بسم الله الرحمن الرحيم

Palestine Polytechnic University

College of Engineering & Technology
Civil & Architecture Engineering Department

Graduation Project

DESIGN OF GEODETIC NETWORK BETWEEN PPU BUILDINGS

Project Team

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Hebron – Palestine

June 2004

<u>Certification</u>

Palestine Polytechnic University

PPU

Hebron-Palestine

The Senior Project Entitled:

DESIGN OF GEODETIC NETWORK
BETWEEN PPU BUILDINGS

Prepared by

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In according with the recommendation of the project supervisors and the acceptance of all examining committee members, this project has been submitted to the department of Civil and Architectural Engineering in the College of Engineering and Technology in partial fulfillment of the requirements of the department for the degree of Bachelor of Engineering.

Project Supervisors **Department Chairman**

الإهداء

Dedication

إلى من رووا بدمائهم الزكية تراب هذا الوطن الغالي

إلى الذين حملوا أرواحهم على اكفهم من اجل وطنهم

إلى والدتي و والدي و اخوتي ... نبع الحنان و العطاء

إلى الأصدقاء... نبع الحب و السعادة

إلى رواد العلم المبدع ، طلاب اليوم ، بناة المستقبل ، قادة الغد

إلى طلاب جامعة بوليتكنيك فلسطين من اخوتنا وأخواتنا من خالفنا منهم الرأي أو من اتفق معنا وانطلق لآفاق التجدد و الإبداع.

فريق العمل :

شكر و تقدير

م يتم هذا الجزء من المشروع بجهودنا الخالصة بل شارك و ساهم الكثيرون في إنجازه. تقدم لهم بجزيل الشكر و الامتنان منهم سائلين المولى عز و جل ان يديمهم ذخرا و عطاءا لوطن العزيز.

تقدم بالشكر العظيم الى إدارة جامعة بوليتكنيك فلسطين على الدعم و التوجيه و نخص بالذكر دائرة الهندسة المدنية و المعمارية.

ما نتقدم بالشكر الى العاملين في مكتبة جامعة بوليتكنيك فلسطين لما قدموه لنا من مراجع تم الاستفادة منها.

ما نتوجه بالشكر الكبير و الامتنان الى الأستاذ المهندس القدير فيضي شبانة الذي قدم لنا لدعم و المشورة الصائبة و المعلومة الدقيقة و جزاه الله كل خير.

ما نتوجه بالشكر الجزيل الى جميع محاضري قسم هندسة المساحة و المباني و نخص بالذكر الأستاذ المهندس القدير كمال غطاشة و الأستاذ احمد الشريف و الأستاذ غادي زكارنة ما قدموه لنا من مساعدة.

كما نتقدم بالشكر الى الجمعية الخيرية الإسلامية والهلال الأحمر ومديرية التربية والتعليم، وكل من ساعدنا لانجاز الجزء العملي من هذا المشروع.

كذلك نشكر كل من مد لنا يد العون لإنجاح هذا المشروع.

ABSTRACT

DESIGN OF GEODETIC NETWORK BETWEEN PPU BUILDINGS

BY

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This project is establish geodetic network point between Palestine Polytechnic University building in Wadi elhariya district and major PPU building in Ein khair Aldeen district to determine Palestine coordinate for this point to use it in each survey applications and this project contain three parts:

The first part is practical.

The second part is theoretical.

Third part is programming.

الخلاصة

إنشاء شبكة نقاط جيوديسية بين مباني
جامعة بوليتكنيك فلسطين

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م. فيضي شبانة

المشروع هو عبارة عن انشاء شبكة نقاط جيوديسية بين مباني البوليتكنيك في منطقة وادي الهرية والمبنى الرئيسي في منطقة عين خير الدين وذلك لإيجاد الإحداثيات الفلسطينية لهذه النقاط وذلك لاستخدامها في كافة التطبيقات المساحية ويتكون هذا المشروع من ثلاثة أجزاء:

١- الجزء العملي

٢- الجزء النظري

٣- برنامج لتصحيح الشبكة

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CHAPTER ONE

INTRODUCTION

1.1 Introduction

There are many different types of surveys. Generally speaking, surveys will either take into account the true shape of the earth (Geodetic surveys) or treat the earth as a flat surface (Plane surveys). Additionally, surveys are conducted for the purpose of positioning features on the ground (Horizontal surveys), determining the elevation or heights of features (Vertical surveys) or a combination of both.

In our project, we will concentrate on geodetic surveys, especially geodetic control network.

Geodesy is a science that determines the size and shape of the earth**.**

1.2 The Objective of Project

The main aim of our project is to establish many full control points, join together between Polytechnic Building to use it in some application of survey such as geodesy , cartography, boundary demarcation and engineering projects.

1.3 Study Area

The study area is inside Hebron city, especially between polytechnic university buildings (Wadi Alharriya and Ein Kheir alddin buildings), to join these buildings by control points.

1.4 Literature Review

The first serious mapping of Palestine on modern lines was undertaken in 1798 by Napoleon, as an extension of his survey of Egypt. A Topographic Section was formed which consisted of four officers, an astronomer, and four “intelligent soldiers.” Bases were measured at Alexandria and Cairo by the “Service Topographique de l’Armee d’Egypte,” and topographic maps were compiled using a 10 km grid with an origin at the great pyramids of Giza.

The coastline depicted on these early French topographic maps was actually based on British Admiralty Charts. Survey work on the ground was completed late in 1801, and, by the end of 1803, compilation in Paris had reached a stage where the maps could be engraved on copper plates. The sheets were printed in 1808, but Napoleon ordered that they should remain under seal as state secrets. The maps were not finally published until 1817. In 1865, Captain C. W. Wilson, RE (later Major General Sir Charles Wilson), surveyed the City of Jerusalem at a scale of 1:2,500. The success of Wilson’s survey led directly to the establishment of an association called the Palestine Exploration Fund (PEF). November of 1871 was the beginning of the PEF surveying and mapping activities,

The first map, that of Gaza, was produced on 25 January 1917, and was probably the first town-map ever made using aerial photographs, Other maps produced during 1918, such as those of Nablus and El-Krak, were maps that demonstrated a new solution to the problem of the use of aerial photographs for the purpose of mapping towns situated in hilly areas. Town-maps for the Palestine Front were an immediate necessity, not an academic exercise, and the war served as an immediate catalyst. The new Survey of Palestine department was established by the Occupied Enemy Territory Administration after the war, and therefore inherited some good topographic maps. They were then able to concentrate on improving the triangulation network and connecting it with the French triangulation in Syria, as well as carrying out cadastral surveys for land settlement.

John W. Hagar, offered that the Palestine Datum Number 2 where: Φ = 31° 18' 06.27" North, λ = 34° 31' 42.02″ East of Greenwich, the ellipsoid of reference is the Clarke 1880 where a = 6,378,300.789 meters, 1/f = 293.466004983713280, and elevation = 98.9 m. The Cassini-Soldner Civil Grid of 1933 (origin adopted is the principal point 82'M (Jerusalem)) having the geographic coordinates Φo = 31° 44' 02.749" N, λo = 35° 12' 39.29" East of Greenwich + 04.200" E = 35° 12' 43.490". The addition of 04.200" to the longitude is in accordance with the decision in 1928 to adopt the French value for the longitude at the points of junction 73'M and 98'M in the north, and to correct all Palestine longitudes accordingly. Palestine longitudes were originally based on those of Egypt at the Transit of Venus station, and a correction of 3.45" was indicated to the Egyptian longitudes. Imara Base (1'M or 5'DM) is the original false origin of the Grid coordinates (i.e., FN = FE = 100 km) for the Cassini-Soldner Civil Grid. Final implemented Cassini-Soldner False Easting is then 170,251.555 m, False Northing = 126,867.909 m.

A military version of this system based on the Gauss-Krüger Transverse Mercator is identical to the Civil Cassini-Soldner Grid, except for the False Easting at False Origin where 1,000,000 meters is added, and for coordinates used for the southern Sinai while it was still occupied by the Israelis, an additional 1,000,000 meters was added south of the South False Origin!

1.5 Work Methodology

In the first part of this project we choose a number of routes that we can use them, and then we study all these routes and analyze it one by one, and we visited these routes and check each one.

Then we choose the places that we can locate our points on them, we choose a number of schools , mosques and public buildings high in the route that have been chosen, and we make sure that every point should be visible from many other points.

Then we start the observations using total station, by reading the horizontal and vertical angles, five face left and five face right, we measured the slope and horizontal distances, and we use the navigation global position system (GPS),(it receiver's name is Magellan and its precise (σ) in horizontal = ± 3meter, in vertical = ± 6meter) to make check for our calculations.

After getting the observations we find the mean values and standard deviations for each reading, then we correct the angels in each quadrilateral using the equal shift method, after these treatments we get correct readings that don't contain any blunders or errors, strength of figure was determined to have the most suitable route.

Then we can determine the coordinate for each point which now can be considered as a control point.

CHAPTER TWO

SHAPE OF THE EARTH

2.1 Introduction

In the past, the nations described the shape of the earth according their belief, so this beliefs was different about together, for example the Greek's belief for the shape of earth was different about Roman's and bible's belief, this different because not finding means to describe the actual shape of earth, but in this days, the scientist can invent and developed some means for describing the actual shape of earth such as satellites, and journey to moon.

The earth's topographic features range from about 9 km above this surface (Mount Everest) and to about 12 km below this surface (Mariana Trench). The thickness of the line drawn to show the circumference, including our 'topographic' features would change less than 0.2 mm. That's less than a pencil line thickness. The shape of our planet is so complex that in order to study it properly, we need a nice simple, easy to use, 'mathematical model' to represent its shape.

That's where the ellipse comes in. An ellipse is almost like a circle, but not quite. It's like an oval or a 'flattened' circle. Take a look back at the picture of our measurements between the poles. Looks like a flattened circle doesn't it? It's an ellipse. An ellipse is the easiest way we have to describe the overall shape of the earth.

2.2 Position

Surveying is concerned essentially with fixing the position of a point in two or three dimensions.

For example, in the production of a plan or map, one is concerned in the first instance with the accurate location of the relative position of survey points forming a framework, from which the position of topographic detail is fixed. Such a framework of points is referred to as a control network.

The same network used to locate topographic detail may also be used to set out points, defining the position, size and shape of the designed elements of the construction project.

Precise control networks are also used in the monitoring of deformation movements on all types of structures.

In all these situations the engineer is concerned with relative position, to varying degress of accuracy and over areas of varying extent. In order to define position to the high accuracies required in engineering surveying, a suitable homogeneous coordinate system and reference datum must be adopted.

Consideration of Figure 2.1 illustrates that if the area under consideration is of limited extent, the orthogonal projection of AB onto a plane surface may result in negligible distortion. Plane surveying techniques could be used to capture field data and plane trigonometry used to compute position. This is the case in the majority of engineering surveys. However, if the area extended from C to D, the effect of the Earth's curvature is such as to produce unacceptable distortion if treated as a flat surface. It can also be clearly seen that the use of a plane surface as a reference datum for the elevations of points is totally unacceptable.

If Figure 2.2 is now considered, it can be seen that projecting CD onto a surface (cd) that was the same shape and parallel to CD would be more acceptable. Further, if that surface was brought closer to CD, say c´d´, the distortion would be even less. This then is the problem of the geodetic surveyor: that of defining a mathematical surface that approximates to the shape of the area under consideration and then fitting and orientating it to the Earth's surface. Such a surface is referred to in surveying as a 'reference ellipsoid'.

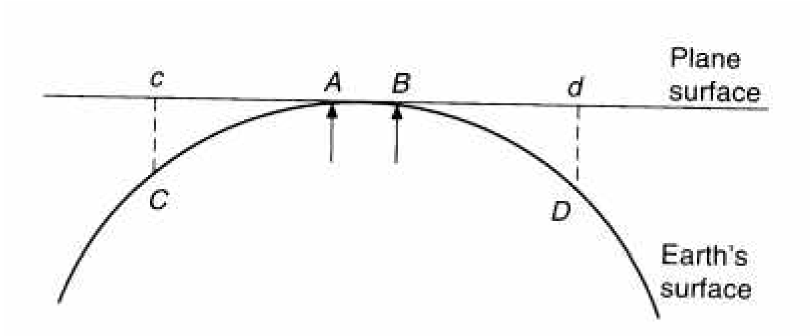

Fig 2.1 Distortion in projection[1]

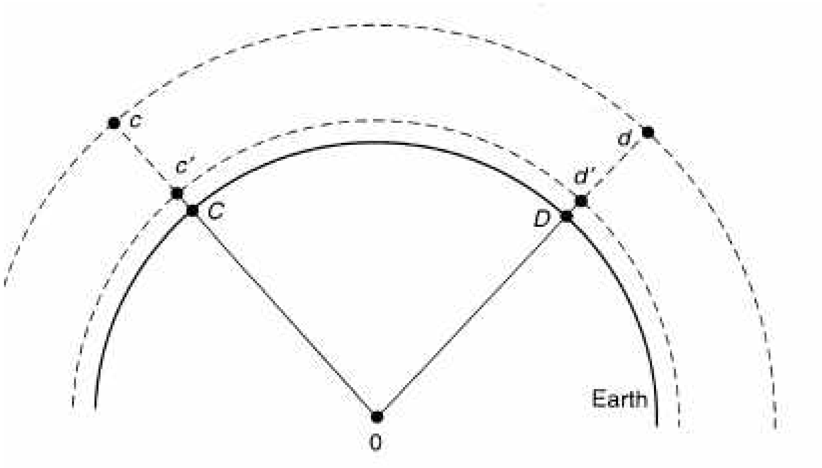

Fig 2.2 Reference ellipsoid[2]

[1] Ref. no. 1, page 209
[2] Ref. no.1, page 209

2.3 Reference Ellipsoid

To arrive at the concept of a reference ellipsoid, the various surfaces involved must be reviewed.

23.1 Earth's Surface

The Earth's physical surface is a reality upon which the surveying observations are made and points located. However, due to its variable topographic surface and overall shape, it cannot be defined mathematically and so position cannot be computed on its surface. It is for this reason that in surveys of limited extent, the Earth is treated as flat and plane trigonometry used to define position.

2.3.2 The Geoid

What is the geoid?

Sounds like something to do with the earth - but what is it? Well for starters, you can't see it, you can't touch it, most people have never heard of it, and most will never know anything about it. And yet everyone benefits from it.

The geoid is still an unfamiliar idea to most people even though geodesy, the science that studies the size, shape and gravity field of the Earth, is the oldest of what we call the "geosciences", or sciences which study the Earth.

The geoid is, for all intents and purposes, the same as mean sea level. We study it, by making use of the latest satellite technology, in order to help us measure the Earth we live on. Whether we simply want to know how high we are above sea level when using a handheld GPS receiver or want to build a road faster and cheaper, using the geoid will help, the Figure 2.3 show the actual shape of Geoid which is equal to the mean sea level.

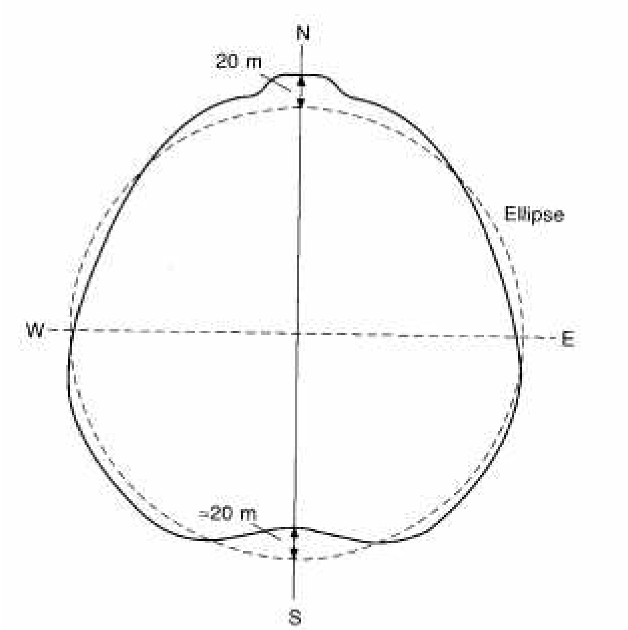

Fig 2.3 The Geoid (Solid Line)[1]

2.3.3 The Ellipsoid

The ellipsoid of rotation is the closest mathematically definable shape to the figure of the Earth. It is represented by an ellipse rotated about its minor axis and is defined by its semi-major axis a (Figure 2.4) or the flattening f. Although the ellipsoid is a concept and not a physical reality, it represents a smooth surface for which formulae can be developed to compute ellipsoidal distance, azimuth and ellipsoidal coordinates. Due to the variable shape of the geoid, it is not possible to have a global ellipsoid of reference for use by all countries. The best-fitting in Palestine geocentric ellipsoid is (Clarke-1880-Benoit), which has the following dimensions:

Semi-major axis	6 378 300.79m
Semi-minor axis	6 356 566.43 m

[1] Ref. no. 1, page 210.

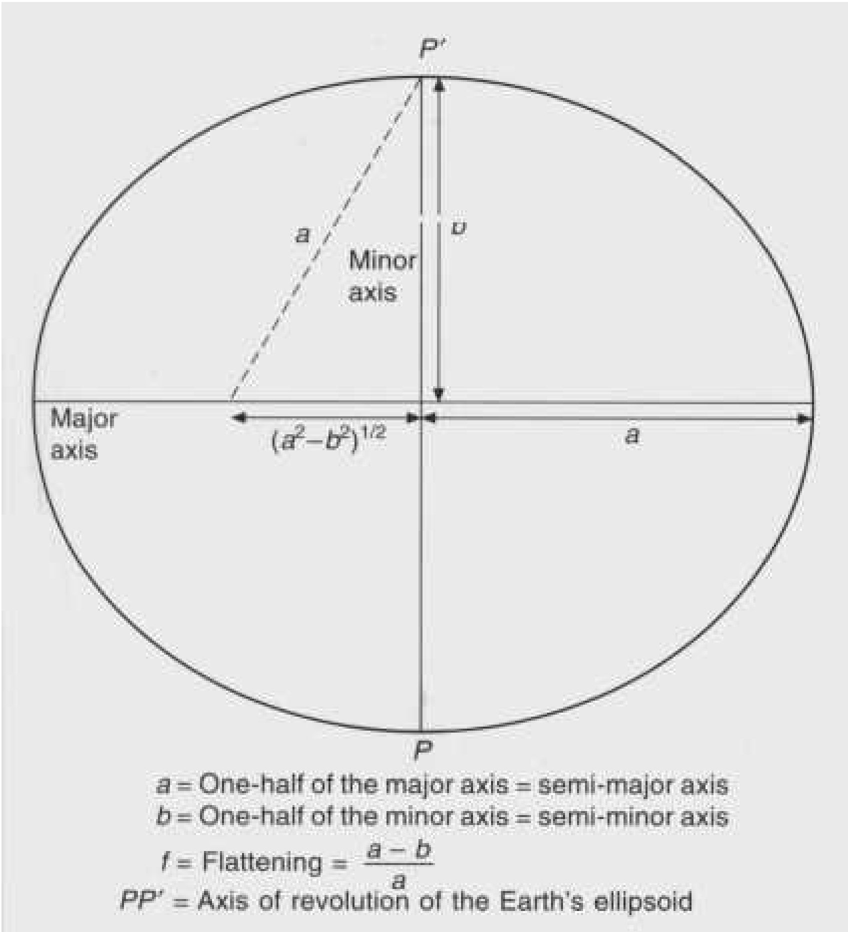

Fig. 2.4 Elements of an ellipse[1]

A small sample of ellipsoids used by different countries is shown

[1] Ref. no. 1, page 211.

