CHAPTER THREE

3.0 SYSTEM ANALYSIS AND DESIGN

There is a need to further enumerate and analyse the issues involved before a proper working system can be obtained. It will help in taking the right decisions and anticipating inherent problem arising from such design.

In the previous chapters the problems have virtually been identified and enacted. However, it will be better to specifically formulate them so as to serve as a guide to achieving our goals.

3.1 DEFINING THE PROBLEMS

The problem areas are here listed in a way that they will serve as a guide to solving the problems. It will give in simple terms what needs to be done.

3.1.1 COMPUTATION FACILITIES

The lack of computer facilities is causing delay in producing or checking maps produced by consulting firms. The computer facility is needed for aerial triangulation of aerial photographs to obtain control Extension for mapping.

3.1.2 COMPUTER FACILITY FOR STORAGE AND RETRIEVAL

This is for storage, retrieval, and analysis of data from the field surveys, satellite imagery and other photogrammetric compilation

3.1.3 REPLACEMENT OF MANUAL PLOTTING

There is need to automate certain aspects of plotting and capturing of data during detailing of maps from aerial photograph or satellite imagery.

3.1.4 THE NEED TO UPGRADE TO A TOTAL WORKSTATION

The existing equipment is becoming obsolete and there is the need to upgrade them to total work station which will eventually help to generate digital mapping for Geographic and Land Information System. A Total work station will comprise of the stereoplotters and computer and its peripherals.

3.2 EXISTING SYSTEM

The mapping unit is equipped with two stereoplotters capable of generating data for aerial triangulation and also for final plotting of maps. The two plotters are the A8 and Kern PG2 plotters. There are trained personnel in the field of surveying and photogrammetry capable of applying these equipment for mapping. The equipment have only been used for producing in-house maps from plotting stage. Controls are provided totaly from field survey and therefore no aerial triangulation have been carried out with them because of lack of computing facilities. This makes in-house mapping very slow and tedious.

3.3 DESIGN SPECIFICATIONS

There are certain requirements which the computer system to be applied should have to be of optimum benefit for map compilation. Therefore specification of hardware and associated software are listed in the next section.

3.3.1 HARDWARE:-

The computer hardware should be able to handle large data and capacity to access record fast as it will work interactively with encoders and digitezers which will pass information to and from the computer to the plotting equipment. The memory capacity should be able to handle large data and program and use them to do complex mathematical computation and display same fast enough or transfer to next process of other equipment.

It should be able to handle several sophisticated software in the field of surveying photogrammetry and satellite imagery.

3.3.2 THE PROCESSOR AND PHERIPHERALS

The following types of processor and pheripheral are required:

1. A processor having at least 720 megabyte Hard Disc; Quad speed CD - ROM Drive; 3 ^{1}"/$_{2}$ in 1.44 megabyte floppy disc Drive; a clock speed of not less than 90 m H_z; Q" Vision + Graphic Controller of mp to 1280 x 1024 pixel. An ASC 11 keyboard; MS - DOS 6.2, / Window 95 (English)
2. A HRC Monitor with Q" Vision
3. Laser Jet Printer Capable of accepting the normal sizes of office stationary.

3.3.3 SOFTWARE

i. A Software package for P. C. Of the type mentioned above which supports absolute orientation of analogue stereoplotter like wild A8 and kern PG2. All these should be delivered on $3^{1}/_{2}$ in floppy disk of 1.44 MB.

ii. An interface software to read transform and present the digitally collected data to micro station from version 5.0 on.

iii. Software installation and maintenance should be provided.

iv. Training should be provided for the personnel after installation.

3.4 MATHEMATICAL MODELING

The previous sections have enumerated the problems and suggested various existing facilities for solving the problems. However, those are long term solution which takes time to put through to the authority that makes the final decision. Therefore, the above solutions should be considered as long term solution, while we shall undertake a mathematical modeling of the aspect of Aerial Triangulation which can help keep the existing equipment and personnel in production.

3.4.1 AERIAL TRIANGULATION AND ADJUSTMENT.

Aerial Triangulation is a process of using the known qualities of the aerial photographs to obtain control extension needed for producing topographical maps. In aerial triangulation the following processes are undertaken to obtain ground Truth position relative orientation and absolution orientation. This lead to transformation of one model coordinate system to the other or to the final correct terrain coordinate system.

After the triangulation data has been obtained which are the x, y, z coordinates of all points there is the need to sieve it of all forms of random errors. Much of the systematic errors have been taken care of by the relative orientation processes and the compensational ability of the stereoplotter. That is, errors like lens distortion, Earth Curvature and atmospheric refraction and so on are minimised.

The random errors are always determined through least squares adjustment methods.

3.4.2 THE PHOTO MODEL AND GROUND COORDINATE SYSTEM

i. To be able to formulate a mathematical model that will lead to obtaining the aerial triangulation computation we have to know a few things about the coordinate systems of the aerial photograph, model and ground coordinate systems in a very simple term.

ii. <u>COORDINATES OF AERIAL PHOTOS:</u> The aerial photographic coordinate system has its origin at the principal point which is the centre of the photograph. This point can be established by joining the opposite fudicial marks of the photograph. Normally photos are flown from East to West and the East to West line formed on the photo by joining the fudicial marks is known as the X - axis while the North - South line is the y - axis. Note that the lower case letters are differential from other systems.

iii. <u>MODEL COORDINATE SYSTEM:</u> Models are formed from two over lapping aerial photographs to achieve stereoscopic vision when viewed under stereoscope or stereoplotter. By this way Valleys, hills and tall trees, and buildings can be seen in relief. The perspective center which can be established analytically or through the analogue plotter is the origin of this coordinate system. Its determination serve as another control for the model. The coordinate axes may be denoted by the later Xm, Ym and Zm. Note that there are three axes.

iv. <u>GROUND COORDINATE SYSTEM:</u> The aerial photograph represents a two dimensional situation of the terrain, while the model is a three dimensional representation of the same terrain. The coordinate axes of the Terrain may be denote by the letters Xg,Yg,Zg.

v. <u>STRIP FORMATION:</u> In mapping, it is necessary to join all the individual models in the strip and then adjust them. The process of joining is known as strip formation and this is done by transforming all the models in the strip into one continuous strip by using the following mathematical relations.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad \lambda \begin{bmatrix} \text{COS}\,\theta z & -\,\text{Sin}\,\theta_z & 0 \\ \text{Sin}\,\theta z & \text{Cos}\theta_z & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\,\theta Y & 0 & \text{Sin}\,\theta_Y \\ 0 & 1 & 0 \\ -\,\text{Sin}\theta y & 0 & \text{Cos}\theta_y \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \text{Cos}\theta_x & -\,\text{Sin}\,\theta_x \\ 0 & \text{Sin}\theta_x & \text{Cos}\theta_x \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} CX \\ CY \\ CZ \end{bmatrix}$$

The above expression could be written in a shorter form as:-

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \lambda\ M \begin{bmatrix} x \\ y \\ z \end{bmatrix} + \begin{bmatrix} CX \\ CY \\ CZ \end{bmatrix} \quad - - - - \quad (3.1)$$

Where X,Y,Z are the coordinate system of the reference model and x,y,z is the coordinate system to be rotated to the reference system. For example, from model (x,y,z) to ground system (X, Y, Z) CX CY CZ are the shift from the origin of the reference coordinate system.

In this project the first model is the reference model and all other models are to be rotated to the first model system. The sign λ (Lamda) is the scale factor attached to the rotated model. $\bar{M}$ is a product of the three rotation parameter which are θz, θy, and θx respectively.

The above expression in equation (I) is the linear confirm conform transformation.

This is also known as similarity transformation.

After all the models have been connected using the above expression they would then be transformed again to the ground or Terrain system using the same expression.

3.4.4 COMPUTATIONAL PROCEDURE OF THE TRANSFORMATION

$$\begin{bmatrix} \text{COS}\,\theta_z & -\text{Sin}\,\theta_z & 0 \\ \text{Sin}\,\theta_z & \text{Cos}\theta_z & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \text{COS}\,\theta_Y & 0 & \text{Sin}\,\theta_Y \\ 0 & 1 & 0 \\ \text{Sin}\theta_y & 0 & \text{Cos}\theta_y \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \text{Cos}\theta x & -\text{Sin}\,\theta_x \\ 0 & \text{Sin}\theta x & \text{Cos}\theta_x \end{bmatrix}$$

$$\text{that is } M=\begin{bmatrix} \cos\theta_z - \cos\theta_z\ 1 & \cos\theta_x \sin\theta_z + \sin\theta_x \sin\theta_y \cos\theta_z & \sin\theta_x \sin\theta_z - \cos\theta_x \sin\theta_y \cos\theta_z \\ \cos\theta_z \sin\theta_z\ 1 & \cos\theta_x \sin\theta_z - \sin\theta_x \sin\theta_y \cos\theta_z & \sin\theta_x \cos\theta_z + \cos\theta_x \sin\theta_y \sin\theta_z \\ \sin\theta_y\ 1 & -\sin\theta_x \cos\theta_y & \cos\theta_x \cos\theta_y \end{bmatrix}$$

The matrix expression M can again be written as

$$M=\begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{12} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix}$$

The matrix may then be written in a generalised form as

$$\begin{bmatrix} X_i \\ Y_i \\ Z_i \end{bmatrix} \begin{matrix} =\lambda \\ =\lambda \\ =\lambda \end{matrix} \begin{bmatrix} (M_{11} X_i + M_{12} Y_i + M_{13} Z_i \\ (M_{21} X_i + M_{22} Y_i + M_{23} Zi \\ (M_{31} Xi + M_{32} Y_i + M_{33} Z_i \end{bmatrix} \begin{matrix} + \\ + \\ + \end{matrix} \begin{bmatrix} Cx \\ Cy \\ Cz \end{bmatrix}$$

$$i = 1,\text{-------}, n.$$

From the equations there are seven parameters,

$$(\lambda, \theta_Z, \theta_Y, \theta_X, CX, CY, CZ)$$

and the only observations are x,y,z. If the equations are regarded as adjusted quantities, eqn 3.1 may be expressed as a mathematical model of the form:-

$$L^a = f(X^a)$$

which is an observation equation, non linear type. The adjustment formula can therefore be applied to this problem. The solution to the normal equation has been found to be

$$X = -(A^T P A)^{-1} A^T P L$$

$$A = \frac{df(X^a)}{d(\theta_Z, \theta_Y, \theta_X, \lambda, CX, CY, CZ}$$

$$L = L^o - b^b$$

$(L^b)^T = (X_i \; Y_i \; Z_i)$, $L^0 = f(X^0)$, P = weight of observation

Minimum of two points with known plan coordinates in both systems and three in elevation is needed for absolute orientation. However, if more than two points are available which have known plaminetic and height points are then, least squares solution is feasible.