Table 2.1 Sample of Ellipsoidal used in different country[1]

Ellipsoid	a meters	1/f	Where used
Airy (1830)	6 377 563	299.3	Great Britain
Everest (1830)	6 377 276	300.8	India, Pakistan
Bessel (1841)	6 377 397	299.2	East Indies, Japan
Clarke (1866)	6 378 206	295.0	North and Central America
Australian National (1965)	6 378 160	298.2	Australia
South American (1969)	6 378 160	298.2	South America
Clark (1880)	6 378 300	293.4	Palestine

When f = 0, the figure described is a circle, and the flattening of this circle is described by $f = (a - b)/a$. A further parameter used in the definition of an ellipsoid is e, referred to as the first eccentricity of the ellipse, and is equal to $(a^2 - b^2)^{1/2}/a$.

Figure 2.5 illustrates the relationship of all three surfaces. It can be seen that if the geoid and ellipsoid were parallel at A, then the deviation of the vertical would be zero in the plane shown. If the value for geoid—ellipsoid separation (N) was zero, then not only would the surfaces be parallel, they would fit each other exactly. As the ellipsoid is a smooth surface and the geoid is not, perfect fit can never be achieved. However, the values for deviation of the vertical and geoid—ellipsoid separation can be used as indicators of the closeness of fit.

[1] Ref. no. 1, page 211.

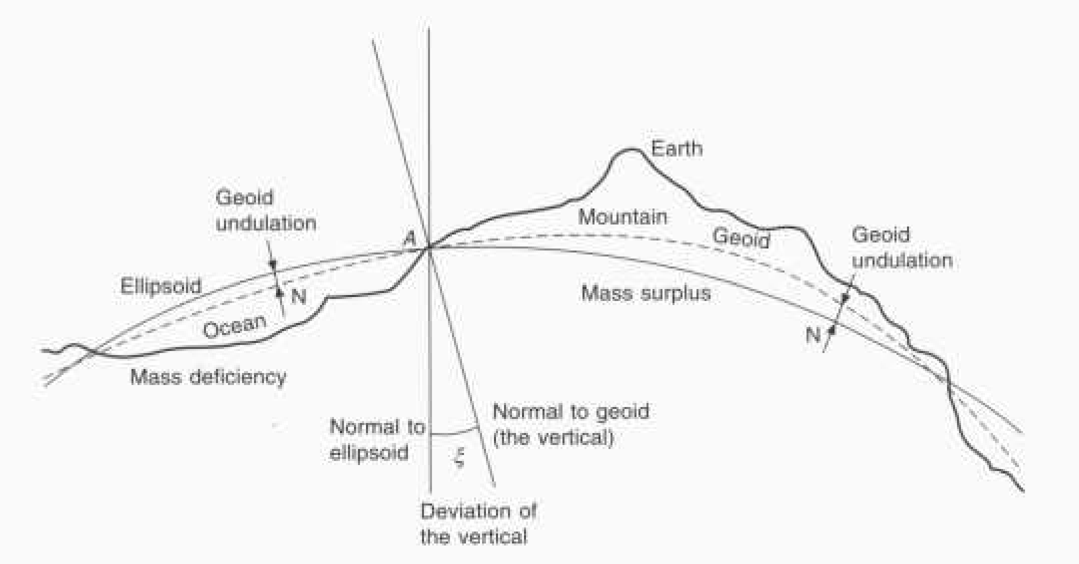

Fig. 2.5 Geoid and ellipsoid surface[1]

2.4 COORDINATE SYSTEMS

2.4.1 Astronomical Coordinates

As shown in Figure 2.6, astronomical latitude Φ_A defines the latitude of the vertical (gravity vector) through the point in question (P) to the plane of the equator, whilst the astronomical longitude λ_A is the angle in the plane of the equator between the zero meridian plane (Greenwich) and the meridian plane through P, both of which contain the spin axis.

[1] Ref. no.1, page 212.

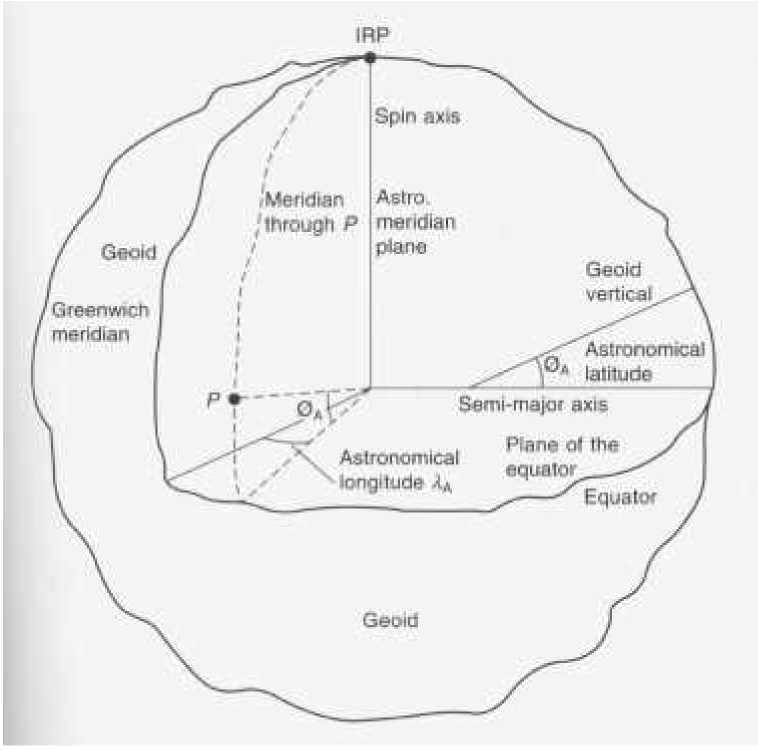

Fig. 2.6 Astronomical coordinates[1]

2.4.2 Geodetic Coordinates

Considering a point P at height h, measured along the normal through P, above the ellipsoid, the ellipsoidal latitude and longitude will be Φ_G and λ_G, as shown in Figure 2.7. Thus the ellipsoidal latitude is the angle describing the inclination of the normal to the ellipsoidal equatorial plane. The ellipsoidal longitude is the angle in the equatorial plane between the ((International Earth Rotation Service) IERS Reference Meridian) IRM and the geodetic meridian plane through the point in question P. The height h of P above the ellipsoid is called the ellipsoidal height.

[1] Ref. no.1, page 213.

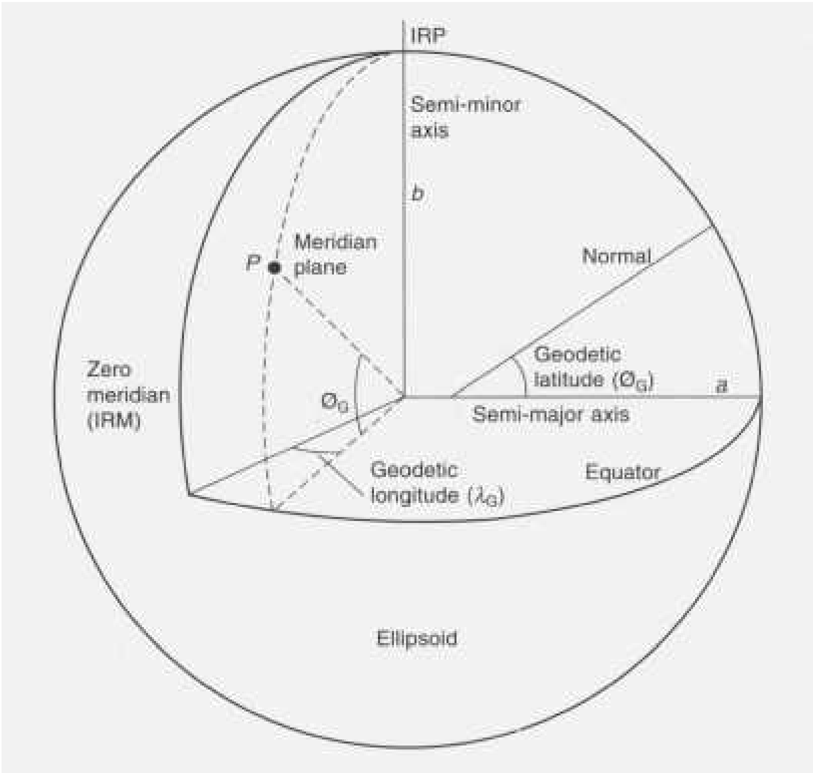

Fig. 2.7 Geodetic Coordinates[1]

2.4.3 Cartesian Coordinates

As shown in Figure 2.8, if the IERS spin axis is regarded as the Z-axis, the X-axis is in the direction of the zero meridian (IRM) and the Y-axis is perpendicular to both, a conventional three-dimensional coordinate system is formed. If we regard the origin of the Cartesian system and the ellipsoidal coordinate system as coincident at the mass centre of the Earth.

[1] Ref. no.1, page 214.

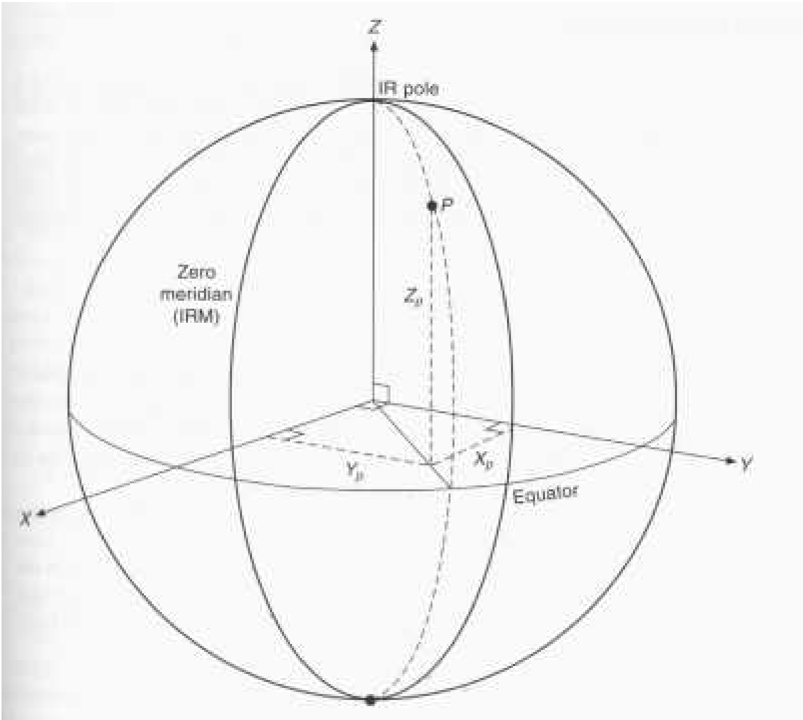

Fig. 2.8 Geocentric Cartesian Coordinates[1]

2.4.4 Plane Rectangular Coordinates

For limited areas curvature of the earth may be processed by the mathematical projection of ellipsoidal position onto a plane surface. e.g. coordinates in the U.K are termed easting (E) and northing (N) and are obtained from:

$$E = f_E(¤_G, ª_G) \qquad \text{(ellipsoid parameters)}$$
$$N = f_N(¤_G, ª_G) \qquad \text{(ellipsoid parameters)}$$

The result is the definition of position by plane coordinates (E, N) which can be utilized using plane trigonometry. These positions will contain same distortion.

[1] Ref. no.1, page 215.

Figure (2.9) illustrates the concept involved and shows the plane tangential to the ellipsoid at local origin O .

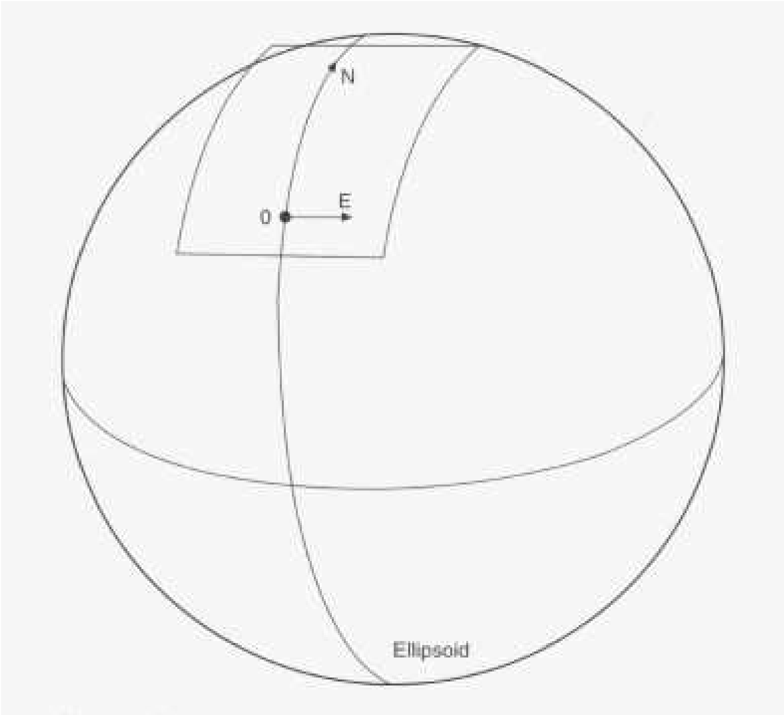

Fig 2.9 Plan Rectangular Coordinates[1]

2.5 Heights

The heights on earth's surface include two types:

1) - Orthometric Height.

2) - Ellipsoidal Height.

2.5.1 Orthometric Height (H)

Orthometric height is the height of a point on the physical surface of the earth above or below the geoid, measured along a line that passes through both the point

[1] Ref. no.1, page 216

on the earth and the point on the geoid and is normal to the surface of the WGS-84 ellipsoid. This is the height usually found on geographic maps for ground elevation.

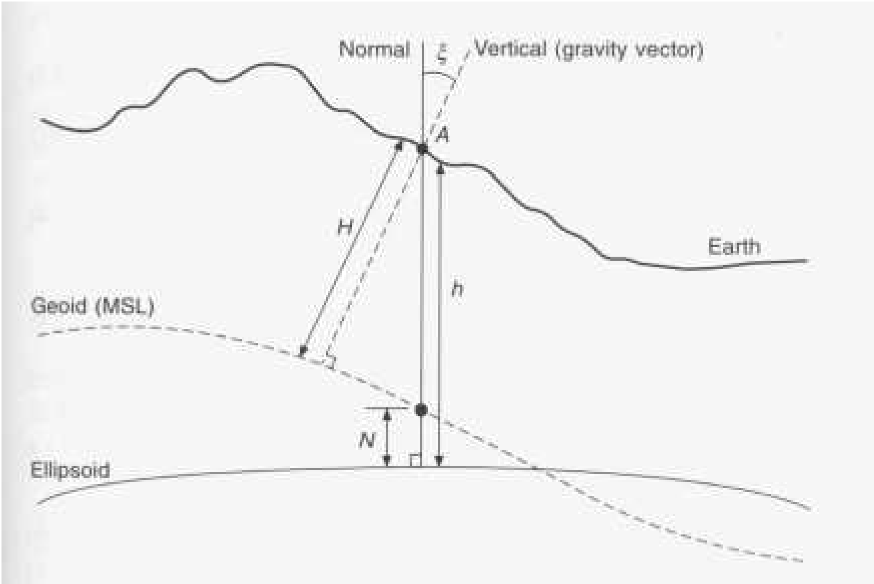

Fig 2.10 Height in geoid and ellipsoid[1]

2.5.2 Ellipsoidal Height (h)

After using satellite positioning in X Y Z system which for use in Local systems are first transformed to Φ_G, λ_G and h.

The value of h is the ellipsoidal height if h is not related to gravity it is useless (in practical).

$h = N + H \cos\xi$

ξ is always less than 60″, and it can be ignored.

$h = N + H$ with an error less than 0.4 mm.

The term N is referred as the "geoid-ellipsoid separation" or "geoid height".

[1] Ref. no.1, page 217

2.6 Local System

In local system we have reference ellipsoids which most closely fit the geoid of that area and are defined by the following 8 parameters.

1- The size and shape of the ellipsoid defined by the semi-major axis a and one other chosen from the semi-minor axis b or the flattening f or the eccentricity e (2 parameters).

2- The minor axis of the ellipsoid is orientated parallel to the mean spin axes of the earth as defined by IERS (2 parameters)

3- The center of the ellipsoid is implicitly. Defined with respect to the mass center of the earth by choice of geodetic latitude, longitude and ellipsoidal height at the origin of the system (3 parameters).

4- The zero meridian or X-axis of the system is chosen to be parallel to the mean (Greewhich) meridian as defined by IERS (1 parameters)

It follows that all properly defined geodetic systems will have their axes parallel and can be related to each other by simple translations in X, Y and Z.

2.7 Reduction to mean sea level

Triangulation networks extending over large areas must be reduced to a common mean sea-level datum. In Fig. 2.11 distance *d* is measured from *F'* to *0'* at elevation *h* above mean sea level. If *R* is the radius of curvature for the earth's surface at that section, then by proportion

$$\frac{b}{d} = \frac{R}{R+h} \quad \text{or} \quad b = d\,\frac{R}{R+h} \qquad \text{2-2}$$

R = mean radius of the earth in the region.

In which *b* is the mean sea-level distance. For most mean sea-level reductions, an average radius of the earth 6 378 137.0 m.

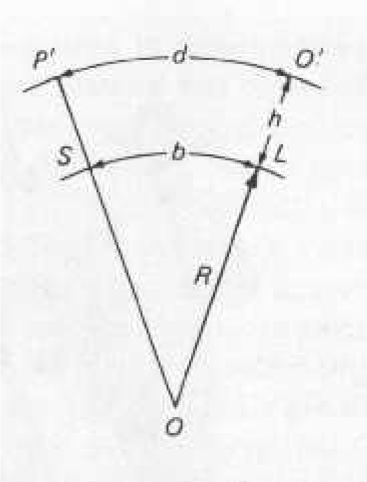

Fig 2.11 Reduction to mean sea level[1]

2.8 GRID DISTANCE

The coordinates of control points in geodesy network be calculated reliance grid bearing and grid distance which be calculated using following law:

$$G = S \times F$$

Where: G=grid distance.

S=Ellipsoidal Distance at MSL (mean sea level).

F=Scale Factor is Used in Palestine =1.000067.

[1] Ref. no.3, page 409.

CHAPTER THREE

ERRORS

3.1 Introduction

All surveying operations are subject to three sources of error. The first source is, Natural errors: caused by variation in or adverse weather conditions, refraction, gravity effects, etc. the second source Instrumental errors: caused by imperfect construction and adjustment of the surveying instruments used, Personal errors: caused by the inability of the individual to make exact observations due to the limitations of human sight, touch and hearing.

In fact, no surveying measurement is exact, and the true value of the parameters being measured is never known. Therefore, a surveyor must thoroughly understand the sources of errors in the various methods of surveying, as well as, the methodology for evaluating the achievable accuracy of surveying methods.

3.2 Measurement Errors

The true error in a measurement is the difference between the measured value of a parameter and its true value.

Let $e_i =$ true error.

$x_i =$ measured value.

$x_o =$ true value.

$$\Rightarrow e_i = x_i - x_o \qquad (3.1)$$

But since the true value (x_o) is never known, e_i can never be exactly determined. Therefore, the error in a measurement must be estimated by comparing it with another more accurately determined value of the same parameter. Let ($\hat{x}$) represent such as a value. Then, an estimate (v_i) of the true error (e_i) is:

$$v_i = x_i - \hat{x} \qquad (3.2)$$

3.3 Classification of Errors

Error in surveying measurements can be classified into following three groups:

(1) Blunders or mistakes.

(2) Systematic errors.

(3) Random errors.

3.3.1 Blunders or Mistakes

These are simply mistakes caused by human carelessness, fatigue and haste.
A blunder can be of any sign (- or +) and any magnitude and its occurrence is unpredictable. Some examples of blunders are: transposition of digits in recording an observation (such as recording 3.18 instead of 3.81) and sighting a wrong target when measuring an angle.

Blunders must be eliminated by careful work and by using field procedures that provides checks for blunders.

3.3.2 Systematic Errors

These are mostly caused by the maladjustment of the surveying instruments and by the uncontrollable nature of the environment. Both the signs and magnitudes of systematic errors behave according to some specific pattern or physical law of nature, which may or may not be known. When the law of occurrence is known, systematic errors can be eliminated.

A special type of systematic error is an error that always occurs with the same sign and magnitude and it's therefore often referred to as constant error. The most common source of constant error is the measuring instruments. For example a 30-m tape may in fact be missing the first 0.10 m (i.e., 10 cm) due to the deterioration of the tape after the repeated use. Then, if not noticed, every time the tape is used would contain a constant error of +0.10 m. Constant errors of this type can be detected by careful attention and calibration of the instruments.

3.3.3 Random Errors

These are caused by imperfections of the measuring instruments, imperfections of the human operator to make an exact measurement, and uncontrollable variations in the natural environment. These errors can be minimized by using better instruments and properly designed field procedure and by making repeated measurements.

3.3.3.1 Characteristics of Random Errors

Random errors have the following characteristics:

(1) Positive and negative errors of the same magnitude occur with the same frequency.

(2) Small errors occur more frequently than large ones.

(3) Very large errors seldom occur.

(4) The mean of an infinite number of observations is the true value.

For example, suppose that a distance is measured using the same instruments and the same degree of care, a large number of times, say 1000 times, the mean or average of the 1000 repeated measurements is computed, and the estimated error in each individual length measurement computed by subtracting the mean value from the measured value (equation 3.2). The estimated error computed in this manner is called the deviation from the mean.

Plotting the magnitude of the estimated errors against the frequency of occurrence may result in a histogram similar to that shown in Figure 3.1.

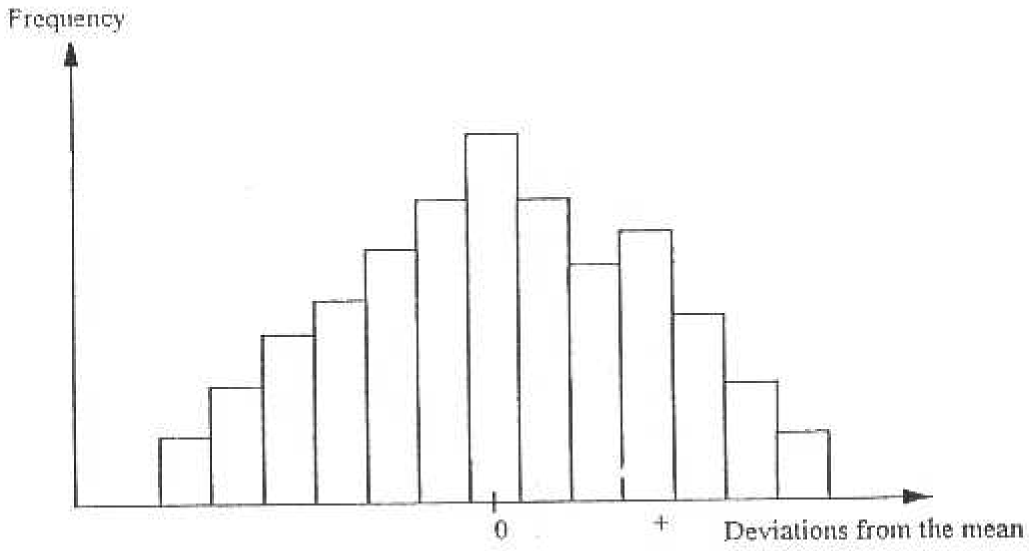

Figure3.1: A histogram which shows the distribution of random errors.

For an infinite number of repetitions of the measurements, this histogram approximates to a continuous normal curve with the following probability density function (p.d.f):

$$f(v) = \frac{1}{\pm\sqrt{2®}} \cdot e^{-\frac{1}{2}\left(\frac{V}{\pm}\right)^2} \qquad (3.3)$$

This curve is shown in Figure 3.2.

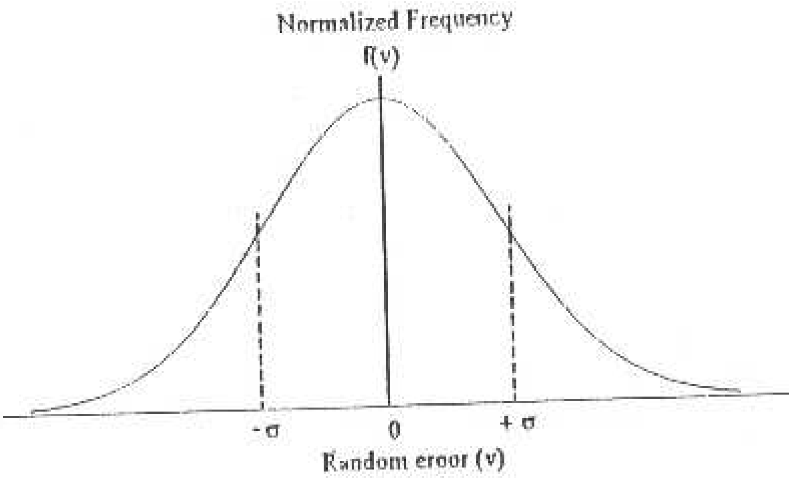

Figure 3.2: Normal curve of error.

Where v = random error.

σ = standard error or deviation of the measurements.

The normal curve is symmetrical about v = 0. The probability that the random

Error in a measurement takes on a value between a and b, is equal to the area under the curve and bounded by the values of a and b as shown in Figure 3.3.

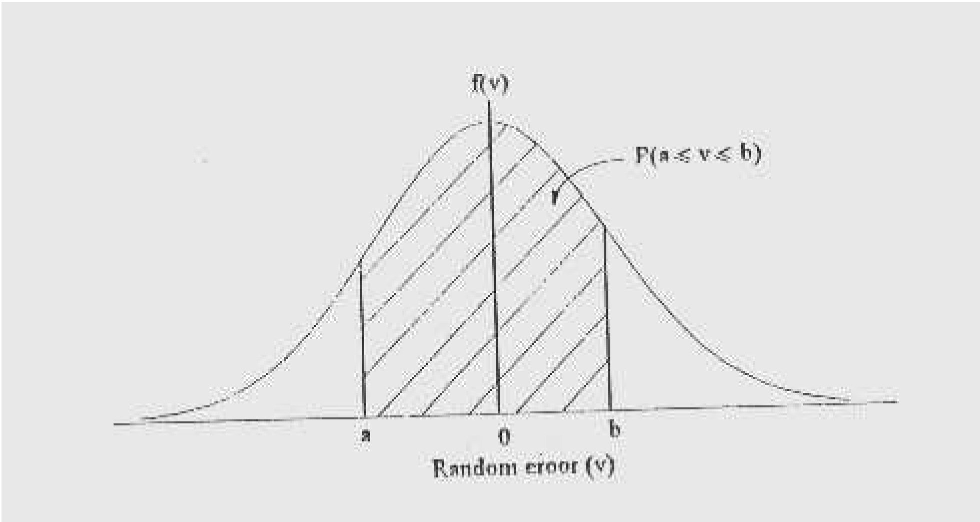

Figure 3.3: Probability of random errors.

In mathematical terms, if P(a ≤ v ≤ b) represents that probability, then

$$P(a \le v \le b) = \int_a^b \frac{1}{\pm\sqrt{2®}} \cdot e^{-\frac{1}{2}\left(\frac{V}{\pm}\right)^2} \cdot dv \qquad (3.4)$$

The curve is normalized so that the area under5 the entire curve is equal to 1.

Since this integral is so complicated, probability values can be taken from already prepared tables which can be found in any statistics book.

Table3.1 Multipliers for various percent probable errors.

Symbol	Error Range	Probability (%)
E_{50}	0.6745σ	50
E_{90}	1.6449σ	90
E_{95}	1.960 σ	95
E_{99}	2.576 σ	99
$E_{99.7}$	2.965 σ	99.7
$E_{99.9}$	3.290 σ	99.9

3.4 Mean, Standard Deviation and Standard Error OF The Mean

Let $X_1, X_2, X_3, ..., X_n$ be n repeated measurements of the same quantity, and let it be assumed that all n measurements were made with the same instrument and same degree of care. Then:

(1) The mean denoted by $\overline{X}$, of then n measurements is computed as follows:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

(3.5)

(2) An estimate of the standard error $\hat{±}_X$ of one measurement of the quantity is:

$$\hat{±}_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(X_i - «\right)^2}{n}} \qquad (3.6)$$

(3) An estimate of the standard deviation S_X of one measurement of the quantity is:

$$S_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(\overline{X} - X_I\right)^2}{n-1}} \qquad (3.7)$$

(4) An estimate of the standard error of the mean of the n measurements, to be denoted by $±_{\overline{X}}$, can be computed as follows:

$$\sigma_{\overline{X}} = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(X_i - \overline{X}\right)^2}{n(n-1)}} \qquad (3.8)$$

or

$$\sigma_{\overline{X}} = \frac{\sigma_X}{\sqrt{n}} \qquad (3.9)$$

$\sigma_{\overline{X}}$ is called the RMS error of the mean.

Where:

S_X = standard deviation which is defined the square root of the sample variance.

σ_X = standard error which is defined the square root of the population variance.

$\overline{X}$ = most probable value, that value for a measured quantity which, based upon the observations, has the highest probability. It is derived from a sample set of data rather than the population, and is simply the mean if the repeated measurements have the same precision.

μ = true value which is a quantity's theoretically correct or exact value, it can never be determined.

(n-1)= degrees of freedom which is defined the number of observations that are in excess of the number necessary to solve for unknowns.

3.5 Probable Error and Maximum Error

The probable error of a measurement is defined to be equal to 0.6745σ. There is a 50 % probability that the actual error exceeds the probable error, as well as, a 50% probability that it is less than the probable error.

The maximum error in a measurement is most commonly defined as being equal to 3σ, and only a 0.3% probability that the actual error exceeds 3σ.

Example: if the standard error of an angle measurement is ± 1.5 seconds, then,

The probable error = ± (0.6745 ×1.5) = ±1.0 seconds

The maximum error = ± (3 ×1.5) = ± 4.5 seconds

The maximum error is often used as the criterion for separating mistakes or blunders from random errors. For example, after the mean and standard deviation of n repeated measurements have mean computed, the deviation (v_i) of each measurements from the mean can be computed $(v_i = x_i - \hat{x})$. If any measurement deviates from the mean by more than 3σ, the measurement is considered to contain a blunder. It is rejected, and a new mean and standard deviation are computed without this particular measurement.

3.6 Precision and Accuracy

Precision: A measurement is said to have high precision if it has a small standard deviation. For example, assume that team A measured a distance with $\sigma_A =$ ±0.05, and team B measured the same distance with this $\sigma_B =$ ± 0.10. The measurement of team A is said to be more precise than the of team B. Figure 3.4 shows that a large standard deviation means a flatter distribution curve for the random errors.

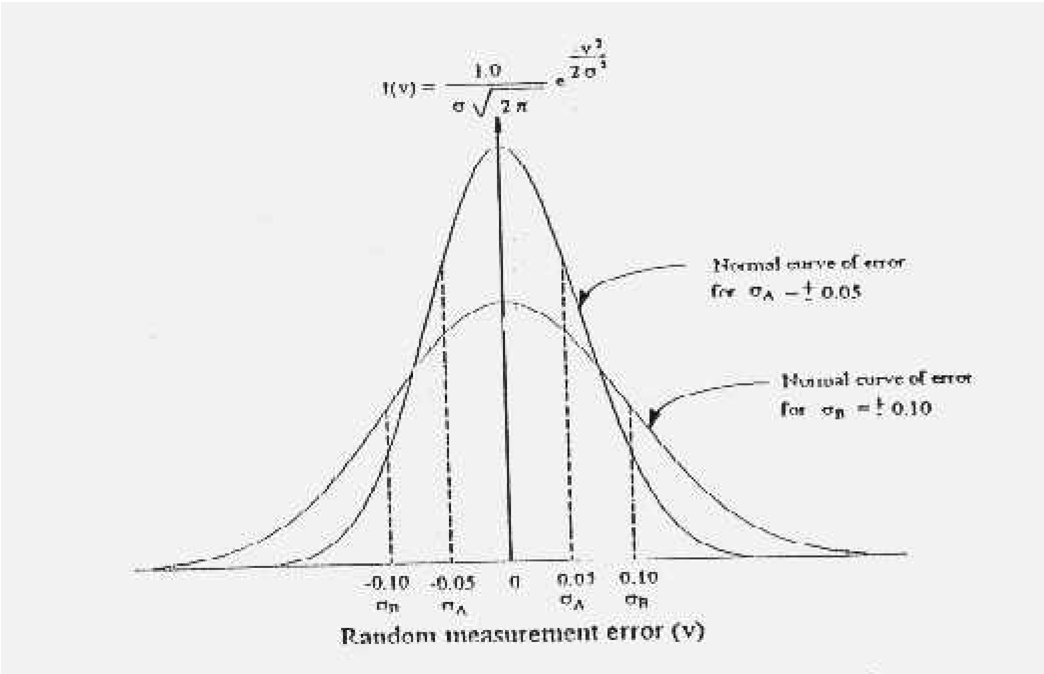

Figure 3.4: Standard error and the distribution of random errors.

Accuracy: A measurement is said to have high accuracy if it is close to the true value. High precision does not necessarily mean high accuracy. A measurement that is highly precise is also highly accurate if it contains little or no systematic errors with all blunders removed.

To obtain high precision and accuracy in surveying, the following strategies must be followed:

(1) Eliminate all blunders

(2) Eliminate or correct all systematic errors by frequent calibration and adjustment of the instruments.

(3) Minimize the random errors by using good instruments and field procedures.

CHAPTER FOUR

GEODETIC NETWORKS

4.1 Introduction

Geodetic Control Networks provide us with a tool to relate features to one another using a common reference system. The positions and elevations of the points that make up a control network have been accurately determined and are marked by markers (often called 'monuments') placed permanently in the ground.

The monuments of these control networks are spaced at various intervals depending on how and why they were established. As a result of the methods used to determine the positions and elevations of monuments in older control networks, they may or may not be in convenient places for future use.

4.2 Types of Geodetic Control Network

There are different types or levels of control networks depending on where and why they are established. A control network may have very accurate positions but no elevations (called a Horizontal Control Network) or very accurate elevations but no positions (called a Vertical Control Network). Some points in a control networks have both accurate positions and elevations (called a Full Control Network).

4.3 Methods of Establishing Geodetic Control Network

1- Triangulation.
2- Trilateration.
3-Triangulataration.

4.3.1 Triangulation

A triangulation system consists of a series of joined or overlapping triangles in which an occasional line is measured and the balance of the sides are calculated from angles measured at the vertices of the triangles. The lines of a triangulation system from a network that ties together all the triangulation stations at the vertices of the triangles. Figure 4.1 shows the triangulation network and Figure 4.2 shows the shapes of the triangle.

4.3.1.1 Triangulation procedure

The work of triangulation consists of the following steps:

1. Reconnaissance, to select the location of stations.
2. Evaluation of the strength of figure for the proposed network.
3. Erection of signals and, in some cases, tripods or towers for elevating the signals and /or instruments.
4. Observations of directions or angles.
5. Measurement of the base lines.
6. Observation at one or more stations in order to determine the true meridian to which azimuths are referred.
7. Computations including: reduction to sea level, reduction to center (which necessary), calculation of spherical excess (when necessary), calculation of all

lengths of triangle sides and coordinates for all triangulation stations, and adjustment of the triangulation network to provide the best estimates of coordinates for all points.

4.3.2 Trilateration

A trilateration system also consists of a series of joined or overlapping triangles. However, for trilateration all of the lengths of the triangle's sides are measured and the few directions or angles observed are only those required to establish azimuth. Trilateration has become feasible with development of EDM equipment which makes practical the measurement of all lengths with a high order of accuracy under almost all field conditions.

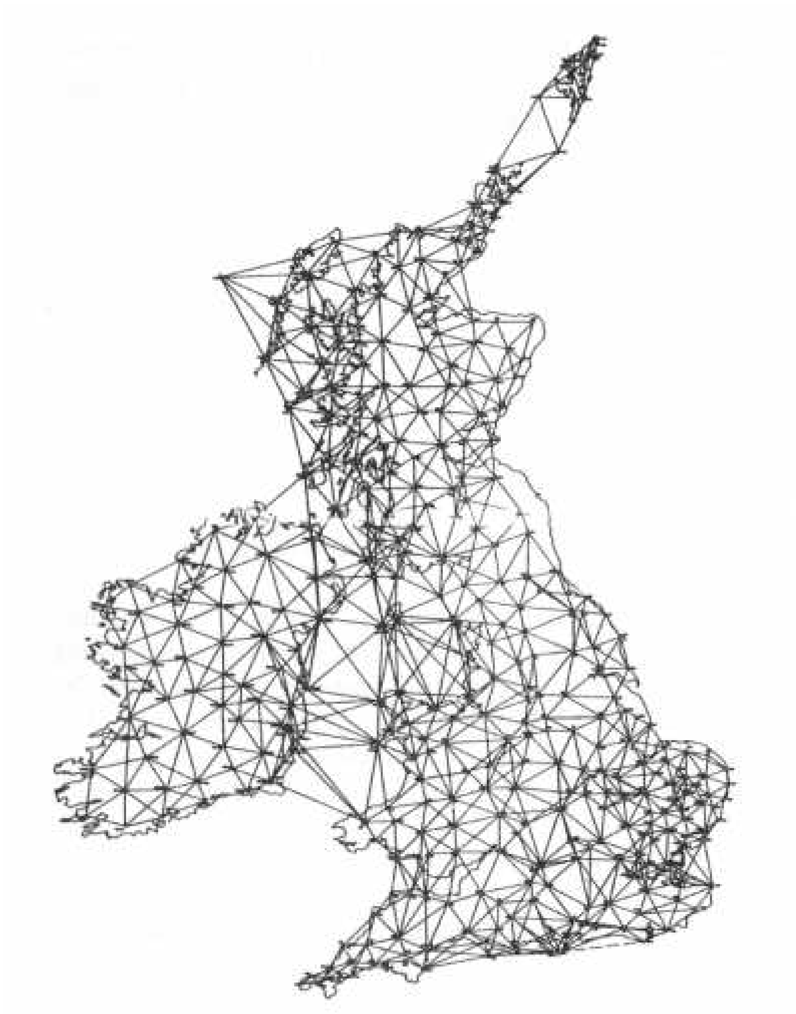

Fig. 4.1 An example of Triangulation[1]

[1] Ref. no. 1 page 272.