The determination of the solution will be an iterative one. To obtain least square solution n points with known X, Y, Z and x,y,z coordinates will give 3n equations in the seven unknown parameters as follows.

Define X, Y, Z and x, y, z

$$\begin{bmatrix} X_1 \\ X_2 \\ 1 \\ 1 \\ Xn \\ Y_1 \\ Y_2 \\ 1 \\ 1 \\ Yn \\ Z_1 \\ Z_2 \\ 1 \\ 1 \\ Zn \end{bmatrix} = \begin{bmatrix} x_1 & 0 & z_1 & -y_1 & 1 & 0 & 0 \\ x_2 & 0 & z_2 & -y_2 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 & . & - & - \\ 1 & 1 & 1 & 1 & . & - & - \\ xn & 0 & zn & -yn & 1 & 0 & 0 \\ y_1 & -z_1 & 0 & x_1 & 0 & 1 & 0 \\ y_2 & -z_2 & 0 & x_2 & 0 & 1 & 0 \\ 1 & 1 & 1 & 1 & . & . & . \\ 1 & 1 & 1 & 1 & . & . & . \\ yn & -zn & 0 & xn & 0 & 1 & 0 \\ z_1 & y_1 & -x_1 & 0 & 0 & 0 & 1 \\ z_2 & y_2 & -x_2 & 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 & . & . & . \\ 1 & 1 & 1 & 1 & . & . & . \\ zn & yn & -xn & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \lambda \\ \theta_x \\ \theta_y \\ \theta_z \\ cx \\ cy \\ cy \end{bmatrix} \qquad \text{----- 3.3}$$

$L \Rightarrow (3n,1)$ A (3nx7)

Where X, Y, Z are the reference coordinate system and x, y, z are the coordinate system being transformed

The normal equation to Equ. 3.3 becomes

$$\begin{bmatrix} \Sigma\,(Xixi + Yiyi + Zizi) \\ \Sigma\,(-YiZi + ziyi) \\ \Sigma\,(XiZi - zixi) \\ \Sigma\,(-XiZi + Yixi) \\ \Sigma Xi \\ \Sigma Yi \\ Zi \end{bmatrix} = \begin{bmatrix} \Sigma x2y2z2 & 0 & 0 & 0 & \Sigma x & \Sigma y & \Sigma z \\ 0 & (\Sigma y2+\Sigma z2) & \Sigma(yz) & (-\Sigma xz) & 0 & -\Sigma z & \Sigma y \\ 0 & 0 & (\Sigma(x2+x2)) & (\Sigma zx) & \Sigma z & 0 & -\Sigma x \\ 0 & 0 & 0 & (\Sigma(x2+y2)) & -\Sigma y & \Sigma x & 0 \\ 0 & 0 & 0 & 0 & n & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & n & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & n \end{bmatrix} \begin{bmatrix} \lambda \\ \theta_x \\ \theta_y \\ \theta_z \\ CX \\ CY \\ CZ \end{bmatrix} \quad \text{--Equ 3.4.0}$$

The solution for the parameters is the solution of the seven equations with seven unknown or inversion of a 7 x 7 matrix which requires the use of a computer. The problem can be simplified by finding the centre of gravity of each system thus:-

$X = \lambda\, xi + \theta_{yi} - \theta_z y_i + CZ$ --- 3.4.1

$\Sigma X = \lambda \Sigma xi + \theta_y \Sigma zi - \theta_Z \Sigma yi + nCX$ ----3.4.2

$\frac{\Sigma Xi}{n} = \frac{\lambda \Sigma xi}{n} + \frac{\theta_y \Sigma y_i}{n} - \frac{\theta_z y_i}{n} + CX$ --- 3.4.3

$\bar{X} = \frac{\Sigma Xi}{n}$ $\quad \bar{x} = \frac{\Sigma xi}{n}$ --- Eqn 3. 4.4

$\bar{Y} = \frac{\Sigma Yi}{n}$ $\quad \bar{y} = \frac{\Sigma yi}{n}$ ---Eqn 3. 4.5

$\bar{Z} = \frac{\Sigma Zi}{n}$ $\quad \bar{z} = \frac{\Sigma zi}{n}$ ----Eqn 3. 4.6

$\bar{X}, \bar{Y}, \bar{Z}$ are coordinates of centre of gravity in X, Y, Z system.

$\bar{x}, \bar{y}, \bar{z}$ are coordinates of centre of gravity in x, y, z system.

By subtracting eqn3.4.3 from each in Eqn3.4.1 we have;

$\Delta xi = \left[\lambda\, \Delta xi - \theta_y \Delta zi - \theta_z \Delta y_i\right]$ - - Eqn 3. 4.7

$\Delta Xi = Xi - \bar{X}, \Delta Yi = Yi - \bar{Y}, \Delta Zi = Zi - Z,$

The equation becomes

$$\begin{bmatrix} \Delta X_1 \\ \Delta X_2 \\ 1 \\ 1 \\ \Delta Xn \\ \Delta Y_1 \\ \Delta Y_2 \\ 1 \\ 1 \\ \Delta Yn \\ \Delta Z_1 \\ \Delta Z_2 \\ 1 \\ 1 \\ \Delta Zn \end{bmatrix} = \begin{bmatrix} \Delta x_1 & 0 & \Delta x_1 & -\Delta y_1 \\ \Delta x_2 & 0 & \Delta z_2 & -\Delta y_2 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ \Delta xn & 0 & \Delta zn & -\Delta yn \\ \Delta y_1 & -\Delta z & 0 & \Delta x_1 \\ \Delta y_2 & -\Delta z_2 & 0 & \Delta x_2 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ \Delta yn & -\Delta 2n & 0 & \Delta xn \\ \Delta z_1 & \Delta y_1 & -\Delta x_1 & 0 \\ \Delta z_2 & \Delta y_2 & -\Delta x_2 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ \Delta yn & \Delta yn & -\Delta xn & 0 \end{bmatrix} \begin{bmatrix} \lambda \\ \theta_X \\ \theta_Y \\ \theta_Z \end{bmatrix} \quad - - - 3.5.0$$

The normal Eqn becomes

$$\begin{bmatrix} \Sigma \Delta X \Delta x + \Delta Y \Delta y + \Delta Z \Delta z \\ \Sigma(-\Delta Y \Delta z + \Delta Z \Delta y) \\ \Sigma(\Delta X \Delta z - \Delta Z \Delta x \\ \Sigma(-\Delta X \Delta y + \Delta Y \Delta x \end{bmatrix} = \begin{bmatrix} \Sigma \Delta x^2 + \Delta y^2 + \Delta z^2 & 0 & 0 & 0 \\ & \Sigma(\Delta y^2 + \Delta z^2 & -\Sigma xy & -\Sigma zx \\ & & \Sigma(\Delta x^2 + \Delta z^2) & -\Sigma \Delta yz \\ & & & \Sigma \Delta x^2 + \Delta y^2 \end{bmatrix} \begin{bmatrix} \lambda \\ \theta_X \\ \theta_Y \\ \theta_Z \end{bmatrix} \quad 3.5.1$$

Note that the solution for the scale is done indpendently , that is -

$$- - - \text{Eqn3 } 5.2 \qquad \lambda = \frac{\Sigma(\Delta X1\, xi + \Delta Yiyi + \Delta Zizi)}{(\Sigma\theta_x 2 + \Delta yi^2 + \Delta xi^2)} \quad - - - - 3.5.2$$

After the determination of the final value of λ, θX, θY, θZ the solution for the shifts can be done as follows.

$$\begin{bmatrix} CX \\ CY \\ CZ \end{bmatrix} = \begin{bmatrix} \bar{X}i \\ \bar{Y}i \\ \bar{Z}i \end{bmatrix} \lambda\ M \begin{bmatrix} \Delta xi \\ \Delta yi \\ \Delta zi \end{bmatrix} - - - 3.\ 5.3$$

However, because the parameters are non linear we have to make further to remove the residuals.

The following least squares iterative solution is valid for small coordinate difference, consequently an initial transformation has to be performed to remove the largest part of coordinate differences.