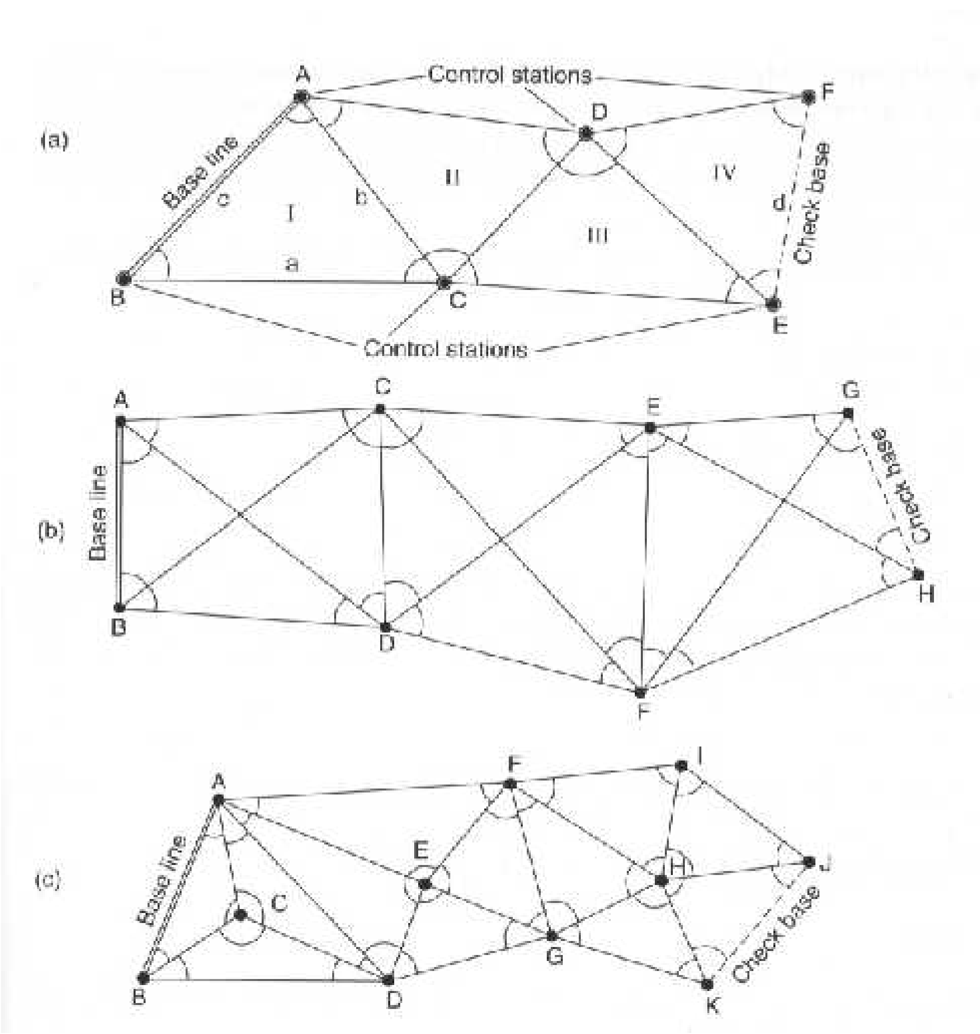

Fig. 4.2 Shape of the triangle [1]

a- Chain of simple triangles. b- braced quadrilaterals. c- Polygons with central point.

4.3.3Triangulateration

A combined triangulation and trilateration system consists of a network of triangles in which all the angles and all distances are observed. Such as a combined system represents the strongest network for creating horizontal control that can be

[1] Ref. no. 1 Page 273

established by conventional terrestrial methods.

The improvement in the redundancy checks for a braced quadrilateral is shown in the table 4.1.

Table 4.1 Comparing between types of network[1]

	Triangulation	Trilateration	Triangulateration
Quadrilateral			
No. of directions	12	0	12
No. of sides	1	6	6
No. of checks	4	1	9

Because triangulateration is more accurate than the previously mentioned systems, and include triangulation and trilateration methods we will use it, especially quadrilaterals shapes in our project.

4.4 The Orders of Geodetic Networks

The geodetic networks are classified to four order, first, second, third and fourth order. Every one of these orders has some specifications make it different to other orders.

First-Order: is a single chain; average length 20 km; all angles and sides measured**.**

Second, Third and Fourth-Order: are a single chain; average lengths 15 km, 10 km and 5 km respectively; all angles measured; 1 side measured every fourth triangle.

The following table shows the specifications of orders of geodetic network.

[1] Ref. no.1, page 289

Table 4.2 Specifications of orders[1].

NO. OF ORDER	ALLOWABLLE AVERAGE LENGTH OF SIDE	ALLOWABLLE ERROR IN LENGTH		ALLOWABLE ERROR IN ANGLES
		triangulation	**trilateration**	
First-order	20 km	4 ppm	3 ppm	0.7"
Second-order	15 km	10 ppm	5 ppm	2"
Third-order	10 km	20 ppm	10 ppm	4"
Fourth-order	5 km	40 ppm	20 ppm	8"

4.5 Angle and side conditions in triangulation:

The computations for triangulation involve calculation of the lengths of sides in successive triangles, polygons, or quadrilaterals using the initial measured base line and the observed directions or angles. To ensure homogeneous results from these computations, the network must have adequate geometric strength. One important factor that affects geometric strength of a network is the magnitude of the angles observed. Another factor that influences the geometric strength of a configuration is the number of angle and side conditions in the network.

4.5.1 Angle conditions:

The angle-condition equations in a figure express the following:

(1) The sum of the interior angles in a polygon must equal some multiple of 180°.

(2) If one or more directly observed angle αI at a station can be expressed as a function of other angles βj also observed at that station, there is a station equation.

[1] Ref. no. 5

(3) If all angles about a point are observed (i.e., the horizontal is closed), then a center-point equation which states that the sum of these angles is equal to 360° is required. First consider the number of angle conditions in a polygon.

Start with one line a as illustrated in (fig. 4.3a), where there are no angles. Add one line b to yield one angle $\alpha 1$(fig.4.3b), so that there are two lines and one angle.

Next, add a third line c (fig.4.3c) to yield $\alpha 2$, so that there are three lines and two angles. This process continues until line n is added, yielding angle (n-1), so that in general, n lines result in (n-1) angles to produce a determinant figure. Any angles measured in excess of those required for the determinant case are redundant and need a condition equation. For example, in a plane triangle, if three angles are measured, there is one redundancy, for which the angle condition is

$$\alpha 1+\alpha 2+\alpha 3 = 180°$$

It is necessary to be able to evaluate the number of angle conditions in a given figure. Let

C_A = total number of angle conditions (including center-point equations) in a polygon

L = number of lines in the polygon

A = number of angles measured in the polygon

$$C_A = A-(L-1) = A-L+1 \quad (4.2)$$

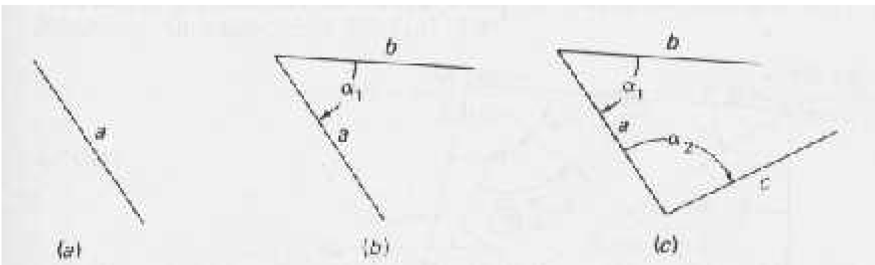

Fig 4.3 Angle conditions in a polygon[1]

[1] Ref. no.3, page 393.

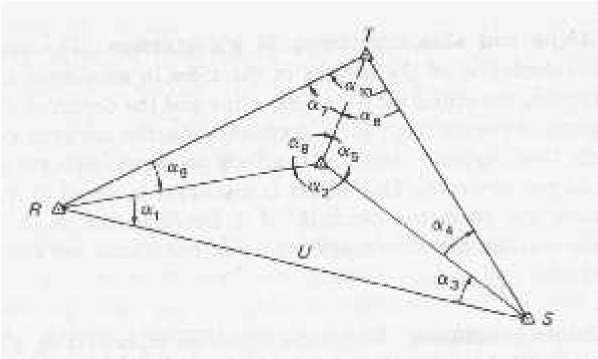

Fig 4.4 Center-point triangle[1]

In which C_A is the total number of angle conditions, including a center-point equation and a station equation. The angle-condition equation equations that can be written for the figure are

$$\alpha 1+\alpha 2+\alpha 3 = 180^\circ \quad \text{(a)}$$

$$\alpha 4+\alpha 5+\alpha 6 = 180^\circ \quad \text{(b)}$$

$$\alpha 7+\alpha 8+\alpha 9 = 180^\circ \quad \text{(c)}$$

$$\alpha 1+\alpha 3+\alpha 4+\alpha 6+\alpha 7+\alpha 9 = 180^\circ \quad \text{(d)}$$

$$\alpha 2+\alpha 5+\alpha 8 = 360^\circ \quad \text{(e)}$$

$$\alpha 6+\alpha 7-\alpha 10 = 0^\circ \quad \text{(f)}$$

In which Eqs. (a), (b), (c), (e), and (f); (b), (c), (d), (e), and (f); or (a), (b), (d), (e), and (f) are permissible sets of independent angle-condition equations for the example.

[1] Ref. no.3, page 394.

4.5.2 Side conditions

The angle conditions in a figure can be satisfied without having consistent lengths in the sides. Equation (4-2) gives the number of angle conditions necessary for adjusting a triangulation figure. The total number conditions will always be larger than C_A except for a simple triangle in which cases C_A will be the total number of conditions. Now, let n be the total number of measured angle and be the minimum number of angle necessary to construct the designated figure. Then the total number of conditions is

$$C = n - n_0 \tag{4.3}$$

Figure 4.5 shoes a braced quadrilateral with n = 8 observed internal angles. It can be seen that a minimum of n_0 = 4 measured angles are necessary for fixing the shape of the figure. Consequently, the total number of a condition equations according to eq. (4.3) is C = 8 – 4 = 4.

If these four conditions are all angle conditions, it will not be possible to guarantee having a consist quadrilateral. For instance, let line CB be rotated a small amount $d\alpha$ about station B. angle α_6 will then become $\alpha_6 - d\alpha$. However, since α_7 become $\alpha_7 + d\alpha$, the angle conditions involving α_7 and α_6 will still check in spite of the fact that CB now has a different length. To avoid inconsistencies of this type, a side condition is required.

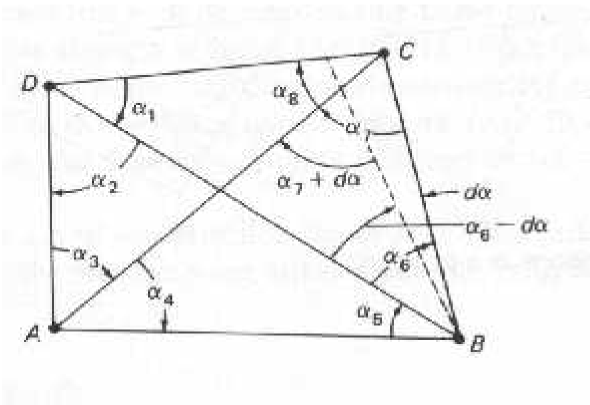

Fig 4.5 Braced quadrilateral[1]

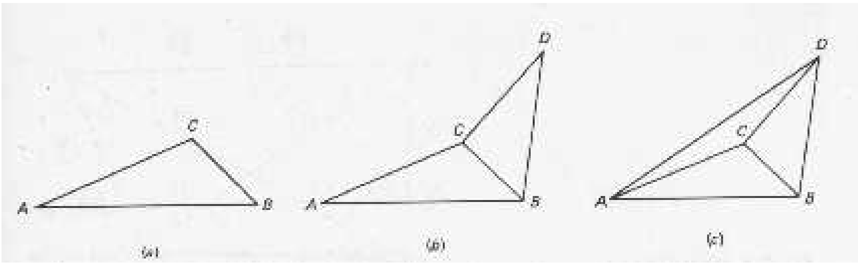

Fig 4.6 Side conditions in triangulation[2]

Side conditions are needed when lengths of a side in a triangle can be computed by more than one route using the law of sines. For example, in fig 4.6a one triangle is formed by three points and three sides. Since there is only one route, no side condition is required. In fig. 4.6b, two lines are added, the intersection of which creates point D. there still only one route for calculating lengths, so no side condition is necessary. Next, add a line passing through point A and D as shown in fig.4.6c. Now there are two routes by which side DA can be calculated using (1) triangles ABC and ACD or (2) triangles BDC and ACD. Thus, line AD is an extra or redundant line. For every one of these extra lines in a triangulation network, a side condition is required. Let

C_s = number of side conditions

[1] Ref. no.3, page 394.
[2] Ref. no.3, page 395.

n′= number of sides in figure

s = number of stations in the figure

Note that three lines are needed to fix the location of the first point C and two lines are required for each additional point such as D. therefore, the number of extra lines or number of side conditions is

$$C_s = n' - 3 - 2(s - 3) = n' - 2s + 3 \qquad (4.4)$$

For the quadrilateral in fig.4.5, the number of angle conditions according to eq. (4.2) is $C_A = 8 - 6 + 1 = 3$, and the number of side conditions according to eq. 4.4 is $C_S = 6 - 2(4) + 3 = 1$. Thus, the total number of conditions is 4, which is the same as obtained from eq. (4.3), or C = 8 – 4 = 4.

4.6 Strength of Figure in Triangulation:

When a triangulation project is being evaluated in the preliminary stages of the work, it is necessary to determine the strength of figure for the network. This step is required in order to ensure uniform accuracy throughout the network. The strength of figure is a function of:

1. The geometric strength of the triangles that make up the network. The triangles should be equilateral.
2. The number of stations occupied for angle or direction measurements. Lines occupied at only one end should be avoided whenever possible.
3. The number of angle and side conditions used in adjusting the network. This number should be large in proportion to the number of observations.

Calculating or finding strength of figure using following equation.

$$R = \frac{D - C}{D} \sum (₵_{Ai}^{2} + ₵_{Ai} ₵_{Bi} + ₵_{Bi}^{2}) \qquad (4.8)$$

Where R = strength of figure

D = total number of directions in the network

C = total number of angle and side conditions

$₵_{Ai}$ = Difference in sixth decimal place of the log sine of the angle (labeled A) Opposite the side to be calculated in the triangle.

$₵_{Bi}$ = Difference in sixth decimal place of the log sine of the angle (labeled B) Opposite the known side in the triangle.

The number of directions D refers to the directions observed with a theodolite. Thus, a line occupied at both ends would have two directions. The starting line in a network is assumed to be known direction, so that the directions observed along this line are not included in figuring the value of D.

The total number of conditions C is

$$C = C_A + C_S = (A - L + 1) + (n' - 2s + 3) \qquad (4.9)$$

Where $C_A and C_s$ are defined in eqs. (4.2) and (4.4).

Angles A and B_i are designated distance angles in triangle i. these angles may be scaled from a preliminary sketch of the triangulation on an existing map or maybe unadjusted field measurements. Values to the nearest degree are adequate. In fig 4.7 angles A_1 , B_1 are the distances angles in triangle RST; angles A_2 , B_2 are distance angles in triangle TSU; etc. note that these angles A_1 opposite the side to be computed and B_1 opposite the known side, correspond to angles A and B to propagate the variance in the calculated side, using the law of sines.

In eq. (4.8), the two factors (D-C)/D and ($\delta^2_{Ai} + \delta_{Ai}\delta_{Bi} + \delta^2_{Bi}$) are related only to the number of conditions and observations and the geometry of the triangles. Thus, the value for R is independent of the precision of the measurements.

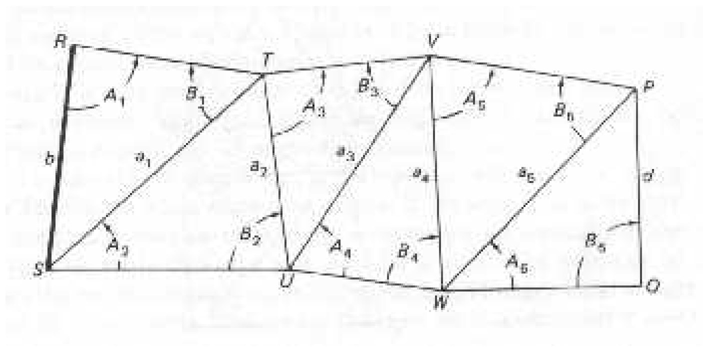

Fig 4.7 Strength of figure, single chain of triangles[1]

4.7 Figural Adjustment by Equal Shifts

Whilst least squares methods permit the adjustment of the network as a whole, the simpler ‘equal shifts’ approach treats each figure in the network separately. The final values for the angles must, however, satisfy the conditions of adjustment of each figure.

(1) Simple triangle. The condition of adjustment of a plane triangle is that the sum of the angles should equal 180˚. It is due to this minimum number of conditions that other figures, such as braced quadrilaterals, are favoured rather than triangles.

For large triangles on an ellipsoid of reference, with sides greater than 10 km. the angles should sum to 180˚ + E. E is the spherical excess of the triangle and may be computed from

[1] Ref. no.3, page 399.

$$E'' = \frac{Area\_Triangle \times 206265}{R} \tag{4.11}$$

where R = local radius of the Earth

After adjusting the angles to equal (180˚ + E), Legendre's theorem stipulates that if one-third of the spherical excess is deducted from each angle, the triangle may be treated as a plane triangle for the computation of its side lengths. Error analysis shows that the computation of the area of the triangle is not critical and may even be scaled from a map. An example is illustrated in Table 4.2

Table 4-3 Spherical correction[1]

Angle	Observed Value ° ′ ″	Correction ″	Ellipsoidal Angles ° ′ ″	E″/3	Plane Angle ° ′ ″
A	52 12 48.15	+1.11	52 12 49.26	-2.29	52 12 46.97
B	76 09 10.27	+1.11	76 09 11.38	-2.29	76 09 09.09
C	51 38 05.12	+1.11	51 38 06.23	-2.29	51 38 03.94
Sum	180 00 13.54	+3.33	180 00 6.87	-6.87	180 00 00.00

(a) The spherical excess was computed as E″ = 6.87″; therefore the observed angles are balanced by + 1.1 1″ per angle so that the sum equals 180˚ + E″= 180˚ 00´06.87″.
(b) The ellipsoidal angles are then reduced to plane by deducting E/3 from each.
(c) The unknown sides of the triangle can now be computed using the sine rule in plane trigonometry.
(d) The azimuths of the sides are obtained from coordinates of two points (first and second points in the first quadrilateral).
(e) The local coordinate system(X, Y) can now be computed using following laws:

[1] Ref. no.1, page 276.

$$X_j = X_i + D_{ij} \sin AZ_{ij}$$
$$Y_j = Y_i + D_{ij} \cos AZ_{ij}$$

and (Z) can be compute using triangles laws.

(2) In a braced quadrilateral (Figure 4.8), the final balanced angles should fulfill the following conditions of adjustment, if the figure is to be geometrically correct.

Conditions of adjustment (Figure 4.8):

Angles $1 + 2 + 3 + 4 + 5 + 6 + 7 + 8 = 360^\circ$

$1 + 2 + 3 + 4 = 180^\circ$

$3 + 4 + 5 + 6 = 180^\circ$

$5 + 6 + 7 + 8 = 180^\circ$

$7 + 8 + 1 + 2 = 180^\circ$

$1 + 2 = 5 + 6$

$3 + 4 = 7 + 8$

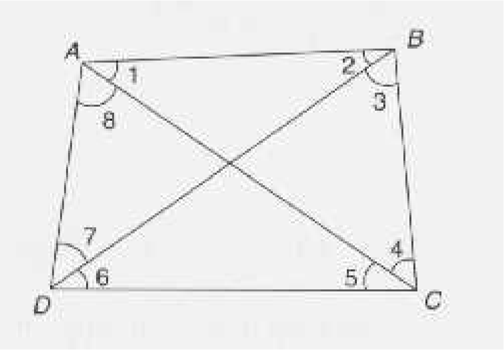

Fig. 4.8 Condition of adjustment[1]

Side condition:

Σlog sins of the odd angles = Σlog sins of the even angles

[1] Ref. no.1, page 276

As many of the above conditions are dependent upon each other, only four are used in the actual adjustment. The 'method of adjustment' is: (a) adjust angles (1-8) to equal 360˚, (b) adjust angles (1 + 2) to equal (5 + 6); (c) adjust angles (3 + 4) to equal (7 + 8); (d) side condition.

Proof of side condition:

From Figure 4.8 it is required to calculate length CD from base AB. This may be done via route BC or AD as follows:

AB/sin 4 = BC/sin 1.   BC = AB sin 1/sin 4

Now BC/sin 6 = DC/sin 3.   DC = BC sin 3/sin 6 = AB sin 1 sin 3/ (sin 4 sin 6)

Similarly via AD   DC = AB sin 2 sin 8/(sin 7 sin 5)

As there can only be one length for DC, then canceling AB gives

sin 1 sin3/ (sin 4 sin 6) = sin 2 sin 8/(sin 7 sin 5)

Cross-multiplying and taking logs:

log sin1 + log sin 3 + log sin 5 + log sin 7 = log sin 2 + log sin 4 + log sin 6 + log sin 8

This method of adjustment will now be illustrated using the following mean observed angles in Figure 4.8:

(a) The first step in the method of adjustment is clearly seen.

(b) The second step shows that the difference between angles (1 + 2) and (5 + 6) is 4″, i.e. 1″ per angle, which is added to the smaller sum and subtracted from the larger.

(c) The third step is identical to the above: the corrections of 2″ and 1″ have been arbitrarily made to prevent the introduction of decimals of a second (correction per angle = 1.5″).

Three steps have produced corrected angles which satisfy the first seven conditions of adjustment. It is now necessary to find the log sin of these angles and to compare their sums. This can be done very quickly on a pocket calculator. (Table 4.4)

Adjustment = (15/217) x 10″ = 0.7″ ≈ 1″

(d) Column 5 represents the change in the log sin of the angles for a change of 10″ in the angle. These values are easily obtained by increasing the value of the angle by 10″ and then finding its log sin on the pocket calculator. The difference of the two log sin values is the difference for 10″ change in the angle.

Normally the difference for 1″ of arc is used, but in this case 10″ differences are used in order to. Facilitate understanding of the principles.

(e) Summing columns 3 and 4 shows a difference of 15 (0.000 015) which must be adjusted. The necessary angular correction (0.7″) is obtained by dividing 15 by the sum of columns 5, i.e. 217 (0.000 217), as shown. This may be explained as follows: if one altered all the angles by 10″, the total change in the log sins would be 0.000 217. However, the change required is only 0.000 015, which by proportion represents an angular change of 15/2 17 x 10″ = 0.7″.

(g) If any angle is greater than 90˚, then a positive correction to the angle would require a negative correction to its log sin. Thus the difference value in column 5 should have a negative sign which is applied in the summing of this column and throughout.

(h) It is worth noting that the accuracy of a triangulation figure is expressed by the magnitude of the difference in the sum of log sins, i.e. 0.000 015. Compensating errors can occur in angles, tending to indicate excellent closure; such errors would, however, substantially unbalance the side equation.

Table 4.4 Example[1]

No	Observed angle				1st correction							2nd correction		
	°	′	″	″	°	′	″	°	′	″	″	°	′	″
1	50	42	27	-1	50	42	26	117	30	19	1	50	42	27
2	66	47	54	-1	66	47	532				1	66	47	54
3	41	24	32	-1	41	24	31	62	29	36	2	41	24	33
4	21	05	06	-1	21	05	05				1	21	05	06
5	74	13	36	-1	74	13	35	117	30	23	-1	74	13	34
6	43	16	49	-1	43	16	48				-1	43	16	47
7	18	36	14	-1	18	36	13	62	29	42	-1	18	36	12
8	43	53	30	-1	43	53	29				-2	43	53	27
	360	00	08	-8	360	00	00				0	360	00	00

[1] Ref. no.1, page 277

Table 4.5 Example[1]

1	2 Angle °	′	″	3 Log sin (odd)	4 Log sin (even)	5 Difference for 10″ arc	6 ″	7 Final Values °	′	″
1	50	42	27	1.888 698		0.000 017	1	50	42	28
2	66	47	54		1.963 374	9	-1	66	47	53
3	41	24	33	1.820 485		24	1	41	24	34
4	21	05	06		1.556 004	55	-1	21	05	05
5	74	13	34	1.983 329		6	1	74	13	35
6	43	16	47		1.836 046	22	-1	43	16	46
7	18	36	12	1.503 810		62	1	18	36	13
8	43	53	27		1.840 913	22	-1	43	53	26
				1.196 322	1.196 337 1.196 322 0.000 015	0.000 217		360	00	00

Although the above method can be done easily on a pocket calculator, the following approach (Smith, 1982) has been produced specifically for a pocket calculator.

The method precludes the use of logarithms and differences for 1” or 10”, and is as follows: in the side condition assume V is the correction per angle; then

sin (1+ v) sin (3+ v) sin (5+ v) sin (7+ v) = sin (2+ v) sin (4+ v) sin (6 + v) sin (8 + v)

Now sin (1 + v) = sin 1 cos v + cos1 sin v, which, as v is very small, = sin 1 + cos 1v

$$\frac{(\sin 1 + \cos 1v)\ (\sin 3 + \cos 3v)\ (\sin 5 + \cos 5v)\ (\sin 7 + \cos 7v)}{(\sin 2 + \cos 2v)\ (\sin 4 + \cos 4v)\ (\sin 6 + \cos 6v)\ (\sin 8 + \cos 8v)} = 1$$

[1] Ref. no.1, page 278

Expanding to the first order only:

$$\frac{(\sin 1 \sin 3 + \sin 1 \cos 3v + \cos 1 \sin 3v)\ (\sin 5 \sin 7 + \sin 5 \cos 7v + \cos 5 \sin 7v)}{(\sin 2 \sin 4 + \sin 2 \cos 4v + \cos 2 \sin 4v)\ (\sin 6 \sin 8 + \sin 6 \cos 8v + \cos 6 \sin 8v)}$$

$$= \frac{\sin 1 \sin 3 \sin 5 \sin 7 + \sin 1 \sin 3 \sin 5 \sin 7v\ (\cot 1 + \cot 3 + \cot 5 + \cot 7)}{\sin 2 \sin 4 \sin 6 \sin 8 + \sin 2 \sin 4 \sin 6 \sin 8v\ (\cot 2 + \cot 4 + \cot 6 + \cot 8)}$$

Let $\sin l\ \sin 3 \sin 5 \sin 7 = A$ $\qquad \cot l\ \cot 3 \cot 5 \cot 7 = B$

$\sin 2 \sin 4 \sin 6 \sin 8 = C$ $\qquad \cot 2 \cot 4 \cot 6 \cot 8 = D$

Then the above expression can be rearranged and expressed thus:

$$v'' = \frac{206265(A - C)}{AB + CD}$$

If v″ is positive then A > C and v″ is subtracted from the odd angles and added to the even.

All the digits as displayed on the pocket calculator are significant and should be carried through the computation.

The previous example is now re-worked using this method for the side condition, and it is shown in Table 4.5.

CHAPTER FIVE

MEASUREMENTS AND CALCULATIONS

5.1 INTRODUCTIONS

In this chapter we will show the measurements or data which we get it in field surveying. It includes horizontal and vertical angles, and two horizontal distance called (base and check line). By base line and vertical angles and horizontals angles which are corrected by equal shifts methods, we determine the horizontal and slope distances for all quadrilaterals in our geodesy network using sine rule.

Then, we calculate strength of figure for first quadrilateral after correction of all horizontal angles in our network using equal shift method, but other quadrilaterals we can be determine the strength of figure for it by program which we built.

Finally, we calculate local coordinate for all points using horizontals distances and azimuth which is calculated from full control points (A) and (B).

5.2 CONDITION OF WORKING

The table 5.1 shows days and date of working and the weather and temperature and other things:

Table 5.1 Work Conditions

Day & Date	**Weather**	**Temp.**	**Period of Obs.**	**Name of Observer**	**Reflector Holding**
Thursday 25\3\2004	Cloudy	16°	8:00-04:00	Mohammad Abdelaziz	Ibrahim Abu-Iram Mohammad Ghanim
Wednesday 31\3\2004	Cloudy	15°	8:00-04:00	Ibrahim Abu-Iram	Mohammad Ghanim Mohammad Abdelaziz
Thursday 01\4\2004	Sunny	23°	8:00-04:00	Mohammad Ghanim	Mohammad Abdelaziz Ibrahim Abu-Iram
Monday 5\4\2004	Sunny	27°	8:00-04:00	Mohammad Abdelaziz	Mohammad Ghanim Ibrahim Abu-Iram
Thursday 22\4\2004	Sunny	26°	8:00-04:00	Ibrahim Abu-Iram	Mohammad Abdelaziz Mohammad Ghanim
Monday 26\4\2004	Sunny	28°	8:00-04:00	Mohammad Ghanim	Mohammad Abdelaziz Ibrahim Abu-Iram

5.3 DATA AND CALCULATIONS.

5.3.1 Data for the First Quadrilateral (A, B, C, D).

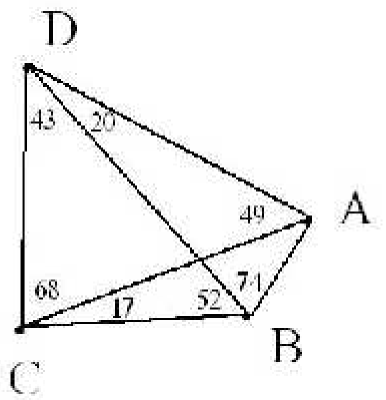

Figure 5.1 Quadrilateral (A,B,C,D)

Table 5.2 The mean of reading for first Quadrilateral [1]

Station	Point	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	A	19 46 05.7	91 53 02
	B		91 54 39
D	C	42 52 34.5	93 49 49
	B		91 54 39
A	C	49 25 12.4	91 19 58
	D		88 06 54
A	B	36 32 45.6	90 10 39
	C		91 19 58
B	C	51 59 36.1	91 40 50
	D		88 05 21
B	D	74 15 54	88 05 21
	A		89 49 22
C	A	67 55 57.2	88 40 02
	D		86 10 11
C	A	17 11 43.2	88 40 02
	B		88 19 10

5.3.2 Calculations for Quadrilateral (A, B, C, D):

• **First step,** we calculate mean and standard deviation for horizontal angle and mean for vertical angles and mean for base line in quadrilateral using following law:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

*The mean of horizontal angle (A D B) = $\frac{57''}{10}$ = 19 46' 05.7" .... # 1

The mean of horizontal angle (C D B) = 42 52' 34.5" .... # 8

The mean of horizontal angle (C A D) = 49 25' 12.4" .... # 2

The mean of horizontal angle (B A C) = 36 32' 45.6" .... # 3

The mean of horizontal angle (C B D) = 51 59' 36.1" .... # 5

[1] See appendix C1

The mean of horizontal angle (D B A) = 74 15' 54" .... # 4

The mean of horizontal angle (A C D) = 67 55' 57.2" .... # 7

The mean of horizontal angle (A C B) = 17 11' 43.2" .... # 6

*The mean of vertical angle (DC) = $\frac{280''}{10} = 93°49'49''$

The mean of vertical angle (DB) = 91°54'39"

The mean of vertical angle (DA) = 91°53'02"

The mean of vertical angle (AD) = 88°06'54"

The mean of vertical angle (AB) = 90°10'39"

The mean of vertical angle (AC) = 91°19'58"

The mean of vertical angle (BA) = 89°49'22"

The mean of vertical angle (BD) = 88°05'21"

The mean of vertical angle (BC) = 91°40'50"

The mean of vertical angle (CD) = 86°10'11"

The mean of vertical angle (CA) = 88°40'02"

The mean of vertical angle (CB) = 88°19'10"

*The mean of horizontal distance AB (base line) $= \frac{4172.178}{10} = 417.2178m$

*The mean of slope distance AB= $\frac{4172.198}{10} = 417.2198$ m

*Then we determine the standard deviation for horizontal angles at 99.7% level confidence using the following law:

$$S_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(\overline{X} - X_I\right)^2}{n-1}}$$

Standard deviation of angle (A D B) $= \pm\sqrt{\frac{22.9}{9}} = \pm 1.6''$, $E_{99.7}$=2.756*1.6= ±4. 4”

Standard deviation of angle (B D C) $= \pm\sqrt{\frac{20.5}{9}} = \pm 1.5''$, $E_{99.7}$=2.756*1.5= ±4.13”

Standard deviation of angle (D A C) $= \pm\sqrt{\frac{10.4}{9}} = \pm 1''$, E99.7=2.756*1= ±2.756”

Standard deviation of angle (B AC) $= \pm\sqrt{\frac{22}{9}} = \pm 1.56''$, E99.7=2.756*1.56= ±4.3”

Standard deviation of angle (C B D) $= \pm\sqrt{\frac{25.3}{9}}\ \pm 1.67''$, E99.7=2.756*1.67= ±4.6”

Standard deviation of angle (D B A) $= \pm\sqrt{\frac{24}{9}}\ \pm 1.63''$, E99.7=2.756*1.63= ±4.5”

Standard deviation of angle (A C D) $= \pm\sqrt{\frac{21.6}{9}}\ \pm 1.55''$, E99.7=2.756*1.55= ±4.3”

Standard deviation of angle (A C B) $= \pm\sqrt{\frac{28.8}{9}}\ \pm 1.79''$, E99.7=2.756*1.79= ±4.9”

*No blunders in all readings for any angle.

•**Second step,** we correct all horizontal angles using equal shift method.

No	Observed angle				1st correction							2nd correction		
	°	′	″	″	°	′	″	°	′	″	″	°	′	″
1	19	46	5.7	+1.41	19	46	7.11	69	11	20.92	+0.3	19	46	7.41
2	49	25	12.4	+1.41	49	25	13.81				+0.31	49	25	14.12
3	36	32	45.6	+1.41	36	32	47.01	110	48	42.4	-1.95	36	32	45.06
4	74	15	54	+1.41	74	15	55.41				-2	74	15	53.41
5	51	59	36.1	+1.41	51	59	37.51	69	11	22.13	-0.31	51	59	37.2
6	17	11	43.2	+1.41	17	11	44.62				-0.3	17	11	44.32
7	67	55	57.2	+1.41	67	55	58.61	110	48	34.5	+2	67	56	0.61
8	42	52	34.5	+1.41	42	52	35.91				+1.95	42	52	37.86
	359	59	48.7	+11.3	360	00	00				0	360	00	00

1	**2** **Angle** °	 ′	 ″	**3** **Log sin** **(odd)**	**4** **Log sin** **(even)**	**5** **Difference** **for 10″ arc**	**6** ****** ″	**7** **Final Values** °	 ′	 ″
1	19	46	7.41	1.529 205		0.000 058	-1.67	19	46	6.75
2	49	25	14.12		1.880 531	18	1.67	49	25	14.79
3	36	32	45.06	1.774 857		28	-1.67	36	32	43.39
4	74	15	53.41		1.983 412	6	1.67	74	15	55.08
5	51	59	37.2	1.896 495		16	-1.67	51	59	35.53
6	17	11	44.32		1.470 757	66	1.67	17	11	45.99
7	67	56	0.61	1.966 962		1	-1.67	67	55	58.94
8	42	52	37.86		1.832 783	23	1.67	42	52	39.53
				1.167 519	1.167483 1.167519 -0.000 036	0.000 216		360	00	00

**Angular Change = $\dfrac{-0.000036\times 10}{0.000216} = -1.67''$

• **Third step,** we calculate all distances in this quadrilateral using sine rule.

The distance which is known in (A, B, C, D) quadrilateral is AB distance or (base line) = 417.2178m.

Horizontal $AD = \dfrac{417.2178\times\sin(74°15'55.08'')}{\sin(19°46'6.75'')}$ = 1187.340 m

Slope $AD = \dfrac{1187.340}{\cos(1°53'33'')}$ =1187.988m

Horizontal $AC = \dfrac{417.2178\times\sin(126°15'30'')}{\sin(17°11'45.99'')}$ = 1137.948 m

$$\text{Slope } AC = \frac{1137.948}{\cos(1°19'58'')} = 1138.256 \text{ m}$$

$$\text{Horizontal } DB = \frac{417.2178 \times \sin(85°57'58.2'')}{\sin(19°46'6.75'')} = 1230.509 \text{ m}$$

$$\text{Slope } DB = \frac{1230.509}{\cos(1°54'39'')} = 1231.194 \text{ m}$$

$$\text{Horizontal } CB = \frac{417.2178 \times \sin(36°32'43.39'')}{\sin(17°11'45.99'')} = 840.325 \text{ m}$$

$$\text{Slope } CB = \frac{840.325}{\cos(1°40'50'')} = 840.687 \text{ m}$$

$$\text{Horizontal } DC = \frac{1187.340 \times \sin(49°25'14.79'')}{\sin(67°55'58.94'')} = 973.076 \text{ m}$$

$$\text{Slope } DC = \frac{973.076}{\cos(3°49'49'')} = 975.254 \text{ m}$$

•**Fourth step,** we calculate the heights of point (C, D) using the following law.

Height of point = height of any point +instruments height+ D*tanθ-prism height.

* Instruments height=1.66 m.

***** Prism height= 1.10 m**.**

*****D= Horizontal Distance, θ = vertical angle.

* Height of point B=916.42 m

* Height of point A=918.24 m

*height of point C = 918.24+1.66-1137.948*tan1°19′58"-1.10 =892.325 m.

*height of point D =918.24+1.66+1187.340 *tan1°53′33"-1.10= 958.033 m.

*for check.

*height of point C = 916.42+1.66-840.325*tan1°40′50"-1.10 =892.325 m.

*height of point D =916.42+1.66+1230.509 *tan1°54′39"-1.10= 958.033 m.

•**Fifth step**, we reduced the distances in this quadrilateral to mean sea level using following law:

$$b = d\frac{R}{R+h}$$

*Where, b: is the mean sea-level distance.

d: is distance measured at any elevation.

h: elevation above mean sea level.