PROCEDURE:

1 Enter the coordinates X, Y, Z; x, y, z, for n points ($n \geq 3$)

2 Compute the centers of gravity of both system $\bar{X}\,\bar{Y}\,\bar{Z}$, $\bar{x}, \bar{y}, \bar{z}$,

3 Compute the reduced coordinates $\overline{\Delta X}, \overline{\Delta Y}, \overline{\Delta Z}; \overline{\Delta x}, \overline{\Delta y}, \overline{\Delta z}$

4 Compute the scale $$\frac{\Sigma(\Delta X \Delta x + \Delta Y \Delta y + \Delta Z \Delta z)}{\Sigma(\Delta x^2 + \Delta y^2 + \Delta z^2)}$$

5 Construct normal equations for $\theta X, \theta Y, \theta Z$ =

$$\begin{bmatrix} \Sigma(-\Delta Y \Delta z + \Delta Z \Delta y \\ \Sigma(\Delta X \Delta z - \Delta Z \Delta x \\ \Sigma(-\Delta X \Delta y + \Delta Y \Delta x \end{bmatrix} = \begin{bmatrix} \Sigma(\Delta y^2 + \Delta z^2 & -\Sigma \Delta x^2 \Delta y^2 & -\Sigma \Delta x \Delta z \\ 0 & \Sigma(\Delta x^2 \Delta z^2) & -\Sigma \Delta y \Delta z \\ 0 & 0 & \Sigma \Delta x^2 + \Delta y^2 \end{bmatrix} \begin{bmatrix} \theta_X \\ \theta_Y \\ \theta_Z \end{bmatrix}$$

6 Solve for $\theta_X, \theta_Y, \theta_Z$

7 Construct an orthogonal Matrix Mk

$$Mk = \frac{1}{2\Delta} \begin{bmatrix} \theta_X \\ \theta_Y \\ \theta_Z \end{bmatrix} \begin{bmatrix} \theta_X, \theta_Y, \theta_Z \end{bmatrix} + \frac{1}{\Delta} \begin{bmatrix} \Delta & -\theta_Z & \theta_Y \\ \theta_Z & \Delta 1 & -\theta_X \\ -\theta_Y & \theta_X & \Delta 1 \end{bmatrix}$$

$$\Delta = 1 + \tfrac{1}{4}\left[\theta_X^2 + \theta_Y^2 + \theta_Z^2\right]; \quad \Delta 1 = 1 - \tfrac{1}{4}\left[\theta_X^2 + \theta_Y^2 + \theta_Z^2\right]$$

8 Tranform $\Delta X\ \Delta Y, \Delta Z$ coordinates using Mk , λk

9 Compute the final scale factor $\lambda = \lambda_1 + \lambda_2 + \lambda_3 - - -\lambda k$ no of itetration 1- - -k

10 Compute the final value of $\theta_X, \theta_Y, \theta_Z$

$$\theta_X = \theta_{X1} + \theta_{X2} - - - - - - - \theta_X k$$
$$\theta_Y = \theta_{Y1} + \theta_{Y2} - - - - - - - \theta_Y k$$
$$\theta_Z = \theta_{Z1} + \theta_{Z2} - - - - - - - - \theta_Z k$$

11 Construct the final rotation matrix M from the final Values of θX, θY, θZ.

12 Compute the three shifts

$$\begin{bmatrix} CX \\ CY \\ CZ \end{bmatrix} = \begin{bmatrix} \bar{xi} \\ \bar{yi} \\ \bar{zi} \end{bmatrix} - \lambda . M \begin{bmatrix} \bar{x} \\ \bar{y} \\ \bar{z} \end{bmatrix}$$

Repeat steps 4,5,6, using the X Y Z coordinates unit λ k tends to be one ie $\lambda \Rightarrow 1$ and $\theta_X k$, $\theta_Y k$, $\theta_Z k$ tends or are less than 0.00001 in magnitude.

Check number of iterations here.

3.4.5 ADJUSTMENT

After strip formation with the mathematical Transformation described above, we obtain strip coordinate of all points measured in successive models linked together to form a strip. These coordinates must however, be related or transformed to the ground using the same similarity transformation. Adjustment is a further refinement of the transformed coordinates in order to remove residual discrepancies and also to confirm the reliability of the computer values.

There are various methods of adjustment of which polynomial strip adjustment is one.

Another way of looking at the adjustment is that in a more rigorous approached a whole block of models comprising of several strips are adjusted at once. We shall not delve into the many forms of adjustment since time and available space in this project is limited. There are software packages, as has been mentioned in the previous chapter for solving this problem. However, a program will be written to carry out transformation only. With time, which will be outside this project the writer will develop the adjustment programs. The adjustment processes and equations are given below.

One of the methods of adjustment that can be used and will suffice for this program is known as polynomial strip adjustment. After strip formation we obtain strip coordinates of all points measured in successive models linked together to form the strip. These coordinates must however be related to or transformed to the ground system of coordinates. This can be accomplished by the use of polynomial fitted to the strip. From the strip coordinates and their given ground coordinates differences, or (discrepancies) between these two sets of coordinates can be computed in X, Y, Z. For example Dx = Xg - Xs j DY = Yg - Ys Dz = Zg - Zs - Where subscripts g and s denote ground and strip coordinates respectively. These are then equated to the polynomial as follows:

$$DX = a_1 + a_2 Xs + a_3 Ys + a_4 X^2 s + a_5 Y^2 s + a_6 X^2{}_5 Ys$$

$$DY = b_1 + b_2 Xs + b_3 Ys + b_4 X^2 s + b_5 Y^2 s + b_6 X^2{}_5 Ys$$

$$DZ = c_1 + c_2 Xs + c_3 Ys + c_4 X^2 s + c_5 Y^2 s + c_6 X^2{}_5 Ys$$

It has to be stated here that each of the discrepancies has to be computed separately for the parameters. That is for DX, seven observed ground controls are needed so as to obtain redundant equation for least square approach (see equation 3.3). The same thing is done for DY and DZ discrepancies.

It should be noted that the number of terms in the polynomial depends on the number of ground control available and the length of the strip. Let us consider the nature of the 'A' - Matrix and 'L' Matrix

$$\hat{X}a = \begin{matrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \end{matrix} \qquad A = \frac{@DX}{@\,Xa}, \quad Lb = \begin{matrix} Dx_1 \\ DX_2 \\ DX_3 \\ DX_4 \\ DX_5 \\ DX_6 \\ DX_7 \end{matrix}$$

It is obvious that for a least square solution seven ground controls will be needed to solve 6 unknown parameters in the polynomial. there are thus seven equations where we have six unknowns.

From the following

$$A = \begin{bmatrix} 1 & xs_1 & ys_1 & x^2s_1 & y^2s_1 & xs_1 & ys_1 \\ 1 & xs_2 & ys_2 & x^2s_2 & y^2s_2 & xs_2 & ys_2 \\ 1 & xs_3 & ys_3 & x^2s_3 & y^2s_3 & xs_3 & ys_3 \\ 1 & xs_4 & ys_4 & x^2s_4 & y^2s_4 & xs_4 & ys_4 \\ 1 & xs_5 & ys_5 & x^2s_5 & y^2s_5 & xs_5 & ys_5 \\ 1 & xs_6 & ys_6 & x^2s_6 & y^2s_6 & xs_6 & ys_6 \\ 1 & xs_7 & ys_7 & x^2s_7 & y^2s_7 & xs_7 & ys_7 \end{bmatrix}$$

The value of the adjusted unknown parameters can be obtained from

$$\hat{X} = (A^TPA)^{-1} \; A^TPL^{b}$$

From the values of these coefficients we can compute DX, in equation (I) for an arbitrary point in the strip which is not ground control. The ground control of this arbitrary point can be obtained from the relationship:- $Xg_2 = DX_1 + Xs_1$

Where DX_1 is computed from equation (i) for an arbitrary point (I).

CHAPTER FOUR

SYSTEM DEVELOPMENT AND IMPLEMENTATION

4.1 INTRODUCTION

Software is a terminology used to describe all programs which are used in a particular computer installation. It is a program procedure or rules with associated documentation pertaining to the operation of a computer system. Software development entails series of activities or processes that should be carried out in the cause of developing a system. The software development starts with the laid down structure in general design and detailed design of the automated system.

The design determine the appropriate language for implementing the system. However, system life cycle is all about system development, software development. When a system is on ground, the mechanism that automate the system is software, therefore, the stages for their development are interwoven.

4.2 CHOICE OF LANGUAGE

Computer language is a means of communication between the programmer and the computer. The computer programmer use this language to instruct the computer how certain task or job should be carried out. The choice of computer language depend on the following:-

a. Type of Task or job

b. The application of the Task

c. The structure of files

d. Volume of data elements

e. Complexity of the Task or Job.

Basic programming language is the language of choice for the implementation of this project. The Basic Version 4.0 use in this project is known as Quick Basic or Qbasic. Quick Basic is an advancement in GWBasic and TurboBasic in terms of speed and flexibility of program compilation, debugging and execution. Quick Basic therefore allows for better interaction between the program and sub programs.

Microsoft Qbasic is a programming environment that includes all tools you need for writing, editing, running and debugging the programs. These tools are integrated into a powerful version of the Basic programming and on - line help system that explains everything about both the environment and the language. Microsoft Quick Basic speeds programming and learning by giving virtually instant feedback for ideals. When you enter "program code" (Sequence of Quick Basic statement) that describe what you want the program to do .

Quick Basic checks the validity of each line of program code as you enter it into the computer and then immediately translate your code into a form the computer can execute. If your code contains errors that make it impossible to translate, Quick Basic specifies the error and help to correct it. As soon as the code is corrected, you can press the enter key and immediately run it. If your program code does not run as you expect it you can use Quick Basic sophisticated debugging tools to track and correct errors in your logic code. Quick Basic set the speed and power a computed program without the tedious cycle of a separate editing, computing, debugging and running.

4.3 SOFTWARE DEVELOPMENT AND TESTING.

After defining the formulae and procedures in the previous chapters, the next step is to encode the program following the laid down formula. As earlier mentioned, coding is done in

Basic language. The program is written in modular form. The REM statements have been used extensively to introduce every program segment. This makes for easy modification and maintenance of the program care should be taken of other program segments relate to any segment that has been modified as this could also affect the working of the related segment after such correction.

4.3.1 SOFTWARE DEVELOPMENT

The program is designed to do the following:-

i. Input coordinates of all model points of aerial photograph obtained from aerial Triangulation observations.

ii. Compute the sums, means, deviations from the mean of the coordinates.

iii. Form all the matrices using the coordinates, the mean of the coordinates and their deviations in accordance with the transformation formulae.

iv. Normalize the redundant equations arising therefrom by first transposing the coefficient matrix 'A' and pre-multiply not by the original coefficient matrix. That is obtain: A^TA which is a square matrix.

v. Upon normalizing the equation the new matrix which is a square matrix a (4 x 4) matrix it is further reduced to a 3 x 3 matrix by deleting the first row and the first column. The advantage is to find the inverse of a matrix of a smaller dimension. The scale is computed separately because of this approach.

vi. The program computed the inverse of the matrix obtained in step 5.

vii. The inverted matrix $(A^TA)Y$ is used in the equation $X^\wedge = (A^TPA)^{-1}$ A^TPL, P is a unit matrix.

viii) a The result of step (vii) yields a (3,1) matrix whose elements are the three parameters of rotation about the three axis X, Y and Z.