R: average radius of the earth**.**

* Average Height for Distance AB = $\frac{918.24 + 916.42}{2} = 917.33m$

*****Distance AB at mean sea level = $\frac{417.2178 \times 6378137}{6378137 + 917.33} = 417.158m$

***** Average Height for Distance AD = $\frac{918.24 + 958.033}{2} = 938.137m$

***** Distance AD at mean sea level = $\frac{1187.340 \times 6378137}{6378137 + 938.137} = 1187.165m$

***** Average Height for Distance AC = $\frac{918.24 + 892.325}{2} = 905.283m$

***** Distance AC at mean sea level **=** $\frac{1137.948 \times 6378137}{6378137 + 905.283} = 1137.787m$

***** Average Height for Distance DB = $\frac{916.42 + 958.033}{2} = 937.227m$

***** Distance BC at mean sea level**=** $\frac{840.325 \times 6378137}{6378137 + 937.227} = 840.202m$

***** Average Height for Distance DC= $\frac{958.033 + 892.325}{2} = 925.179m$

***** Distance DC at mean sea level= $\frac{973.076 \times 6378137}{6378137 + 925.179} = 972.935m$

***** Average Height for Distance DB= $\frac{916.42 + 958.033}{2} = 937.227m$

***** Distance DB at mean sea level= $\frac{1230.209 \times 6378137}{6378137 + 937.227} = 1230.028m$

•**Sixth step,** we determine grid distance for all distances in the quadrilateral, to use it in coordinates calculations by following law:

$G = S \times F$

Where: G = grid distance.

S = Ellipsoidal Distance at MSL (mean sea level).

F = Scale Factor is Used in Palestine =1.000067.

*****Grid distance AB= $417.158 \times 1.000067 = 417.186m$

*****Grid distance AC= $1137.787 \times 1.000067 = 1137.863m$

*****Grid distance AD= $1187.165 \times 1.000067 = 1187.245m$

*****Grid distance DB= $1230.028 \times 1.000067 = 1230.110m$

*****Grid distance DC= $972.935 \times 1.000067 = 973m$

*****Grid distance CB= $840.202 \times 1.000067 = 840.258m$

• **Seventh step,** we determine the strength of figure for the quadrilateral using the following law:

$$R''' = \frac{D - C}{D} \sum (\delta^2_{Ai} + \delta_{Ai} \delta_{Bi} + \delta^2_{Bi}) .$$

*the values of (R) are taken from special table in appendix (B).

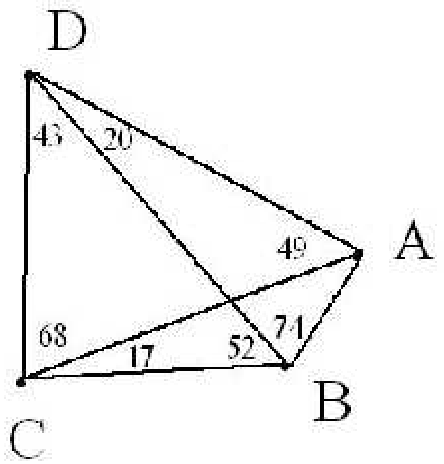

Figure 5.2 first Quadrilateral (A,B,C,D)

* the route is chosen are triangles (BAD), (ADC).

*(D) =10, (C) = 4.

* $\frac{D-C}{D} = \frac{10-4}{10} = 0.6$

*the first route is triangle (ABD), known side is AB and the side to be calculated is AD.

$A = 74°$
$B = 20°$

$A = 74° \rightarrow 70° \Rightarrow R = 38$
$A = 74° \rightarrow 75° \Rightarrow R = 37$

$$75° - 70° \to 37 - 38$$
$$74° - 70° \to R' - 38$$

$$5° \to -1$$
$$4° \to R' - 38$$

$$5(R' - 38) = -4 \Rightarrow R' = 37.2$$

* the second route is triangle (ADC), known side is AD and the side to be calculated is CD.

$$A = 49°$$
$$B = 68°$$

$$B = 65° \to A = 45° \Rightarrow R = 7$$
$$B = 65° \to A = 50° \Rightarrow R = 6$$

$$50° - 45° \to 6 - 7$$
$$49° - 45° \to R' - 7$$

$$5° \to -1$$
$$4° \to (R' - 7)$$

$$5(R' - 7) = -4 \Rightarrow R' = 6.2$$

$$B = 70° \to A = 45° \Rightarrow R = 7$$
$$B = 70° \to A = 50° \Rightarrow R = 5$$

$$50° - 45° \to 5 - 7$$
$$49° - 45° \to (R' - 7)$$

$$5° \to -2$$
$$4 \to (R' - 7) \Rightarrow R' = 5.4$$

$A = 49° \rightarrow B = 65° \Rightarrow R' = 6.2$

$A = 49° \rightarrow B = 70° \Rightarrow R' = 5.2$

$70° - 65° \rightarrow 5.4 - 6.2$

$68° - 65° \rightarrow (R'' - 6.2)$

$5 \rightarrow -0.8$

$3 \rightarrow (R'' - 6.2)$

$5(R'' - 6.2) = -2.4 \Rightarrow R'' = 5.72$

$R''' = 0.6 \times (5.72 + 37.2) = 25.75$

*The strength of figure (A, B, C, D) or $R''' = \frac{10-4}{10} \times (5.72 + 37.2) = 25.75$

* This quadrilateral is strong because the value of (R) is small.

• **Calculations Coordinates for Points (C, D).**

POINTS	Y-COORDINATE	X-COORDINATE
Building (A)	158826.720	101832.460
Building (B)	158567.950	101505.170

$$AZ_{AB} = \tan^{-1}\frac{Y_B - Y_A}{X_B - X_A} = \tan^{-1}\frac{158567.95 - 158826.72}{101505.17 - 101832.46} = \tan^{-1}\frac{-258.77}{-327.29}$$

$$AZ_{AB} = 38°19'53.26'' + 180° = 218°19'53.26''$$

$$AZ_{BA} = 218°19'53.26'' - 180° = 38°19'53.26''$$

$$AZ_{BD} = AZ_{BA} - \angle(D\hat{B}A) = 38°19'53.26'' - 74°15'55.08'' = 324°03'58.18''$$

$$AZ_{BC} = AZ_{BA} - \angle(D\hat{B}A) - \angle(C\hat{B}D) = 324°03'58.18'' - 51°59'35.53'' = 272°04'22.65''$$

$$Y_C = Y_B + D_{CB} \times \sin AZ_{BC}$$
$$= 158567.95 + 840.258 \times \sin 272°04'22.65'' = 157728.242$$

$$X_C = X_B + D_{CB} \times \cos AZ_{BC}$$
$$= 101505.17 + 840.258 \times \cos 272°04'22.65'' = 101535.564$$

$$Y_D = Y_B + D_{BD} \times \sin AZ_{BD}$$
$$= 158567.95 + 1230.110 \times \sin 324°03'58.18'' = 157846.059$$

$$X_D = X_B + D_{DB} \times \cos AZ_{BD}$$
$$= 101505.17 + 1230.110 \times \cos 324°03'58.18'' = 102501.184$$

5.3.3 Data for the Second Quadrilateral (C, D, E, F)

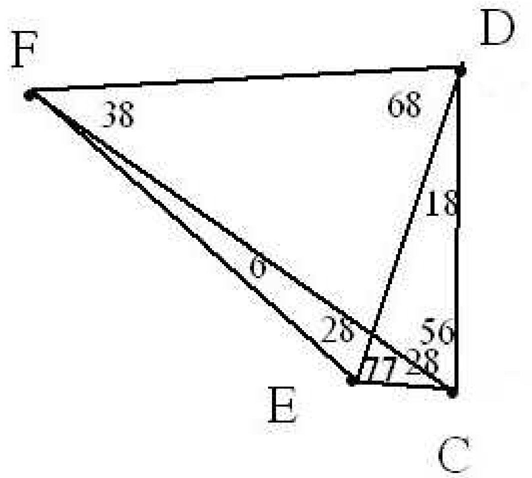

Figure 5.3 Quadrilateral (C,D,E,F)

Table 5.3 The mean of reading for second Quadrilateral [1]

Station	Point	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	C	18 01 16.2	93 49 49
	E		93 31 31
D	E	67 32 17	93 31 31
	F		92 37 05
C	D	56 20 12	86 10 11
	F		89 47 35
C	F	28 27 44	89 47 35
	E		98 10 07
E	C	77 10 22.6	90 49 53
	D		86 28 29
E	D	67 55 9.6	86 28 29
	F		89 58 19
F	E	06 26 41.4	90 01 41
	C		90 12 25
F	C	38 06 12	90 12 25
	D		87 22 55

5.3.4 Calculations for Quadrilateral (C, D, E, F)

*We calculate mean and standard deviation for horizontal angle and mean for vertical angles in quadrilateral using following law:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

*The mean of horizontal angle (C D E) = $\frac{504''}{10}$ = 18° 01' 16.2"--------#1

The mean of horizontal angle (E D F) = 67° 32' 17" ---------------------#8

The mean of horizontal angle (DC F) = 56° 20' 12"----------------------#2

[1] See appendix C2

The mean of horizontal angle (F C E) = 28° 27' 44"------------- --------#3

The mean of horizontal angle (J E D) = 77° 10' 22.6"-------------------#4

The mean of horizontal angle (D E F) = 67° 55' 9.6" -------------------#5

The mean of horizontal angle (E F C) = 06° 26' 41.4"-------------------#6

The mean of horizontal angle (C F D) = 38° 06' 12"---------------------#7

*The mean of vertical angle (DC) = $\frac{490''}{10} = 93°49'49''$

The mean of vertical angle (DE) = 93°31'31"

The mean of vertical angle (DF) = 92°37'05"

The mean of vertical angle (EF) = 89°58'19"

The mean of vertical angle (ED) = 86°28'29"

The mean of vertical angle (EC) = 90°49'53"

The mean of vertical angle (FE) = 90°01'41"

The mean of vertical angle (FC) = 90°12'25"

The mean of vertical angle (FD) = 87°22'55"

The mean of vertical angle (CE) = 89°10'07"

The mean of vertical angle (CF) = 89°47'35"

The mean of vertical angle (CD) = 86°10'11"

- **Determination the standard deviation for horizontal angles at 99.7% level confidence using the following law:**

$$S_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(\overline{X} - X_I\right)^2}{n-1}}$$

Standard deviation of angle (C D E) $= \pm\sqrt{\frac{48.4}{9}} = \pm 2.32''$, $E_{99.7}$=2.756*2.32= ±6.39”

Standard deviation of angle (E D F) $= \pm\sqrt{\frac{42}{9}} = \pm 2.16''$, $E_{99.7}$=2.756*2.16= ±5.95”

Standard deviation of angle (DCF) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.49”

Standard deviation of angle (FCE) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.49”

Standard deviation of angle (C E D) $= \pm\sqrt{\frac{24.4}{9}} \pm 1.65$, $E_{99.7}$=2.756*1.65= ±4.55”

Standard deviation of angle (D E F) $= \pm\sqrt{\frac{22.4}{9}} \pm 1.58''$, $E_{99.7}$=2.756*1.58= ±4.35”

Standard deviation of angle (E F C) $= \pm\sqrt{\frac{24.4}{9}} \pm 1.65''$, $E_{99.7}$=2.756*1.65= ±4.55”

Standard deviation of angle (C F D) $= \pm\sqrt{\frac{24}{9}} \pm 1.63$, $E_{99.7}$=2.756*1.63= ±4.49”

*No blunders in all readings for any angle.

•Correction all horizontal angles using equal shift method.

No	Observed angle				1st correction							2nd correction		
	°	′	″	″	°	′	″	°	′	″	″	°	′	″
1	18	01	16.2	+0.65	18	01	16.85	74	21	29.5	+5.7	18	01	22.55
2	56	20	12	+0.65	56	20	12.65				+5.7	56	20	18.35
3	28	27	44	+0.65	28	27	44.65	105	38	7.9	+5.6	28	27	50.25
4	77	10	22.6	+0.65	77	10	23.25				+5.6	77	10	28.85
5	67	55	9.6	+0.65	67	55	10.25	74	21	52.3	-5.7	67	55	4.55
6	06	26	41.4	+0.65	06	26	42.05				-5.7	06	26	36.35
7	38	06	12	+0.65	38	06	12.65	105	38	30.3	-5.6	38	06	7.05
8	67	32	17	+0.65	67	32	17.65				-5.6	67	32	12.05
	359	59	54.8	5.2	360	00	00				0	360	00	00

1	2 Angle			3 Log sin (odd)	4 Log sin (even)	5 Difference for 10″ arc	6 **	7 Final Values		
	°	′	″				″	°	′	″
1	18	01	22.55	1.490517		0.0000646	-7.8	18	01	14.75
2	56	20	18.35		1.920294	0.0000135	+7.8	56	20	26.15
3	28	27	50.25	1.678159		0.0000392	-7.8	28	27	42.45
4	77	10	28.85		1.989027	0.0000053	+7.8	77	10	36.65
5	67	55	4.55	1.966914		0.0000085	-7.8	67	54	56.75
6	06	26	36.35		1.050079	0.0001861	+7.8	06	26	44.15
7	38	06	7.05	1.790329		0.0000272	-7.8	38	05	59.25
8	67	32	12.05		1.965730	0.0000091	+7.8	67	32	19.85
	360	00	00	0.925919	0.925130 0.9249340 -0.000789	0.001011		360	00	00

**Angular Change = $\frac{-0.000789\times 10}{0.001011} = 7.8''$

•Calculation the length of sides in quadrilateral (C, D, E, F).

Horizontal $CE = \frac{973.076\times\sin(18°01'14.75'')}{\sin(77°10'36.65'')}$ = 308.732 m

Slope $CE = \frac{308.732}{\cos(49'53'')}$ =308.764m

Horizontal $DE = \frac{973.076\times\sin(84°48'8.6'')}{\sin(77°10'36.65'')}$ = 993.862 m

Slope $DE = \frac{993.862}{\cos(3°31'31'')}$ = 995.746 m

Horizontal $DF = \frac{973.076\times\sin(56°20'26.15'')}{\sin(38°05'59.25'')}$ = 1312.631 m

Slope $DF = \frac{1312.631}{\cos(2°37'05'')}$ = 1314.003 m

Horizontal $CF = \frac{973.076\times\sin(85°33'34.6'')}{\sin(38°05'59.25'')}$ = 1572.290 m

Slope $CF = \frac{1572.290}{\cos(12'25'')}$ = 1572.300 m

Horizontal $EF = \frac{1312.631\times\sin(67°32'19.85'')}{\sin(67°54'56.75'')}$ = 1309.099 m

Slope $EF = \frac{1309.099}{\cos(01'41'')}$ = 1309.099 m

• Calculations Heights of Points (E, F).

*Height of Point E= 892.325+1.66+308.732*tan 0°49′53"-1.1=897.365m

*Height of Point F= 892.325+1.66+1572.290*tan 0°12′25"-1.1=898.564m

*For Check

* Height of Point E=958.033+1.66-993.862*tan 3°31′31"-1.1= 897.366m

* Height of Point F=958.033+1.66-1312.631*tan 2°37′05"-1.1=898.572m

*Average Height of Point E= $\frac{897.365+897.366}{2}=897.366m$

*Average Height of Point F= $\frac{898.564+898.572}{2}=898.568m$

•Reduction Distances in Quadrilateral (C, D, E, F) to Mean Sea Level.

* Average Height for Distance CF = $\frac{892.325+898.568}{2}=895.447m$

***Distance CF at mean sea level= $\frac{1572.290\times6378137}{6378137+895.447}=1572.069m$

* Average Height for Distance CE= $\frac{897.366+892.325}{2}=894.846m$

* Distance CE at mean sea level= $\frac{308.732\times6378137}{6378137+894.846}=308.689m$

* Average Height for Distance EF= $\frac{898.568+897.366}{2}=897.967m$

* Distance EF at mean sea level= $\frac{1309.099\times6378137}{6378137+897.967}=1308.915m$

* Average Height for Distance ED= $\frac{897.366+958.033}{2}=927.6995m$

* Distance ED at mean sea level= $\frac{993.862\times6378137}{6378137+927.6995}=993.717m$

* Average Height for Distance FD= $\frac{958.033+898.568}{2}=928.301m$

* Distance FD at mean sea level= $\frac{1312.631\times6378137}{6378137+928.301}=1312.440m$

• Determination the Grid Distance.

***Grid distance CE=** $308.689 \times 1.000067 = 308.710m$

***Grid distance CF=** $1572.069 \times 1.000067 = 1572.174m$

***Grid distance FE=** $1308.915 \times 1.000067 = 1309.003m$

***Grid distance FD=** $1312.440 \times 1.000067 = 1312.528m$

***Grid distance DE=** $993.717 \times 1.000067 = 993.784m$

• Determination the strength of figure.

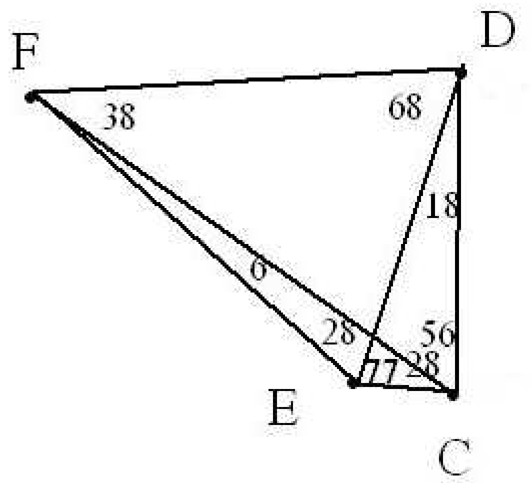

Figure 5.4 Second Quadrilateral (C,D,E,F)

*the route is chosen are triangles (ECD), (EFD).

*(D) =10, (C) = 4.

* $\frac{D-C}{D} = \frac{10-4}{10} = 0.6$

*The first route is triangle (ECD), known side is CD and the side to be calculated is ED.

$A = 56° + 28° = 84°$

$B = 77°$

$B = 75° \rightarrow A = 80° \Rightarrow R = 1$

$B = 75° \rightarrow A = 85° \Rightarrow R = 0$

$85° - 80° \rightarrow 0 - 1$

$84° - 80° \rightarrow (R' - 1)$

$5 \rightarrow -1$

$4 \rightarrow (R' - 1) \Rightarrow 5(R' - 1) = -4 \Rightarrow R' = 0.2$

$B = 80° \rightarrow A = 80° \Rightarrow R = 0$

$B = 80° \rightarrow A = 85° \Rightarrow R = 0$

$85° - 80° \rightarrow 0 - 0$

$84° - 80° \rightarrow (R' - 0) \Rightarrow R' = 0$

$A = 84° \rightarrow B = 75° \Rightarrow R' = 0.2$

$A = 84° \rightarrow B = 80° \Rightarrow R' = 0$

$80° - 75° \rightarrow 0 - 0.2$

$77° - 75° \rightarrow (R'' - 0.2)$

$5 \rightarrow -0.2$

$2 \rightarrow (R'' - 0.2) \Rightarrow R'' = 0.12$

*The second route is triangle (EFD), known side is ED and the side to be calculated is FD.