Note that the fourth parameter which is the scale is computed separately from the equation $S = \frac{\Sigma(Xx + Yy + Zz)}{\Sigma(X2 + Y2 + Z2)}$

The numerator of the above equation is the first element of matrix 'L'; while the denominator is the first element of the (4 x 4) matrix obtained in step 4 above.

b. The computation obtained by the program so far are scale the three rotations about the X, Y and Z axis and the shifts Cx Cy Cz. These parameters are used to transform from one model system to another.

c. We can now put the parameters back into the equations as given in equation 3.5. The program is used to ~~invite~~ invert and enter all the values of the matrices involved. The result is the transformation of he model coordinates on the right hand side of the transformation equation. All common points which appear on both models will have the same coordinates values therefore.

However many reasons which is connected to the peculiar nature of photogrammetric measurements and the mathematical model, this may not necessarily be so. An iteration is therefore necessary to obtain the best result.

d. The coordinates obtained in step (viii)c replaces the coordinate in the right hand side of the equation or model. It is assumed that if you have models 1 and 2, the coordinates of the model 2 is converted to the coordinates system of model 1. When model 2 is satisfactorily in model 1 system, model 3, is then converted to the 'new' model 2 and so on until the nth model is in the system of model 1.

The program iterates the computation until the difference between two successive computation of parameters is no more than 0.00001 for the rotations and nearly equal to unity for the scale.

4:3:2 DATA INPUT

There are rules to be followed while inputting the data values for the coordinates of each point in the model and these are stated below:

The points in a model should be numbered 1 - 15. For the purpose of this program 15 points have to be measured in a model. Points to the left hand side of the model are numbered 1 - 5 from top to bottom; the points in the middle are numbered 6 - 10 from top to bottom; and those to the right of the model are numbered 11 - 15

If these rules are followed then any of the adjacent models will appear as below:

1	6	11
2	7	12
3	8	13
4	9	14
5	10	15

1	6	11
2	7	12
3	8	13
4	9	14
5	10	15

The computer program will therefore compare five pair of points. That is

Model 1 points { 11 - 1, 12 - 2, 13 - 3, 14 - 4, 15 - 5 } Model 2 points

- 11 - 1
- 12 - 2
- 13 - 3
- 14 - 4
- 15 - 5

Each of the 15 points in a model has the coordinate values X, Y, Z and they are enter in the data file or along with the program for each point in that order. The entry for the next point follows immediately in a similar pertern so there are three data values for each point in the data file.

There are 3 x number of coordinate or data values for the number of points in the file. For example in this project since we have 15 points in a model, the number of data values for the 15 points is 15 x 3, which is 45 (see Appendix). A subprogram prints the point number and the X, Y, Z coordinates in a tabular form. (See Appendix)

Having entered the data thus the program is written in such a way that the sum, mean and the deviation from the mean of the last five points in the 'first' model and the 1st five points in the second model is always computed. The deviation from model 1 form the 'L' matrix in the manner stated in the transformation equations, while the second or next model forms the coefficient matrix 'A'. The shifts in the equations are obtained from the mean of first model. We should note that all models the coordinates system of the first model. Model 1 is therefore taken as the reference coordinate system. The parameters connecting the models obtained from the transformation equation. New values of models 2 which is now in model 1 system are after putting the parameters back into the equation. The transformation between model 1 and 2 is repeated again with the new values of model 2. The process is repeated again and again until the difference between the latest parameters and the previous is very small (not more than 0.00001 for the rotations and the scale should be nearly equal to unity). Having obtained model 2 in model 1 coordinates system, model 3 is brought into the computation. Model 2 is now occupying the position of model 1 which is now set aside. Model 3 is converted to new model 2 system. After model 3 has been satisfactorily rotated, model 4 is brought to be rotated to the new model 3 system. The process continues until all points in the strip has been transformed. When all the models have been rotated they will all now be in one uniform system i.e. the coordinate system of the reference model which is model 1 in this case.

This is not the end of the computation. The coordinates have to be converted to ground coordinate system. So the control points whose ground coordinates are known are now brought into the computation. The coordinates of the ground control are treated as if it were the first model (model 1). While the model coordinates of the same points which were obtained from the transformation are treated as model 2. The deviation of the ground coordinates will form the 'L' matrix in the equation while that of the model will form the coefficient matrix 'A'.

After obtaining the coordinates in ground system the adjustment is carried in similar way by writing another adjustment equation which includes the differences between the given ground coordinates values and that obtained by the transformation. After the adjustment parameters have been obtained corrections are made and all mathematical analysis of the computation can also be derived from the adjustment equations. For the adjustment equations see page ..25

4:3:3 TESTING THE PROGRAM

The program has been run with data collected from the Lower Usman Dam mapping. Three models have been transformed. After running the program with these data the result obtained were compared with that obtained by manual computation. For example the sum, mean, deviations and the formation of matrices contained in the transformative equations were also done manually and compared with those computed by the program. The transpose and inverse of the matrices were also computed manually for comparison. These computations were producing the same result and therefore confirms the efficiency of the program. The inversion of the matrices were made easy for both programming and manual computation because the matrix 'A' had been reduced to a 3 x 3 matrix in the equations.

It is assumed that if the model and ground controls are accurately observed the final result will be a true representation of the actual situation.

The adjustment aspect is to take care of other sources of error peculiar to photogrammetry so that even when the program is working properly the data being used may be in error and this may affect the final result.

4:4 SYSTEM IMPLEMENTATION

In this section the method of the program in the computer are explained. The hardware and personnel required has been mentioned earlier.

4:4:1 STARTING THE SYSTEM

After the normal booting and installation of the operating disk the following steps are taken: Insert the project or program diskette.

4:4:2 TO ACCESS PROJECT FILE

Type WIN at Dos prompt and Press Enter key

Click Microsoft word

Click file

Open

Type A:\SARKIPJ.DOC

4:4:3 TO RUN THE PROGRAM

Type CD Dos and press enter

Type Qbasic and press enter

Press ESC

Press ALT, F,O

Type A:\TRMAT22.BAS and Press Enter

Press F5

4:4:4 TO QUIT

Press Alt+F

4:5 FILE MAINTENANCE

File maintenance is always a continuous process and this entails Insertion, Deletion and Edition of program or data values. For this program a lot needs to be done to this program to make it a more useful tool for map computation. There already exist in the market more sophisticated programs such that this program is only a minute unit of these sophisticated programs. The advantage however of in-house program is well known.

As new ideas and possibilities reaches the writer or user of this program changes could be made in the area of data manipulation. Since the program is written in modular form such corrections or modifications are done with ease. For example it is possible that the program may be shortened if direct matrix formation, multiplication, division and addition can be achieved by in-built command within the programming language. Therefore any language that has these facilities will make the program shorter and faster.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5:1 SUMMARY

This project addresses the subject of the application of computer to problems of mapping and photogrammetry with special reference to the mapping unit of the Department of Planning and Survey.

In chapter 1 - 2 the functions and duties of the Department of Planning and Survey and of the mapping unit in particular were enumerated and the need for computer to assist in carrying out these functions were stated. Chapter 3 discusses the coordinates systems and transformation of such system using least squares approach. Transformation of these coordinate and their adjustment is a very important and process in photogrammetry and mapping.

From mathematical models explained in chapter 3 computer program were developed in chapter 4. The hardware requirements were also stated. The programs was executed with data from Lower Usman Dam mapping and the results, the program and data used are at appendix

5:3 RECOMMENDATION

It is recommended here that mapping and survey sections in most Nigerian organisations should establish and maintain a computer service unit due to the immense benefits listed below:

i. Computer can facilitate efficient data capture or collection;

ii. Computer helps establishment of efficient Data processing;

iii. Help in presentation of digital or graphical Data (processed or raw);

iv. Help in fast computation and implementation of all aspects and kinds processes in Mapping Surveying and Photogrammetry;

v. It is a pre-requisite for the establishment of a Geographic and Land Information System;

vi. Help in interdisciplinary management of all information and resources associated with the information system;

vii. Computer can broaden the scope of services the Surveyor, Cartographer and Photogrammetrist can render;

viii. Most modern surveying and photogrammetric equipment are highly computerised and computers are necessary to analyze and access data collected by such equipment; and

ix. The program in this project is recommended for mapping jobs of limited nature (say a strip of five models), and the hardware and software suggested in the project are recommended for serious surveying and mapping works.

5:2 CONCLUSION

This project and the associated program is a practical analysis of some aspects of computations in photogrammetry where computer application will be of immense help. When the mapping unit has a job of very limited area at hand the program will be adequate enough to do it. There are other sophisticated programs in the market which automates every aspect of map compilation from aerial triangulation to manuscript of map. These will do bundle adjustment, block adjustment, help in data collection and memory management associated with such data. However this program which is simple and down to earth will lead beginners into more sophisticated programs.

The author of this program intends to develop it further as more information and needed resources are at his disposal. It is also hoped that those who come across this program will take interest in it and contribute in developing it further.

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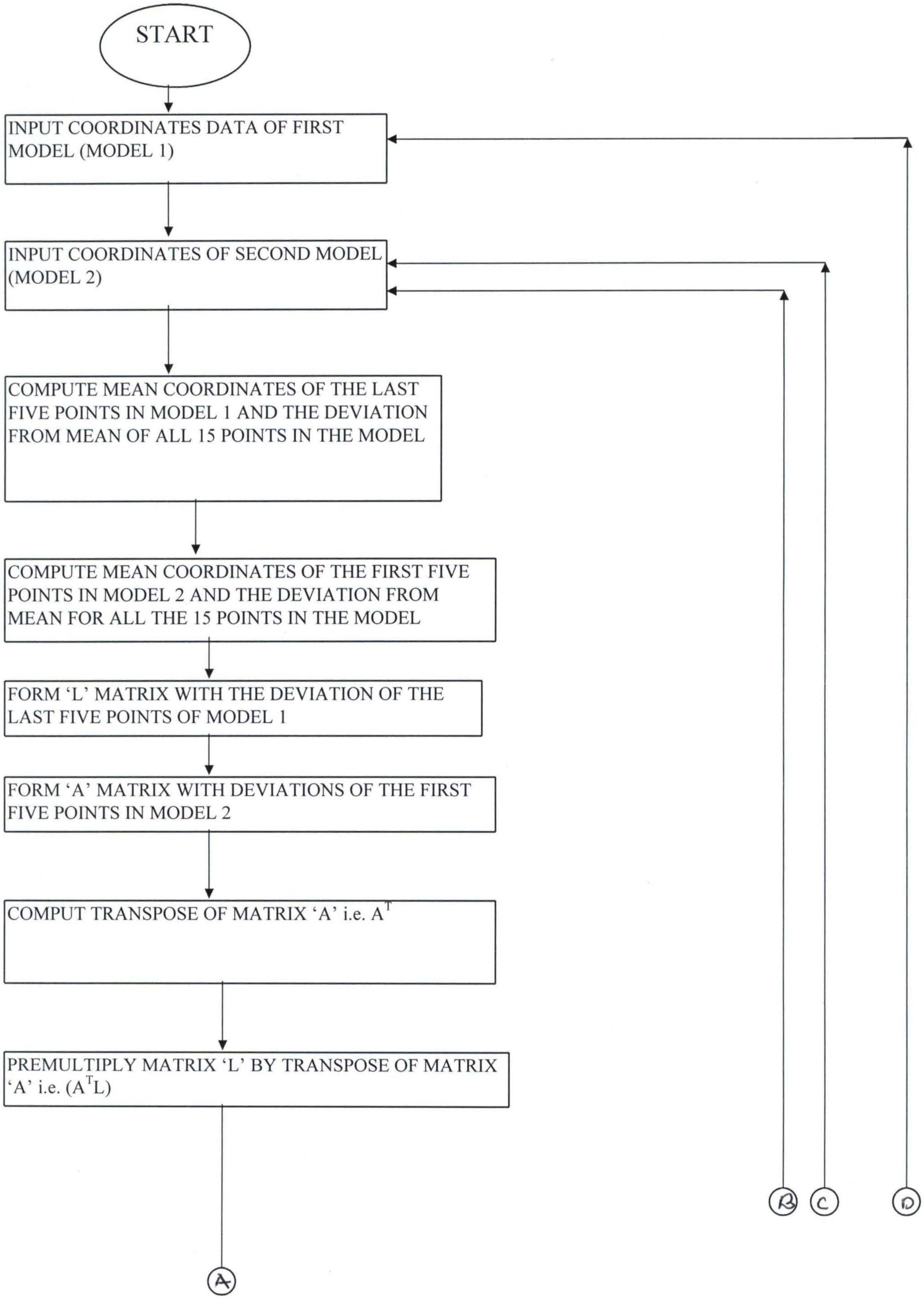
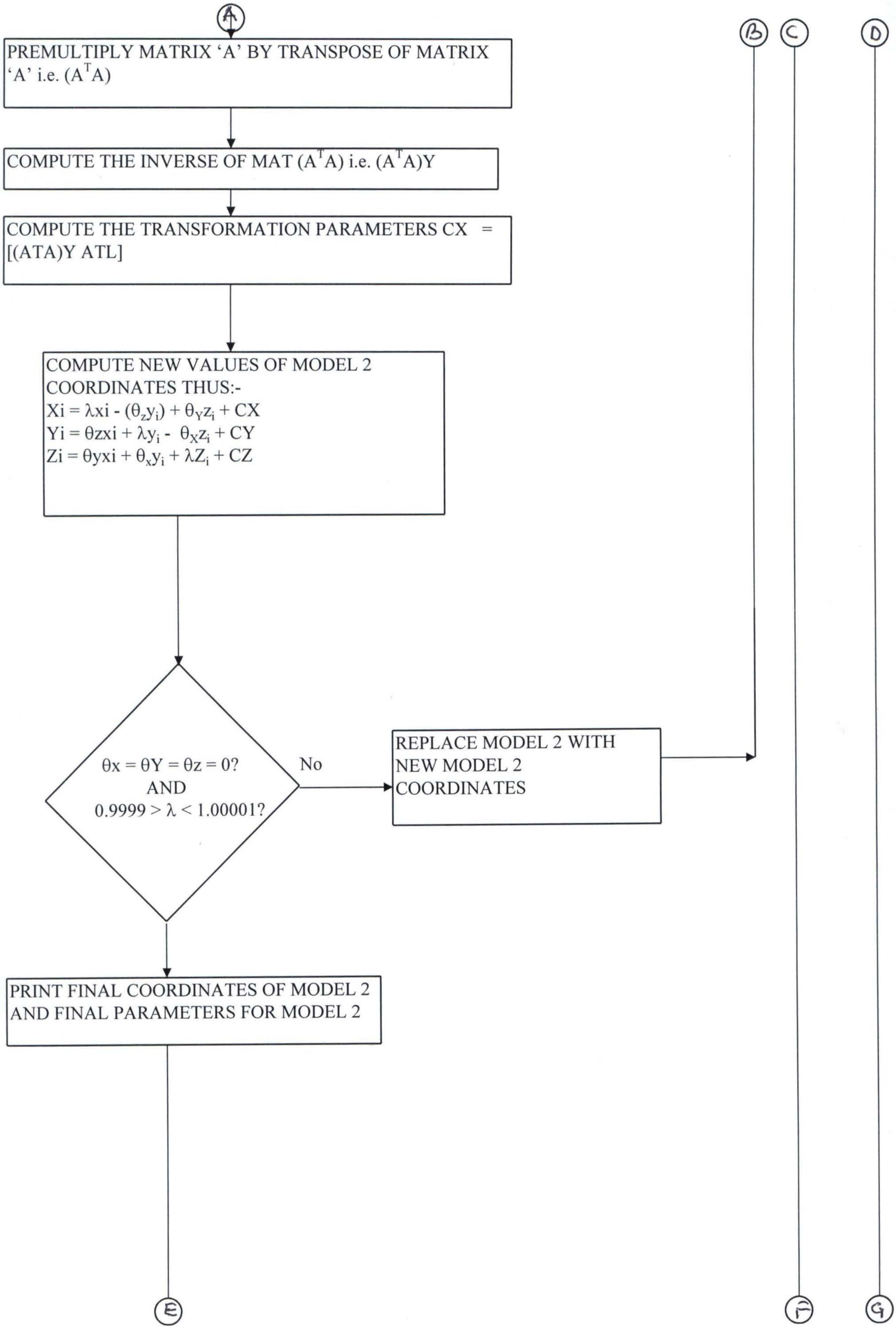
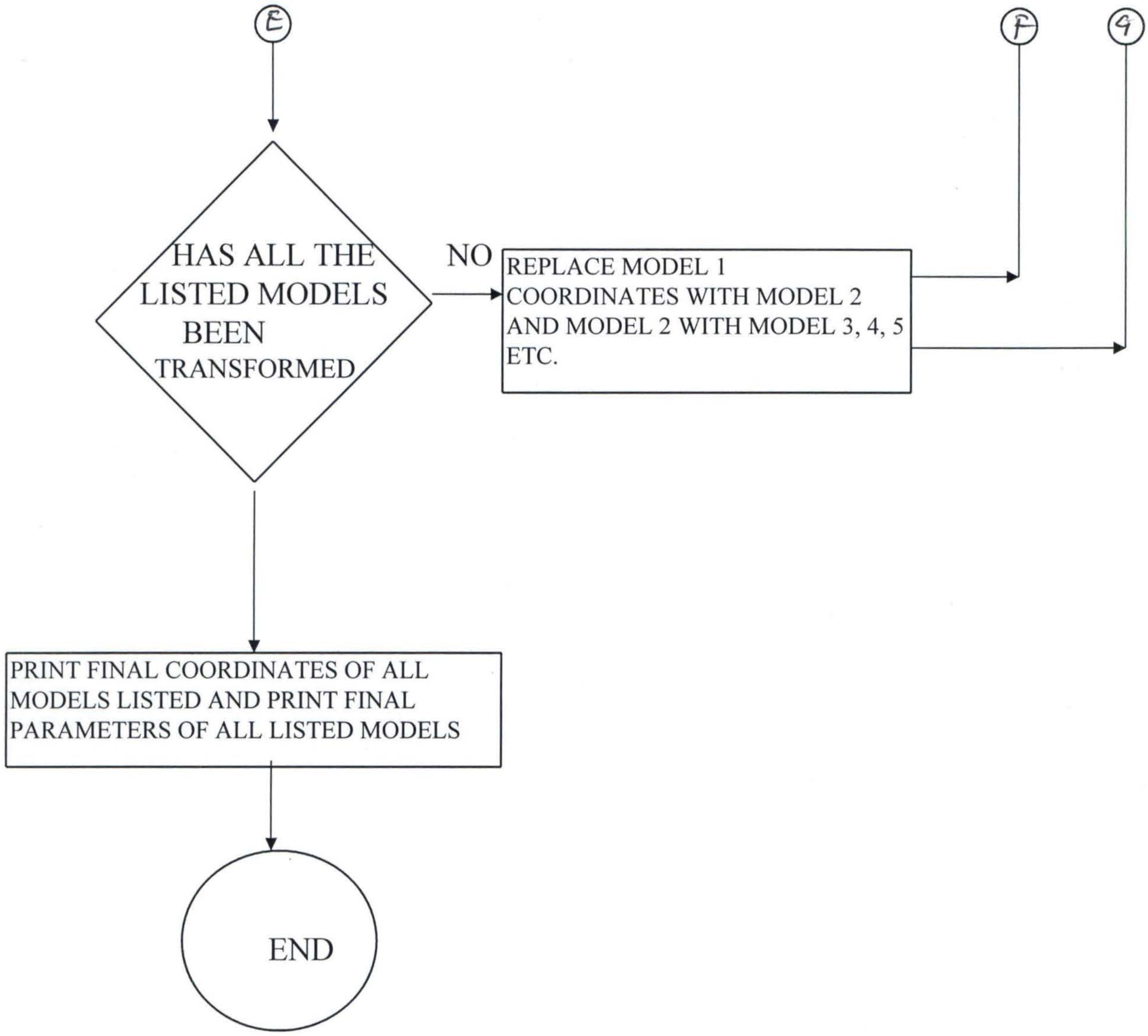
PROGRAM FLOW CHART FOR MODEL TRANSFORMATION