$A = 68°$
$B = 44°$

$B = 40° \rightarrow A = 65° \Rightarrow R = 10$
$B = 40° \rightarrow A = 70° \Rightarrow R = 9$

$70° - 65° \rightarrow 9 - 10$
$68° - 65° \rightarrow (R' - 9)$

$5 \rightarrow -1$
$3 \rightarrow (R' - 9) \Rightarrow R' = 8.4$

$B = 45° \rightarrow A = 65° \Rightarrow R = 7$
$B = 45° \rightarrow A = 70° \Rightarrow R = 7$

$70° - 65° \rightarrow 7 - 7$
$68° - 65° \rightarrow (R' - 7)$

$5 \rightarrow 0$
$3 \rightarrow (R' - 7) \Rightarrow R' = 7$

$A = 68° \rightarrow B = 40° \Rightarrow R' = 8.4$
$A = 68° \rightarrow B = 45° \Rightarrow R' = 7$

$45° - 40° \rightarrow 7 - 8.4$
$44° - 40° \rightarrow (R'' - 8.4)$

$5 \rightarrow -1.4$
$4 \rightarrow (R'' - 8.4) \Rightarrow R'' = 7.28$

*The strength of figure (C, D, E, F) or $R''' = \frac{10-4}{10} \times (0.12 + 7.28) = 4.44$

* This quadrilateral is very strong because the value of (R) is very small.

• **Calculations Coordinates for Points (E, F).**

$$AZ_{CD} = \tan^{-1}\frac{Y_D - Y_C}{X_D - X_C} = \tan^{-1}\frac{157846.059 - 157728.242}{102501.184 - 101535.564} = \tan^{-1}\frac{117.817}{965.62}$$

$$AZ_{CD} = 06°57'22.95''$$

$$AZ_{CF} = AZ_{CD} - \angle(D\hat{C}F) = 06°57'22.95'' - 56°20'26.15'' = 310°36'56.8''$$

$$AZ_{CE} = AZ_{CD} - \angle(D\hat{C}F) - \angle(F\hat{C}E) = 310°36'56.8'' - 28°27'42.45'' = 282°09'14.35''$$

$$Y_F = Y_C + D_{CF} \times \sin AZ_{CF}$$
$$= 157728.242 + 1572.174 \times \sin 310°36'56.8'' = 156534.817$$

$$X_F = X_C + D_{CF} \times \cos AZ_{CF}$$
$$= 101535.564 + 1572.174 \times \cos 310°36'56.8'' = 102559.023$$

$$Y_E = Y_C + D_{EC} \times \sin AZ_{CE}$$
$$= 157728.242 + 308.710 \times \sin 282°09'14.35'' = 157426.452$$

$$X_E = X_C + D_{EC} \times \cos AZ_{CE}$$
$$= 101535.564 + 308.710 \times \cos 282°09'14.35'' = 101600.560$$

5.3.5 Data for the Third Quadrilateral (F, D, H, G).

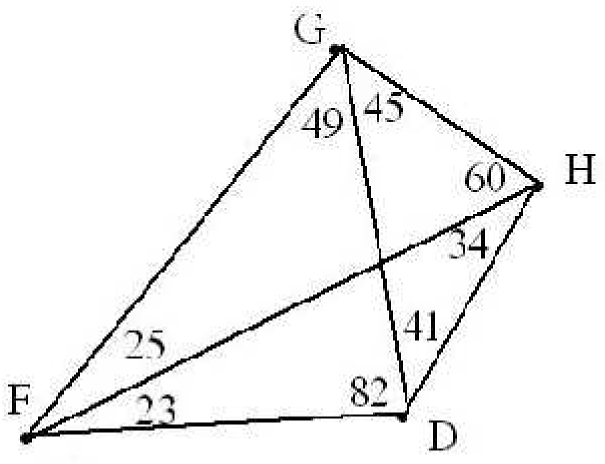

Figure 5.5 Third Quadrilateral (F,D,G,H)

Table 5.4 The mean of reading for third Quadrilateral [1]

Station	Point	Horizontal angle. ° ′ ”	Vertical angle ° ′ ”
H	F	33 45 23.4	91 46 33
	D		90 07 19
H	G	60 04 20.0	89 50 07
	F		91 46 33
D	G	40 41 24.6	89 27 11
	H		89 52 41
D	G	82 23 21.4	89 27 11
	F		92 37 05
F	H	23 09 25	88 13 27
	D		87 22 55
F	G	25 19 46	87 36 43
	H		88 13 27
G	F	49 06 39.4	92 23 17
	D		90 32 49
G	H	45 28 49.0	90 09 53
	D		90 32 49

[1] See appendix C3

5.3.6 Calculations for Quadrilateral (F, G, D, H):

* Calculation mean and standard deviation for horizontal angle and mean for vertical angles in quadrilateral using following law:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

*The mean of horizontal angle (FHD) = $\frac{196''}{10} = 33°\ 45'\ 23.4''$--------- #1

The mean of horizontal angle (G H F) = 60° 04' 20'' --------------------#8

The mean of horizontal angle (GDH) = 40° 41' 24.6''-------------------#2

The mean of horizontal angle (GDF) = 82° 23' 21.4''--------------------#3

The mean of horizontal angle (HFD) = 23° 09' 25''----------------------#4

The mean of horizontal angle (GFH) = 25° 19' 46'' ----------------------#5

The mean of horizontal angle (FGD) = 49° 06' 39.4''--------------------#6

The mean of horizontal angle (HGD) = 45° 28' 49''----------------------#7

The mean of vertical angle (DH) = $\frac{410''}{10} = 89°52'41''$

The mean of vertical angle (DG) = 89°27'11''

The mean of vertical angle (DF) = 92°37'05''

The mean of vertical angle (FG) = 87°36'43''

The mean of vertical angle (FH) = 88°13'27''

The mean of vertical angle (FD) = 87°22'55''

The mean of vertical angle (HD) = 90°07'19''

The mean of vertical angle (HF) = 91°46'33''

The mean of vertical angle (HG) = 89°50'07''

The mean of vertical angle (GH) = 90°09'53''

The mean of vertical angle (GD) = 90°32'49"

The mean of vertical angle (GF) = 92°23'17"

• **Determination standard deviation for horizontal angles at 99.7% level confidence using the following law:**

$$S_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(\overline{X} - X_I\right)^2}{n-1}}$$

Standard deviation of angle (DHF) $= \pm\sqrt{\frac{24.4}{9}} = \pm 1.65''$, $E_{99.7}$=2.756*1.65= ±4.55"

Standard deviation of angle (G HF) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.5"

Standard deviation of angle (HDG) $= \pm\sqrt{\frac{24.4}{9}} = \pm 1.65''$, $E_{99.7}$=2.756*1.65= ±4.55"

Standard deviation of angle (FDG) $= \pm\sqrt{\frac{24.4}{9}} = \pm 1.65''$, $E_{99.7}$=2.756*1.65= ±4.55"

Standard deviation of angle (HFD) $= \pm\sqrt{\frac{42}{9}} = \pm 2.2''$, $E_{99.7}$=2.756*2.2= ±6"

Standard deviation of angle (HFG) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.5"

Standard deviation of angle (HGD) $= \pm\sqrt{\frac{42}{9}} = \pm 2.2''$, $E_{99.7}$=2.756*2.2= ±6"

Standard deviation of angle (FGD) $= \pm\sqrt{\frac{24.4}{9}} = \pm 1.65''$, $E_{99.7}$=2.756*1.65= ±4.55"

*No blunders in all readings for any angle.

• **Correction all horizontal angles using equal shift method.**

No	Observed angle				1st correction							2nd correction		
	°	′	″	″	°	′	″	°	′	″	″	°	′	″
1	33	45	23.4	+6.4	33	45	29.8	74	27	0.8	-5.65	33	45	24.15
2	40	41	24.6	+6.4	40	41	31				-5.65	40	41	25.35
3	82	23	21.4	+6.4	82	23	27.8	105	32	59.2	+5.65	82	23	33.45
4	23	09	25	+6.4	23	09	31.4				+5.65	23	09	37.05
5	25	19	46	+6.4	25	19	52.4	74	26	38.2	+5.65	25	19	58.05
6	49	06	39.4	+6.4	49	06	45.8				+5.65	49	06	51.45
7	45	28	49	+6.4	45	28	55.4	105	33	21.8	-5.65	45	28	49.75
8	60	04	20	+6.4	60	04	26.4				-5.65	60	04	20.75
	359	59	08.8	+51.2	360	00	00				0	360	00	00

1	**2**			**3**	**4**	**5**	**6**	**7**		
	Angle			**Log sin (odd)**	**Log sin (even)**	**Difference for 10″ arc**	******	**Final Values**		
	°	′	″				″	°	′	″
1	33	45	24.15	1.744815		0.0000316	-2.7	33	45	21.45
2	40	41	25.35		1.814228	0.0000248	+2.7	40	41	28.05
3	82	23	33.45	1.996161		0.0000025	-2.7	82	23	30.75
4	23	09	37.05		1.594729	0.0000495	+2.7	23	09	39.75
5	25	19	58.05	1.631317		0.0000446	-2.7	25	19	55.35
6	49	06	51.45		1.878531	0.0000187	+2.7	49	06	54.15
7	45	28	49.75	1.853097		0.0000204	-2.7	45	28	47.05
8	60	04	20.75		1.937847	0.0000123	+2.7	60	04	23.45
				1.225390	1.225335 1.225401 -0.000055	0.000204 -		360	00	00

**Angular Change= $\frac{-0.000055\times10}{0.000204}=2.7''$

•Calculation the length of sides in quadrilateral (H, D, F, G).

The length of side DF = 1312.631 m

Horizontal $HD=\frac{1312.631\times\sin(23°09'39.75'')}{\sin(33°45'21.45'')}$ = 929.135 m

Slope $HD=\frac{929.135}{\cos(07'19'')}$ =929.137 m

Horizontal $HF=\frac{1312.631\times\sin(123°04'58.8'')}{\sin(33°45'21.45'')}$ = 1979.330 m

Slope $HF=\frac{1979.330}{\cos(1°46'33'')}$ = 1980.281 m

Horizontal $GF=\frac{1312.631\times\sin(82°23'30.75'')}{\sin(49°06'54.15'')}$ = 1720.942 m

Slope $GF=\frac{1720.942}{\cos(2°23'17'')}$ = 1722.438 m

Horizontal $DG=\frac{1312.631\times\sin(48°29'35.1'')}{\sin(49°06'54.15'')}$ = 1300.218 m

Slope $DG=\frac{1300.218}{\cos(32'49'')}$ = 1300.277 m

Horizontal $HG=\frac{1721.038\times\sin(25°19'55.35'')}{\sin(60°04'23.45'')}$ = 849.660 m

Slope $HG=\frac{849.660}{\cos(09'53'')}$ = 849.664 m

•Calculations Heights of Points (H, G).

*Height of Point H= 898.586+1.66+1979.330*tan 1°46′17″-1.1=960.513 m

*Height of Point G= 898.586+1.66+1720.942*tan 2°23′17″-1.1= 970.915 m

*For Check

*Height of Point H=958.033+1.66+929.135*tan 0°07′19″-1.1= 960.571 m

*Height of Point G=958.033+1.66+1300.218*tan 0°32′49″-1.1= 971.005 m

*Average Height of Point H= $\frac{960.513+960.571}{2}=960.542m$

*Average Height of Point G= $\frac{970.915+971.005}{2}=970.960m$

•Reductions of Distances in Quadrilateral (H, G, D, F) to Mean Sea Level.

* Average Height for Distance DH = $\frac{958.033+960.513}{2}=959.273m$

*****Distance DH at mean sea level= $\frac{929.135\times 6378137}{6378137+959.273}=928.995m$

***** Average Height for Distance FH= $\frac{960.513+898.568}{2}=929.541m$

***** Distance FH at mean sea level= $\frac{1979.330\times 6378137}{6378137+929.541}=1979.042m$

***** Average Height for Distance GF= $\frac{898.568+970.960}{2}=934.764m$

***** Distance GF at mean sea level**=** $\frac{1720.942\times 6378137}{6378137+934.764}=1720.690m$

***** Average Height for Distance GD= $\frac{970.960+958.033}{2}=964.497m$

***** Distance GD at mean sea level**=** $\frac{1300.218\times 6378137}{6378137+964.497}=1300.021m$

* Average Height for Distance HG= $\frac{960.513+970.960}{2}=965.737m$

* Distance HG at mean sea level= $\frac{849.660\times6378137}{6378137+965.737}=849.531m$

• Determination the Grid Distance.

*Grid distance DH= $928.995\times1.000067=929.057m$

*Grid distance DG= $1300.021\times1.000067=1300.108m$

*Grid distance HF= $1979.042\times1.000067=1979.175m$

*Grid distance HG= $849.531\times1.000067=849.588m$

*Grid distance GF= $1720.690\times1.000067=1720.805m$

*** Determination the strength of figure.**

Quadrilateral

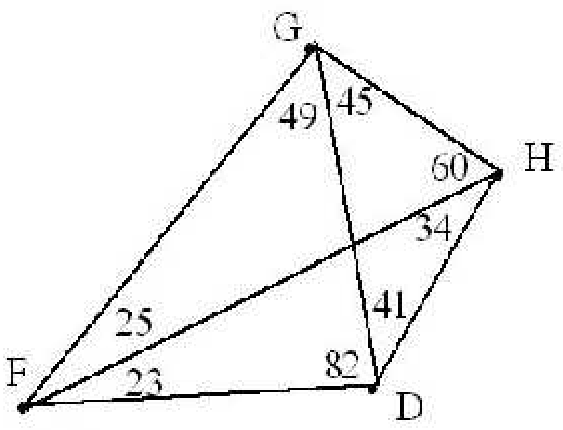

Figure 5.5 Third Quadrilateral (F,D,G,H)

*the route is chosen are triangles (FGD), (HFG).

*(D) =10, (C) = 4.

* $\frac{D-C}{D}=\frac{10-4}{10}=0.6$

*The first route is triangle (FGD), known side is FD and the side to be calculated is FG.

$A=82°$
$B=49°$

$B=45°\rightarrow A=80°\Rightarrow R=5$
$B=45°\rightarrow A=85°\Rightarrow R=5$

$85°-80°\rightarrow 5-5$
$82°-80°\rightarrow (R'-5)$

$5\rightarrow 0$
$2\rightarrow (R'-5)\Rightarrow R'=5$

$B=50°\rightarrow A=80°\Rightarrow R=4$
$B=50°\rightarrow A=85°\Rightarrow R=3$

$85°-80°\rightarrow 3-4$
$82°-80°\rightarrow (R'-4)$

$5\rightarrow -1$
$2\rightarrow \left(R'-4\right)\Rightarrow R'=3.6$

$$A = 82° \rightarrow B = 45° \Rightarrow R' = 5$$
$$A = 82° \rightarrow B = 50° \Rightarrow R' = 3.6$$

$$50° - 45° \rightarrow 3.6 - 5$$
$$49° - 45° \rightarrow (R'' - 5)$$

$$5 \rightarrow -1.4$$
$$4 \rightarrow (R'' - 5) \Rightarrow R'' = 3.88$$

*The second route is triangle (HFG), known side is FG and the side to be calculated is HG.

$$A = 25°$$
$$B = 60°$$

$$B = 60° \rightarrow A = 24° \Rightarrow R = 30$$
$$B = 60° \rightarrow A = 26° \Rightarrow R = 25$$

$$26° - 24° \rightarrow 25 - 30$$
$$25° - 24° \rightarrow (R' - 30)$$

$$2 \rightarrow -5$$
$$1 \rightarrow (R' - 30) \Rightarrow R' = 27.5$$

* The strength of figure (F, D, H, G) or $R''' = \frac{10-4}{10} \times (3.88 + 27.5) = 18.828$

* This quadrilateral is strong because the value of (R) is small.

• **Calculations Coordinates for Points (H, G).**

$$AZ_{FD}=\tan^{-1}\frac{Y_D-Y_F}{X_D-X_F}=\tan^{-1}\frac{157846.059-156534.817}{102501.184-102559.023}=\tan^{-1}\frac{1311.242}{-57.839}$$

$$AZ_{FD}=92°31'32.46''$$

$$AZ_{FH}=AZ_{FD}-\angle(H\hat{F}D)=92°31'32.46''-23°09'39.75''=69°21'52.71''$$

$$AZ_{FG}=AZ_{FD}-\angle(H\hat{F}D)-\angle(H\hat{F}G)=69°21'52.71''-25°19'55.35''=44°01'57.36''$$

$$Y_H=Y_F+D_{FH}\times\sin AZ_{FH}$$
$$=156534.817+1979.175\times\sin 69°21'52.71''=158387.013$$

$$X_H=X_F+D_{FH}\times\cos AZ_{FH}$$
$$=102559.023+1979.175\times\cos 69°21'52.71''=103256.522$$

$$Y_G=Y_F+D_{FG}\times\sin AZ_{FG}$$
$$=156534.817+1720.805\times\sin 44°01'57.36''=157730.893$$

$$X_G=X_F+D_{FG}\times\cos AZ_{FG}$$
$$=102559.023+1720.805\times\cos 44°01'57.36''=103796.186$$

5.3.7 Data for the Fourth Quadrilateral (G, H, I, J).

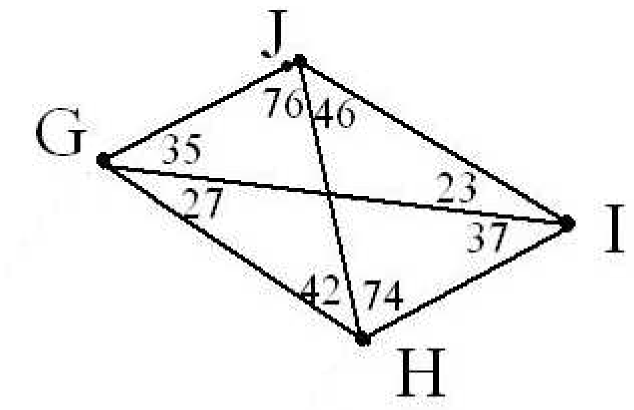

Figure 5.7 Fourth Quadrilateral (G,H,I,J)

Table 5.5 The mean of reading for fourth Quadrilateral [1]

Station	Point	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
J	H	75 55 17.4	90 37 21
	G		89 48 17
J	H	45 45 22.0	90 37 21
	I		90 10 13
G	I	35 17 55.0	90 10 13
	J		90 11 43
G	I	26 59 13.0	90 13 51
	H		90 09 53
H	J	41 47 30.0	89 22 39
	G		89 50 07
H	J	74 16 54.8	89 22 39
	I		89 31 37
I	H	36 56 10.6	90 28 23
	G		89 46 09
I	J	23 01 32.1	89 49 47
	G		89 46 09

[1] See appendix C4

5.3.8 Calculations for Quadrilateral (G, H, I, J)

*We calculate mean and standard deviation for horizontal angle and mean for vertical angles in quadrilateral using following law:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

*The mean of horizontal angle (H J G) = $\frac{174''}{10} = 75°\ 55'\ 17.4''$-------#1

The mean of horizontal angle (H J I) = 45° 45' 22" --------------------#8

The mean of horizontal angle (I G J) = 35° 17' 55"---------------------#2

The mean of horizontal angle (I G H) = 26° 59' 13"------------- ------#3

The mean of horizontal angle (J H G) = 41° 47' 30"--------------------#4

The mean of horizontal angle (J H I) = 74° 16' 54.8" ------------------#5

The mean of horizontal angle (H I G) = 36° 56' 10.6"------------------#6

The mean of horizontal angle (J I G) = 23° 01' 32.2"------------------#7

*The mean of vertical angle (HG) = $\frac{70}{10} = 89°50'07''$

The mean of vertical angle (HJ) = 89°22'39"

The mean of vertical angle (HI) = 89°31'37"

The mean of vertical angle (GJ) = 90°11'43"

The mean of vertical angle (GI) = 90°13'51"

The mean of vertical angle (GH) =90°09'53"

The mean of vertical angle (JH) = 90°37'21"

The mean of vertical angle (JG) = 89°48'17"

The mean of vertical angle (JI) = 90°10'13"

The mean of vertical angle (IJ) = 89°49'47"

The mean of vertical angle (IG) = 89°46'09"

The mean of vertical angle (IH) = 90°28'23"

- **Determination standard deviation for horizontal angles at 99.7% level confidence using the following law:**

$$S_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(\overline{X}-X_I\right)^2}{n-1}}$$

Standard deviation of angle (H J G) $= \pm\sqrt{\frac{16.4}{9}} = \pm 1.35''$, $E_{99.7}$=2.756*1.35= ±3.7"

Standard deviation of angle (H J I) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.5"

Standard deviation of angle (I G J) $= \pm\sqrt{\frac{42}{9}} = \pm 2.2''$, $E_{99.7}$=2.756*2.2= ±6"

Standard deviation of angle (I G H) $= \pm\sqrt{\frac{42}{9}} = \pm 2.2''$, $E_{99.7}$=2.756*2.2= ±6"

Standard deviation of angle (J H G) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.5"

Standard deviation of angle (J H I) $= \pm\sqrt{\frac{17.6}{9}} = \pm 1.4''$, $E_{99.7}$=2.756*1.4= ±3.86"

Standard deviation of angle (H I G) $= \pm\sqrt{\frac{24.4}{9}} = \pm 1.65''$, $E_{99.7}$=2.756*1.65= ±4.55"

Standard deviation of angle (J I G) $= \pm\sqrt{\frac{19.6}{9}} = \pm 1.48''$, $E_{99.7}$=2.756*1.48= ±4.1"

*No blunders in all readings for any angle.