A
PREMULTIPLY MATRIX 'A' BY TRANSPOSE OF MATRIX 'A' i.e. (A^TA)
COMPUTE THE INVERSE OF MAT (A^TA) i.e. $(A^TA)Y$
COMPUTE THE TRANSFORMATION PARAMETERS CX = [(ATA)Y ATL]
COMPUTE NEW VALUES OF MODEL 2 COORDINATES THUS:-
$Xi = \lambda xi - (\theta_z y_i) + \theta_Y z_i + CX$
$Yi = \theta zxi + \lambda y_i - \theta_X z_i + CY$
$Zi = \theta yxi + \theta_x y_i + \lambda Z_i + CZ$
$\theta x = \theta Y = \theta z = 0$?
AND
$0.9999 > \lambda < 1.00001$?
No
REPLACE MODEL 2 WITH NEW MODEL 2 COORDINATES
PRINT FINAL COORDINATES OF MODEL 2 AND FINAL PARAMETERS FOR MODEL 2
B
C
D
E
F
G


E
F
G
HAS ALL THE LISTED MODELS BEEN TRANSFORMED
NO
REPLACE MODEL 1 COORDINATES WITH MODEL 2 AND MODEL 2 WITH MODEL 3, 4, 5 ETC.
PRINT FINAL COORDINATES OF ALL MODELS LISTED AND PRINT FINAL PARAMETERS OF ALL LISTED MODELS
END

```
LPRINT CHR$(12)
CLS : COLOR 15, 0: KEY(1) ON: ON KEY(1) GOSUB 1000
REM  LOWER USMA DAM MAPPING:- MEAN OF FIVE READINGS OF MODEL COORDINATE
REM  IN (X,Y,Z) AND THEIR DX,DY,DZ
REM  *************  GROUND MODEL  **************
REM  Entering of data of observations in the ground model
   CLS
   DIM X(15), Y(15), Z(15), DX(15), DY(15), DZ(15), L(15, 1), MATL1(15, 1)
   DIM MATL2(15, 1), ZER0(15), A(15, 4), MATA2(15, 4), MATB2(4, 15), MATB2A2(4, 4)
   DIM MATB2L1(4, 1), MATB3L2(4, 1), MATB4L3(4, 1)
   DIM A1(3, 3), cf(3, 3), adj(3, 3), E1(3, 3), INVB2A2(3, 3), MATX2(3, 3), MTXB2A2(3, 3)
   DIM MXTB2L1(3, 1), MD1MNX1(1), MD1MNY1(1), MD1MNZ1(1), NXi(15), EYi(15), HZi(15)

REM  Setting loop for 5 times continuous execution of the program

REM  with changes in model name of the data

 FOR P = 1 TO 2
        IF P = 1 THEN MD$ = "    MODEL 1    "
        IF P = 2 THEN MD$ = "    MODEL 2    "
        IF P = 3 THEN MD$ = "    MODEL 3    "
        IF P = 4 THEN MD$ = "    MODEL 4    "
        IF P = 5 THEN MD$ = "    MODEL 5    "
REM  Reading of the data
        FOR I = 1 TO 15
             READ X(I), Y(I), Z(I)
        NEXT I

REM  SUMMING-UP VALUES  FOR X,Y,Z
IF P = 1 THEN
        SUMX1 = 0:   SUMY1 = 0: SUMZ1 = 0
                FOR I = 11 TO 15
            SUMX1 = SUMX1 + X(I)
            SUMY1 = SUMY1 + Y(I)
            SUMZ1 = SUMZ1 + Z(I)
       NEXT I

REM   COMPUTING  AVERAGES:-  X~ , Y~,  Z~
        AVGX1 = SUMX1 / 5
        AVGY1 = SUMY1 / 5
        AVGZ1 = SUMZ1 / 5

REM  COMPUTING DEVIATION  Xi- X~,Yi- y~,Zi- z~
        FOR I = 1 TO 15
             DX(I) = X(I) - AVGX1
             DY(I) = Y(I) - AVGY1
             DZ(I) = Z(I) - AVGZ1
        NEXT I
```

```
REM Defining Matrix -L
    FOR j = 1 TO 5
          L(j, 1) = DX(j + 10)
    NEXT j
    FOR j = 1 TO 5
          L(j + 5, 1) = DY(j + 10)
    NEXT j
    FOR j = 1 TO 5
          L(j + 10, 1) = DZ(j + 10)
    NEXT j
END IF
IF P = 2 THEN
           SUMX2 = 0:   SUMY2 = 0: SUMZ2 = 0
                   FOR I = 1 TO 5
                 SUMX2 = SUMX2 + X(I)
                 SUMY2 = SUMY2 + Y(I)
                 SUMZ2 = SUMZ2 + Z(I)
          NEXT I

REM   COMPUTING  AVERAGES:-  X~ , Y~,  Z~
           AVGX2 = SUMX2 / 5
           AVGY2 = SUMY2 / 5
           AVGZ2 = SUMZ2 / 5

REM  COMPUTING DEVIATION  Xi- X~,Yi- y~,Zi- z~
           FOR I = 1 TO 15
                  DX(I) = X(I) - AVGX2
                  DY(I) = Y(I) - AVGY2
                  DZ(I) = Z(I) - AVGZ2
        NEXT I

END IF
REM defining the mean data of models
  IF P = 1 THEN
        MD1MNX1 = AVGX1
        MD1MNY1 = AVGY1
        MD1MNZ1 = AVGZ1
  ELSEIF P = 2 THEN
        MD2MNX2 = AVGX2
        MD2MNY2 = AVGY2
        MD2MNZ2 = AVGZ2

  END IF
REM   Sending matrix result to array matrix -Li
    IF P = 1 THEN
         FOR j = 1 TO 15
           MATL1(j, 1) = L(j, 1)
         NEXT j
    END IF
REM  Defining matrix ZER0 with zero elements
   FOR K = 1 TO 15
        ZER0(K) = 0
   NEXT K
REM  Defining matrix-A
IF P = 2 THEN

  FOR N = 1 TO 5
         A(N, 1) = DX(N)
         A(N, 2) = ZER0(N)
         A(N, 3) = DZ(N)
         A(N, 4) = -1 * DY(N)
  NEXT N
```

```
   FOR N = 1 TO 5
            A(N + 5, 1) = DY(N)
            A(N + 5, 2) = -1 * DZ(N)
            A(N + 5, 3) = ZER0(N)
            A(N + 5, 4) = DX(N)
   NEXT N
   FOR N = 1 TO 5
            A(N + 10, 1) = DZ(N)
            A(N + 10, 2) = DY(N)
            A(N + 10, 3) = -1 * DX(N)
            A(N + 10, 4) = ZER0(N)
   NEXT N


REM  Sending matrix result to array matrix - Ai

            FOR N = 1 TO 15
              FOR M = 1 TO 4
                    MATA2(N, M) = A(N, M)
              NEXT M
            NEXT N

END IF

REM    Computing the transpose of matrix-A as matrix-B
   IF P = 2 THEN
          FOR M = 1 TO 4
           FOR N = 1 TO 15
            MATB2(M, N) = MATA2(N, M)
          NEXT N, M

   END IF
REM  Computing the product of matrix -B  and  matrix-A as matrix-BA
REM  and defining the 3 by 3  matrix as mtx-BA
    IF P = 2 THEN
           FOR R = 1 TO 4
             FOR S = 1 TO 4
                    MATB2A2(R, S) = 0
                    FOR T = 1 TO 15
                      MATB2A2(R, S) = MATB2A2(R, S) + MATB2(R, T) * MATA2(T, S)
            NEXT T, S, R
              FOR I = 1 TO 3
              FOR j = 1 TO 3
                   MTXB2A2(I, j) = MATB2A2(I + 1, j + 1)
               NEXT j, I

    END IF
REM   Computing the product of matrix -B and matrix-L as matrix-BL
REM  extracting the 3 x 3 matrix -BL
  IF P = 2 THEN
            FOR R = 1 TO 4
              FOR S = 1 TO 1
                  MATB2L1(R, S) = 0
                   FOR T = 1 TO 15
                    MATB2L1(R, S) = MATB2L1(R, S) + MATB2(R, T) * MATL1(T, S)
            NEXT T, S, R
            FOR K = 1 TO 3
             MTXB2L1(K, 1) = MATB2L1(K + 1, 1)
             NEXT K

    END IF
```

```
REM defining the lamda- value
   IF P = 2 THEN
           LAM2 = MATB2L1(1, 1) / MATB2A2(1, 1)
   END IF

 REM ****** COMPUTING THE INVERSE OF 3 X 3 MATRIX-BA INVERSE MATRIX
**************
 IF P = 2 THEN
  FOR e = 1 TO 3
        FOR f = 1 TO 3
          A1(e, f) = MTXB2A2(e, f)
         NEXT f, e
         GOSUB ENTRY1
         FOR e = 1 TO 3
           FOR f = 1 TO 3
                 INVB2A2(e, f) = E1(e, f)
         NEXT f, e

   END IF
REM   computing the solution of the eguation ,as product ofinverse matrix-BA
REM   and   matrix-BL
   IF P = 2 THEN
         FOR I = 1 TO 3
           FOR j = 1 TO 1
                 MATX2(I, j) = 0
                   FOR K = 1 TO 3
                     MATX2(I, j) = MATX2(I, j) + INVB2A2(I, K) * MTXB2L1(K, j)
    NEXT K, j, I
          FOR e = 1 TO 3
           FOR f = 1 TO 3
             MATX2(e, f) = -1 * MATX2(e, f)
          NEXT f, e
   END IF

REM computing the shifts using means,lamda &  rotation parameters
  IF P = 2 THEN

          CX(1) = MD1MNX1 - LAM2 * MATX2(1, 1) * MD2MNX2
          CY(1) = MD1MNY1 - LAM2 * MATY2(2, 1) * MD2MNY2
          CZ(1) = MD1MNZ1 - LAM2 * MATZ2(3, 1) * MD2MNZ2

  END IF
REM   NEW DATA VALUES FOR MODEL TWO COORDINATES AFTER TRANSFORMATION
  IF P = 2 THEN
  FOR I = 1 TO 15
        NXi(I) = LAM2 * DX(I) - MATX2(3, 1) * DY(I) + MATX2(2, 1) * DZ(I) + CX(1)
        EYi(I) = MATX2(3, 1) * DX(I) + LAM2 * DY(I) - MATX2(1, 1) * DZ(I) + CY(1)
        HZi(I) = -1 * MATX2(2, 1) + MATX2(1, 1) * DY(I) + LAM2 * DZ(I) + CZ(1)
  NEXT I
  END IF

' REM defining iteration
'  IF P=2  THEN
'   FOR I=1 TO 15
'     X(I)=NXI(I)
'     Y(I)=EYI(I)
'     Z(I)=HZI(I)
'  NEXT  I
' END IF
```

```
REM TO CLEAR  SCREEN AND DISPLAY RESULTS
    CLS
PRINT TAB(30); MD$
    PRINT TAB(30); "===================="
    PRINT
    PRINT TAB(2); "PT NO"; TAB(10); "Xi(mm)"; TAB(20); "Yi(mm)";
    PRINT TAB(30); "Zi(mm)"; TAB(42); "DXi(mm)"; TAB(55); " DYi(mm)"; TAB(67); " DZi(mm)"
    PRINT "------------------------------------------------------------------------"
    FOR I = 1 TO 15
        PRINT TAB(3); I; TAB(10); X(I); TAB(20); Y(I); TAB(30); USING "###.##"; Z(I);
          PRINT TAB(42); USING "######.##"; DX(I); TAB(55); DY(I); TAB(67); DZ(I)
    NEXT I
    PRINT
    PRINT
    PRINT
    INPUT " PRESS ENTER KEY TO PRT MATRIX L"; S$
    PRINT
    PRINT
    CLS
    PRINT TAB(10); " MATRIX-L     FOR "; MD$
    PRINT TAB(10); "=================================="
    PRINT
REM    Printing result of matrix-L Computations for model-1 to model-4
    IF P = 1 THEN
           FOR j = 1 TO 15
                  PRINT TAB(15); "|"; TAB(20); USING "#########.##"; MATL1(j, 1);
                  PRINT TAB(35); "|"
           NEXT j

        END IF
    PRINT
    PRINT
    PRINT
    INPUT " PRESS ENTER KEY TO PRT MATRIX A"; S$
    PRINT
    PRINT
    CLS
    PRINT TAB(10); " MATRIX-A     FOR "; MD$
    PRINT TAB(10); "=================================="
    PRINT
REM    Printing result of matrix-A Computations for model-2 to model-5
    IF P = 2 THEN
           FOR N = 1 TO 15
                  PRINT TAB(2); "|"; TAB(5); USING "########.##"; MATA2(N, 1); MATA2(N, 2);
MATA2(N, 3); MATA2(N, 4);
                  PRINT TAB(55); "|"
           NEXT N


        END IF
    PRINT
```

```
    PRINT
    PRINT
    INPUT " PRESS ENTER KEY TO PRT MATRIX B"; S$
    PRINT
    PRINT
    CLS
    PRINT
    PRINT TAB(10); " MATRIX-B     FOR "; MD$
    PRINT TAB(10); "=================================="
    PRINT
REM    Printing result of matrix-B Computations for model-2
    IF P = 2 THEN
          FOR N = 1 TO 4
                   PRINT TAB(2); "|"; TAB(5); USING "########.##"; MATB2(N, 1); MATB2(N, 2);
MATB2(N, 3); MATB2(N, 4); MATB2(N, 5); MATB2(N, 6); MATB2(N, 7); MATB2(N, 8); MATB2(N, 9);
MATB2(N, 10); MATB2(N, 11); MATB2(N, 12); MATB2(N, 13); MATB2(N, 14); MATB2(N, 15);
                   PRINT "  |": PRINT : PRINT
           NEXT N

        END IF
    INPUT "PRESS ENTER KEY TO PRINT MATRIX-BA ", S$
        CLS
    PRINT
    PRINT TAB(10); " MATRIX-BA     FOR "; MD$
    PRINT TAB(10); "=================================="
    PRINT
REM    Printing result of matrix-BA Computations for model-2 to model-5
    IF P = 2 THEN
          FOR N = 1 TO 4
                   PRINT TAB(2); "|"; TAB(5); USING "#############.##"; MATB2A2(N, 1); MATB2A2(N,
2); MATB2A2(N, 3); MATB2A2(N, 4);
                   PRINT TAB(75); "|"
                   PRINT
           NEXT N

        END IF
    PRINT
    PRINT
    PRINT TAB(10); "EXT. MATRIX-BA     FOR "; MD$
    PRINT TAB(10); "=================================="
    PRINT
REM    Printing result of matrix-BA Computations for model-2 to model-5
    IF P = 2 THEN
          FOR N = 1 TO 3
                   PRINT TAB(2); "|"; TAB(5); USING "#############.##"; MTXB2A2(N, 1); MTXB2A2(N,
2); MTXB2A2(N, 3);
                   PRINT TAB(75); "|"
                   PRINT
        NEXT N

        END IF
    PRINT
```

```
    INPUT "PRESS ENTER KEY TO PRINT INVERSE OF MATRIX-BA ", S$
    CLS
    PRINT
    PRINT TAB(10); " INVERSE OF EXT.MATRIX-BA    FOR "; MD$
    PRINT TAB(10); "=============================================="
    PRINT
REM    Printing result of inverse of matrix-BA Computations for model-2 to model-5
    IF P = 2 THEN
          FOR N = 1 TO 3
                PRINT TAB(2); "|"; TAB(5); USING "#####.###############"; INVB2A2(N, 1);
INVB2A2(N, 2); INVB2A2(N, 3);
                PRINT "  |": PRINT : PRINT
          NEXT N

        END IF
    PRINT
    PRINT
    INPUT " PRESS ENTER KEY TO PRT MATRIX BL"; S$
    CLS
    PRINT
    PRINT
    PRINT TAB(10); " MATRIX-BL     FOR "; MD$
    PRINT TAB(10); "=================================="
    PRINT
REM    Printing result of matrix-BL Computations for model-2
    IF P = 2 THEN
          FOR j = 1 TO 4
                PRINT TAB(15); "|"; TAB(20); USING "##############.##"; MATB2L1(j, 1);
                PRINT TAB(55); "|"
          NEXT j

        END IF
        PRINT
        PRINT
        PRINT TAB(10); " EXT.MATRIX-BL     FOR "; MD$
    PRINT TAB(10); "=================================="
REM    Printing result of matrix-BL Computations for model-2
    IF P = 2 THEN
          FOR j = 1 TO 3
                PRINT TAB(15); "|"; TAB(20); USING "##############.##"; MTXB2L1(j, 1);
                PRINT TAB(55); "|"
          NEXT j

        END IF
        PRINT
        INPUT " PRESS ENTER KEY TO PRT MATRIX -X "; S$
    CLS

PRINT
    PRINT
    PRINT TAB(10); " ROTATION   MATRIX-R   FOR "; MD$
    PRINT TAB(10); "===================================================="
REM    Printing result of rotational matrix-x Computations for model-2
    IF P = 2 THEN
          FOR j = 1 TO 3
                PRINT TAB(15); "|"; TAB(20); USING "#####.################"; MATX2(j, 1);
                PRINT TAB(55); "|"
          NEXT j
        END IF
```

```
    PRINT
    PRINT
    INPUT " PRESS ENTER KEY TO PRINT NEW COORDINATE VALUE FOR MODEL-2 ", S$
REM printing new coordinate values for model-2

REM 888888888888888888888888888888888888



REM **************** 1
DATA 221674,456284,152.32,223512,470373,158.56,222506,494211,222.24
DATA 222471,522781,161.06,221994,539673,169.12,201460,541953,182.46
DATA 200339,522563,171.10,204419,500134,160.42,202087,478187,154.22
DATA 199352,459159,148.32,176015,459587,162.70,175047,480846,169.44
DATA 172901,502791,161.67,177269,525457,175.76,180948,544278,181.36

REM ***************2


DATA 220134,459874,162.3,219167,480303,169.3,217187,502877,161.3
DATA 221590,525445,175.3,225322,542088,181.0,203400,546663,187.5
DATA 201482,529193,187.5,197458,507804,172.5,200109,480408,174.0
DATA 194577,461513,189.2,171454,456502,183.7,171448,479101,198.8
DATA 178438,502630,199.5,184841,522886,175.3,181300,539661,197.3

REM *************3
DATA 215064,456506,182.0,222027,479159,198.7,223986,502739,200.3
DATA 223988,523034,179.5,224764,539788,200.3,228336,543989,206.8
DATA 200979,526764,183.0,201850,505572,206.0,198404,485185,206.0
DATA 197904,463948,207.7,182321,463318,215.0,182170,479809,198.3
DATA 181436,504242,204.5,176881,525421,192.5,176955,545863,215.0

REM ************4
DATA 224786,463387,215.0,224586,479923,196.6,223730,504328,204.7
DATA 218528,524996,189.8,219087,545887,215.0,198447,544736,201.2
DATA 196214,521819,192.5,203114,503253,205.3,199309,481071,213.8
DATA 195125,460300,237.0,175500,456057,234.0,173984,483398,219.5
DATA 173590,504540,217.4,174848,526469,200.0,179105,545285,212.0

REM ****************5
DATA 216950,456089,233.0,215349,483491,220.0,214857,504592,218.2
DATA 216026,526554,201.8,220225,545393,212.8,193018,545031,205.0
DATA 196694,527262,213.5,196920,505426,215.4,192158,482820,218.0
DATA 193772,457964,240.5,172266,459758,234.5,171802,498123,233.5
DATA 172735,501159,251.5,175868,524893,219.5,176556,546909,206.3

    NEXT P:
```

```
ENTRY1:
REM subroutine to computing the inverse

REM  computing the determinant
det = A1(1, 1) * (A1(2, 2) * A1(3, 3) - A1(2, 3) * A1(3, 2)) - A1(1, 2) * (A1(2, 1) * A1(3, 3) - A1(2, 3) * A1(3, 1)) + A1(1, 3) * (A1(2, 1) * A1(3, 2) - A1(2, 2) * A1(3, 1))

REM  computing the cofactors
cf(1, 1) = (A1(2, 2) * A1(3, 3) - A1(2, 3) * A1(3, 2))
cf(1, 2) = -1 * (A1(2, 1) * A1(3, 3) - A1(2, 3) * A1(3, 1))
cf(1, 3) = (A1(2, 1) * A1(3, 2) - A1(2, 2) * A1(3, 1))

cf(2, 1) = -1 * (A1(1, 2) * A1(3, 3) - A1(1, 3) * A1(3, 2))
cf(2, 2) = A1(1, 1) * A1(3, 3) - A1(1, 3) * A1(3, 1)
cf(2, 3) = -1 * (A1(1, 1) * A1(3, 2) - A1(1, 2) * A1(3, 1))

cf(3, 1) = A1(1, 2) * A1(2, 3) - A1(1, 3) * A1(2, 2)
cf(3, 2) = -1 * (A1(1, 1) * A1(2, 3) - A1(1, 3) * A1(2, 1))
cf(3, 3) = A1(1, 1) * A1(2, 2) - A1(1, 2) * A1(2, 1)

REM computing the adjoint matrix
FOR I = 1 TO 3
FOR j = 1 TO 3
adj(I, j) = cf(j, I)
NEXT j, I

REM computing the inverse matrix
FOR I = 1 TO 3
FOR j = 1 TO 3
E1(I, j) = adj(I, j) / det
NEXT j, I
RETURN


1000  END
 RETURN
```

MODEL 1

PT NO	Xi(mm)	Yi(mm)	Zi(mm)	DXi(mm)	DYi(mm)	DZi(mm)
1	221674	456284	152.32	45238.00	-46307.81	-17.87
2	223512	470373	158.56	47076.00	-32218.81	-11.63
3	222506	494211	222.24	46070.00	-8380.81	52.05
4	222471	522781	161.06	46035.00	20189.19	-9.13
5	221994	539673	169.12	45558.00	37081.19	-1.07
6	201460	541953	182.46	25024.00	39361.19	12.27
7	200339	522563	171.10	23903.00	19971.19	0.91
8	204419	500134	160.42	27983.00	-2457.81	-9.77
9	202087	478187	154.22	25651.00	-24404.81	-15.97
10	199352	459159	148.32	22916.00	-43432.81	-21.87
11	176015	459587	162.70	-421.00	-43004.81	-7.49
12	175047	480846	169.44	-1389.00	-21745.81	-0.75
13	172901	502791	161.67	-3535.00	199.19	-8.52
14	177269	525457	175.76	833.00	22865.19	5.57
15	180948	544278	181.36	4512.00	41686.19	11.17

PRESS ENTER KEY TO PRT MATRIX L?

MATRIX-L FOR MODEL 1

-421.00
-1389.00
-3535.00
833.00
4512.00
-43004.81
-21745.81
199.19
22865.19
41686.19
-7.49
-0.75
-8.52
5.57
11.17

PRESS ENTER KEY TO PRT MATRIX A?

MATRIX-A FOR MODEL 1

PRESS ENTER KEY TO PRT MATRIX B?

MATRIX-B FOR MODEL 1
=================================

PRESS ENTER KEY TO PRINT MATRIX-BA

MATRIX-BA FOR MODEL 1
=================================

EXT. MATRIX-BA FOR MODEL 1
=================================

PRESS ENTER KEY TO PRINT INVERSE OF MATRIX-BA

INVERSE OF EXT.MATRIX-BA   FOR   MODEL 1
===

PRESS ENTER KEY TO PRT MATRIX BL?

MATRIX-BL   FOR   MODEL 1
==================================

EXT.MATRIX-BL   FOR   MODEL 1
==================================

PRESS ENTER KEY TO PRT MATRIX -X ?

ROTATION MATRIX-R FOR MODEL 1
==

PRESS ENTER KEY TO PRINT NEW COORDINATE VALUE FOR MODEL-2

MATRIX-L FOR MODEL 2
================================

PRESS ENTER KEY TO PRT MATRIX A?

MATRIX-A FOR MODEL 2
================================

-546.00	0.00	-7.54	42243.41
-1513.00	0.00	-0.54	21814.41
-3493.00	0.00	-8.54	-759.59
910.00	0.00	5.46	-23327.59
4642.00	0.00	11.16	-39970.59
-42243.41	7.54	0.00	-546.00
-21814.41	0.54	0.00	-1513.00
759.59	8.54	0.00	-3493.00

```
|       23327.59       -5.46        0.00      910.00        |
        39970.59      -11.16        0.00     4642.00
           -7.54   -42243.41      546.00        0.00
           -0.54   -21814.41     1513.00        0.00
           -8.54      759.59     3493.00        0.00
            5.46    23327.59     -910.00        0.00
|          11.16    39970.59    -4642.00        0.00        |


 PRESS ENTER KEY TO PRT MATRIX B?



           MATRIX-B      FOR        MODEL  2
          =================================

|        -546.00   -1513.00   -3493.00     910.00    4642.00  -42243.41   -21814
1     759.59   23327.59   39970.59      -7.54      -0.54      -8.54       5.46
    11.16  |


|           0.00       0.00       0.00       0.00       0.00       7.54        0
4       8.54      -5.46     -11.16  -42243.41  -21814.41     759.59   23327.59
 39970.59  |


|          -7.54      -0.54      -8.54       5.46      11.16       0.00        0
0       0.00       0.00       0.00     546.00    1513.00    3493.00    -910.00
 -4642.00  |


|       42243.41   21814.41    -759.59  -23327.59  -39970.59    -546.00    -1513
0   -3493.00     910.00    4642.00       0.00       0.00       0.00       0.00
     0.00  |

PRESS ENTER KEY TO PRINT MATRIX-BA


          MATRIX-BA     FOR        MODEL  2
         =================================

|      4439940096.00            -0.03             0.00            -7.81       |

|              -0.03    4402776064.00    -260188448.00        -91537.38       |

|               0.00    -260188448.00      37164880.00       -897248.50       |

|              -7.81        -91537.38       -897248.50    4439939584.00       |


         EXT. MATRIX-BA      FOR       MODEL  2
         =================================

|      4402776064.00    -260188448.00        -91537.38                        |

|     -260188448.00      37164880.00       -897248.50                        |

|          -91537.38       -897248.50    4439939584.00                        |
```

RESS ENTER KEY TO PRINT INVERSE OF MATRIX-BA

INVERSE OF EXT.MATRIX-BA FOR MODEL 2
==

0.000000000387416	0.000000002712280	0.000000000000556
0.000000002712280	0.000000045895806	0.000000000009331
0.000000000000556	0.000000000009331	0.000000000225230

PRESS ENTER KEY TO PRT MATRIX BL?

MATRIX-BL FOR MODEL 2
==================================

4527186432.00
-21661.21
-2889.10
24822162.00

EXT.MATRIX-BL FOR MODEL 2
==================================

-21661.21
-2889.10
24822162.00

PRESS ENTER KEY TO PRT MATRIX -X ?

ROTATION MATRIX-R FOR MODEL 2
===

| 0.0000024243347525 |
| -0.0000402618024964 |
| -0.0055906604975462 |

PRESS ENTER KEY TO PRINT NEW COORDINATE VALUE FOR MODEL-2

NEW MODEL 2
============

PT NO	NXi(mm)	NYi(mm)	NZi(mm)	DXi(mm)	DYi(mm)	DZi(mm)
1	175643	459521	162.40			
2	174771	480357	169.58			
3	172878	503386	161.48			
4	177494	526373	175.81			
5	181392	543322	181.66			
6	159065	548109	188.30			
7	157012	530307	188.26			
8	152789	508520	172.91			
9	155339	480571	174.38			
10	149593	461335	189.83			
11	125987	456355	184.21			
12	126107	479398	199.66			
13	133366	503351	200.43			
14	140008	523969	175.80			
15	136492	541093	198.28			

Press any key to continue

OTHER SOFTWARE TYPES AND APPLICATIONS

1. ELISION: A subprogram of Gausian elimination for Triangular Matrices and determinant to solve simultaneous linear equations.
2. EIGEN: Another subprogram by Gauss for finding the eigen vector corresponding to a given eigen value.
3. GSITER: Main program by Gauss-Seidel for solving simultaneous linear equations by the iterative method.
4. ALLAM.M.M: A program for analytical Aerial Triangulation, a Canadian surveyor developed in 1973.
5. SCHUT, G.H.: An introduction to Analytical strip Triangulation with a Fortran program, National Research Council of Canada, Report No. NRC 9396 OF 1996.
6. ACKERMANN[311]: Fully Analytical IMT program.
7. PAT.M.-43: Program by Ackermann using Auxiliary vertical controls from Stethoscope and APR incorporated with PAT. M-43.
8. GHOSH [189]: Program for Ind. Geodetic Control for strip formation and adjustment is by using independent base lines whose lengths and azimuths on the ground are known.
9. AYENI O.O. [180]: Program of Ind. Models polynomial block formation and adjustment of strip or block on the computer.
10. JERIE[93] :
    MORRE[342]: Jerie designed two analog computers for block adjustment of horizontal and vertical points.
11. DERENYI [186]: Semi-Analytical Bundle, a classical bundle adjustment program.