• **Correction all horizontal angles using equal shift method.**

No	**Observed angle**				**1st correction**							**2nd correction**		
	°	′	″	″	°	′	″	°	′	″	″	°	′	″
1	75	55	17.4	+0.625	75	55	18.025	111	13	13.65	-1.75	75	55	16.275
2	35	17	55	+0.625	35	17	55.625				-1.75	35	17	53.875
3	26	59	13	+0.625	26	59	13.625	68	46	44.25	+2.80	26	59	16.425
4	41	47	30	+0.625	41	47	30.625				+2.80	41	47	33.425
5	74	16	54.8	+0.625	74	16	55.425	111	13	06.65	+1.75	74	16	57.175
6	36	56	10.6	+0.625	36	56	11.225				+1.75	36	56	12.975
7	23	01	32.2	+0.625	23	01	32.725	68	46	55.45	-2.80	23	01	29.925
8	45	45	22	+0.625	45	45	22.725				-2.80	45	45	19.925
	359	59	55		360	00	00				0	360	00	00

1	**2**			**3**	**4**	**5**	**6**	**7**		
	Angle			**Log sin**	**Log sin**	**Differene**	**	**Final Values**		
	°	′	″	**(odd)**	**(even)**	**for 10″ arc**	″	°	′	″
1	75	55	16.275	1.986755		0.000005	+6.5	75	55	22.775
2	35	17	53.875		1.761803	0.000029	-6.5	35	17	47.375
3	26	59	16.425	1.656867		0.000041	+6.5	26	59	22.925
4	41	47	33.425		1.823759	0.000023	-6.5	41	47	26.925
5	74	16	57.175	1.983450		0.000006	+6.5	74	17	03.675
6	36	56	12.975		1.778828	0.000028	-6.5	36	56	06.475
7	23	01	29.925	1.592324		0.000049	+6.5	23	01	36.425
8	45	45	19.925		1.855137	0.000020	-6.5	45	45	13.425
				1.219396	1.219527 1.214787 0.000131	0.000201		360	00	00

$$**\text{Angular Change} = \frac{0.000131 \times 10}{0.000201} = 6.5''$$

•Calculation the length of sides in quadrilateral (G, H, I, J).

The length of side HG = 849.660 m

Horizontal $IH = \frac{849.660 \times \sin(26°59'22.925'')}{\sin(36°56'06.475'')}$ = 641.695 m

Slope $IH = \frac{641.695}{\cos(28'23'')} = 641.717 = \text{m}$

Horizontal $IG = \frac{849.660 \times \sin(116°04'30.6'')}{\sin(36°56'6.475'')}$ = 1270.040 m

Slope $IG = \frac{1270.040}{\cos(13'51'')}$ = 1270.050 m

Horizontal $JG = \frac{849.660 \times \sin(41°47'26.925'')}{\sin(75°55'22.775'')}$ = 583.755 m

Slope $JG = \frac{583.755}{\cos(11'43'')}$ = 583.758 m

Horizontal $HJ = \frac{849.660 \times \sin(62°17'10.3'')}{\sin(75°55'22.775'')}$ = 775.476 m

Slope $HJ = \frac{775.476}{\cos(37'21'')}$ = 775.522 m

Horizontal $IJ = \frac{583.755 \times \sin(35°17'47.375'')}{\sin(23°01'36.425'')}$ = 862.299 m

Slope $IJ = \frac{862.299}{\cos(10'13'')}$ = 862.303m

•Calculations Heights of Points (I, J).

*Height of Point I= 960.542+1.66+641.695*tan 28′23"-1.1=966.400m

*Height of Point J= 960.542+1.66+775.476*tan 37′21"-1.1= 969.528 m

*For Check

*Height of Point I=970.960+1.66-1270.040*tan 13′51"-1.1= 966.403m

*Height of Point J=970.960+1.66-583.755*tan 11′43"-1.1= 969.531m

*Average Height of Point I= $\frac{966.400+966.403}{2}=966.402m$

*Average Height of Point J= $\frac{969.528+969.531}{2}=969.530m$

•Reduction Distances in Quadrilateral (G, H, I, J) to Mean Sea Level.

* Average Height for Distance IH = $\frac{966.402+960.542}{2}=963.472m$

***Distance IH at mean sea level=** $\frac{641.695\times 6378137}{6378137+963.472}=641.598m$

***** Average Height for Distance IG= $\frac{966.402+970.960}{2}=968.681m$

***** Distance IG at mean sea level= $\frac{1270.040\times 6378137}{6378137+968.681}=1269.847m$

***** Average Height for Distance JG= $\frac{969.530+970.960}{2}=970.245m$

***** Distance JG at mean sea level**=** $\frac{583.755\times 6378137}{6378137+970.245}=583.666m$

***** Average Height for Distance HJ= $\frac{960.542+969.530}{2}=965.036m$

***** Distance HJ at mean sea level**=** $\frac{775.476\times 6378137}{6378137+965.036}=775.359m$

* Average Height for Distance IJ= $\frac{966.402+969.530}{2}=967.966m$

* Distance IJ at mean sea level= $\frac{862.299\times 6378137}{6378137+967.966}=862.168m$

• Determination the Grid Distance.

*Grid distance IH= $641.598\times 1.000067=641.641m$

*Grid distance IG= $1269.847\times 1.000067=1269.932m$

*Grid distance JG= $583.666\times 1.000067=583.705m$

*Grid distance HJ= $775.359\times 1.000067=775.411m$

*Grid distance IJ= $862.168\times 1.000067=862.226m$

• Determination the strength of figure.

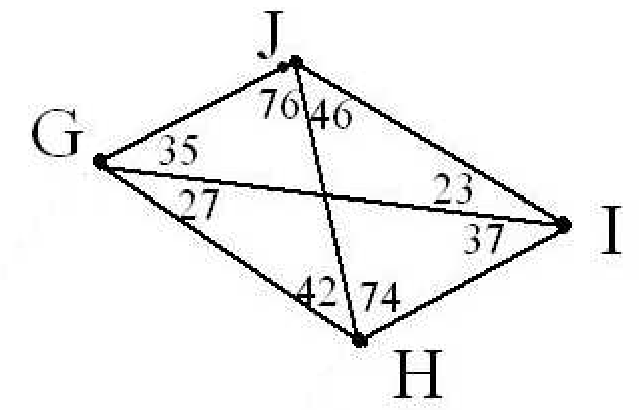

Figure 5.8 Fourth Quadrilateral (G,H,I,J)

*the route is chosen are triangles (H G J), (J I G).

*(D) =10, (C) = 4.

$$* \frac{D-C}{D} = \frac{10-4}{10} = 0.6$$

*The first route is triangle (H G J), known side is HG and the side to be calculated is JG.

$A = 42°$
$B = 76°$

$B = 75° \rightarrow A = 40° \Rightarrow R = 8$
$B = 75° \rightarrow A = 45° \Rightarrow R = 6$

$45° - 40° \rightarrow 6 - 8$
$42° - 40° \rightarrow (R' - 8)$

$5 \rightarrow -2$
$2 \rightarrow (R' - 8)$

$-4 = 5(R' - 8) \Rightarrow R' = 7.2$

$B = 80° \rightarrow A = 40° \Rightarrow R = 7$
$B = 80° \rightarrow A = 45° \Rightarrow R = 5$

$45° - 40° \rightarrow 5 - 7$
$42° - 40° \rightarrow (R' - 7)$

$5 \rightarrow -2$
$2 \rightarrow (R' - 7 \Rightarrow R' = 6.2)$

$A = 42° \rightarrow B = 75° \Rightarrow R' = 7.2$
$A = 42° \rightarrow B = 80° \Rightarrow R' = 6.2$

$80° - 75° \rightarrow 6.2 - 7.2$
$76° - 75° \rightarrow (R'' - 7.2)$

$5 \rightarrow -1$
$1 \rightarrow (R'' - 7.2) \Rightarrow R'' = 7$

*The second route is triangle (I J G), known side is JG and the side to be calculated is IJ.

$A = 35°$
$B = 23°$

$A = 35° \rightarrow B = 22° \Rightarrow R = 52$
$A = 35° \rightarrow B = 24° \Rightarrow R = 46$

$24° - 22° \rightarrow 46 - 52$
$23° - 22° \rightarrow (R' - 52)$

$2 \rightarrow -6$
$1 \rightarrow (R' - 52)$

$-6 = 2(R' - 52) \Rightarrow R' = 49$

* The strength of figure (G, H, I, J) or $R''' = \frac{10-4}{10} \times (7 + 49) = 33.6$

* This quadrilateral is medium strong because the value of (R) is not small.

• **Calculations Coordinates for Points (I, J).**

$$AZ_{GH} = \tan^{-1}\frac{Y_H - Y_G}{X_H - X_G} = \tan^{-1}\frac{158387.013 - 157730.893}{103256.522 - 103796.186} = \tan^{-1}\frac{656.12}{-539.664}$$

$$AZ_{GH} = 129°26'15.2''$$

$$AZ_{GI} = AZ_{GH} - \angle(H\hat{G}I) = 129°26'15.2'' - 26°59'22.925 = 102°26'52.3''$$

$$AZ_{GJ} = AZ_{GH} - \angle(H\hat{G}I) - \angle(I\hat{G}J) = 102°26'52.3'' - 35°17'47.375'' = 67°09'4.96''$$

$$Y_I = Y_G + D_{GI} \times \sin AZ_{GI}$$
$$= 157730.893 + 1269.932 \times \sin 102°26'52.3'' = 158970.972$$

$$X_I = X_G + D_{GI} \times \cos AZ_{GI}$$
$$= 103796.186 + 1269.932 \times \cos 102°26'52.3'' = 103522.451$$

$$Y_J = Y_G + D_{GJ} \times \sin AZ_{GJ}$$
$$= 157730.893 + 583.705 \times \sin 67°09'4.96'' = 158268.797$$

$$X_J = X_G + D_{GJ} \times \cos AZ_{GJ}$$
$$= 103796.186 + 583.705 \times \cos 67°09'4.96'' = 104022.837$$

5.3.9 Data for the Fifth Quadrilateral (J, I, K, L)

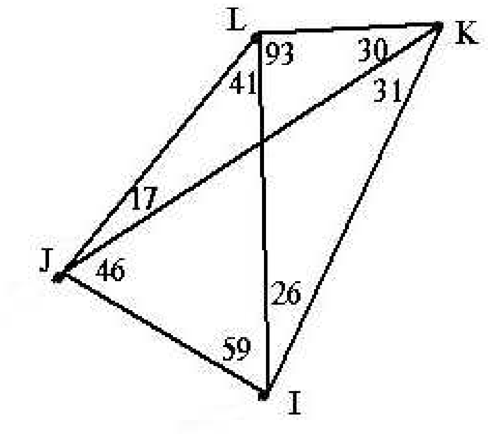

Figure 5.9 Fifth Quadrilateral (J,I,K,L)

Table 5.6 The mean of reading for fifth Quadrilateral [1]

Station	Point	Horizontal angle. ° ′ ”	Vertical angle ° ′ ”
L	J	40 39 39.8	88 57 07
	I		89 13 33
L	K	92 51 24.0	88 54 23
	I		89 13 33
J	K	16 46 56.0	90 15 42
	L		91 02 52
J	K	62 32 15.0	90 15 42
	I		90 10 12
I	J	59 01 55.0	89 49 47
	L		90 46 27
I	K	26 14 55.8	90 10 17
	L		90 46 27
K	I	31 10 57	89 49 43
	J		89 13 33
K	L	29 42 56.4	91 05 37
	J		89 44 17

[1] See appendix C5

5.3.10 Calculations for Quadrilateral (J, I, K, L)

* We calculate mean and standard deviation for horizontal angle and mean for vertical angles in quadrilateral using following law:

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

*The mean of horizontal angle (J L I) = $\frac{504''}{10} = 40°\ 39'\ 39.8''$--------#1

The mean of horizontal angle (K L I) = 92° 51' 24" -------------------#8

The mean of horizontal angle (K J L) = 16° 46' 56"-------------------#2

The mean of horizontal angle (K J I) = 62° 32' 15"------------- -------#3

The mean of horizontal angle (J I L) = 59° 01' 55"--------------------#4

The mean of horizontal angle (K I L) = 26° 14' 55.8" -----------------#5

The mean of horizontal angle (I K J) = 31° 10' 57"--------------------#6

The mean of horizontal angle (L K J) = 29° 42' 56.4"------------------#7

* The average of measured length KL (check line) = $\frac{6597.695}{10} = 659.7695m$

* The mean of vertical angle (KI) = $\frac{430''}{10} = 89°49'43''$

The mean of vertical angle (KL) = 91°05'37"

The mean of vertical angle (KJ) = 89°44'17"

The mean of vertical angle (LI) = 89°13'33"

The mean of vertical angle (LK) = 88°54'23"

The mean of vertical angle (LJ) = 88°57'07"

The mean of vertical angle (IK) = 90°10'17"

The mean of vertical angle (IL) = 90°46'27"

The mean of vertical angle (IJ) = 89°49'47"

The mean of vertical angle (JI) = 90°10'13"

The mean of vertical angle (JK) =90°15'43"

The mean of vertical angle (JL) = 91°02'53"

* **Determination the standard deviation for horizontal angles at 99.7% level confidence using the following law:**

$$S_X = \pm\sqrt{\frac{\sum_{i=1}^{n}\left(\overline{X}-X_I\right)^2}{n-1}}$$

Standard deviation of angle (J L I) $= \pm\sqrt{\frac{19.6}{9}} = \pm 1.48''$, $E_{99.7}$=2.756*1.48= ±4"

Standard deviation of angle (K L I) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.49"

Standard deviation of angle (K J L) $= \pm\sqrt{\frac{24}{9}} = \pm 1.63''$, $E_{99.7}$=2.756*1.63= ±4.49"

Standard deviation of angle (K J I) $= \pm\sqrt{\frac{42}{9}} = \pm 2.16''$, $E_{99.7}$=2.756*2.16= ±5.95"

Standard deviation of angle (J I L) $= \pm\sqrt{\frac{10}{9}} \pm 1.05''$, $E_{99.7}$=2.756*1.05= ±2.89"

Standard deviation of angle (K I L) $= \pm\sqrt{\frac{19.6}{9}} \pm 1.48''$, $E_{99.7}$=2.756*1.48= ±4"

Standard deviation of angle (I K J) $= \pm\sqrt{\frac{10}{9}} \pm 1.05''$, $E_{99.7}$=2.756*1.05= ±2.89”

Standard deviation of angle (L K J) $= \pm\sqrt{\frac{22.4}{9}} \pm 1.58$, $E_{99.7}$=2.756*1.58= ±4.35”

* No blunders in all readings for any angle.

*** The following step, we correct all horizontal angles using equal shift method**

No	Observed angle				1st correction					10.4		2nd correction	
	°	′	″	″	°	′	″	°	′	″	″	°	′	″
1	40	39	39.8	-1	40	39	38.8	57	25	42.8	+2	40	39	40.8
2	16	46	56	-1	16	46	04				+2	16	46	06
3	62	32	15	-1	62	32	14	122	34	8	+2.6	63	32	16.6
4	59	1	55	-1	59	1	54				+2.6	59	1	56.6
5	26	14	55.8	-1	26	14	54.8	57	25	50.8	-2	26	14	52.8
6	31	10	57	-1	31	10	56				-2	31	10	54
7	29	42	56.4	-1	29	42	55.4	122	34	18.4	-2.6	29	42	52.8
8	92	51	24	-1	92	51	23				-2.6	92	51	20.4
	360	00	08	-8	360	00	00				0	360	00	00

1	**2 Angle**			**3 Log sin (odd)**	**4 Log sin (even)**	**5 Differene for 10″ arc**	**6 ** ″**	**7 Final Values**		
	°	′	″					°	′	″
1	40	39	40.8	1.813 972		0.000 025	+7	40	39	47.8
2	16	46	06		1.460 150	70	-7	16	45	59
3	63	32	16.6	1.951 935		10	+7	63	32	23.6
4	59	01	56.6		1.933 213	13	-7	59	01	49.6
5	26	14	52.8	1.645 675		43	+7	26	14	59.8
6	31	10	54		1.714 123	35	-7	31	10	47
7	29	42	52.8	1.695 202		37	+7	29	42	59.8
8	92	51	20.4		1.999 460	1	-7	92	51	13.4
				1.106 782	1.106 946 1.106 782 +0.000 164	0.000 234		360	00	00

$$\text{**Angular Change} = \frac{0.000164 \times 10}{0.000234} = 7''$$

•Calculation the length of sides in quadrilateral (J, I, K, L).

The length of side IJ = 862.299 m

$$\text{Horizontal } IK = \frac{862.299 \times \sin(63°32'23.6'')}{\sin(31°10'47'')} = 1491.081 \text{ m}$$

$$\text{Slope } IK = \frac{1491.081}{\cos(10'17'')} = 1491.088 = \text{m}$$

$$\text{Horizontal } KJ = \frac{862.299 \times \sin(85°16'49.4'')}{\sin(31°10'47'')} = 1659.909 \text{ m}$$

Slope $KJ = \dfrac{1659.909}{\cos(15'43'')}$ = 1659.926 m

Horizontal $JL = \dfrac{862.299 \times \sin(59°01'49.6'')}{\sin(40°39'47.8'')}$ = 1134.678 m

Slope $JL = \dfrac{1134.678}{\cos(1°02'53'')}$ = 1134.868 m

Horizontal $LI = \dfrac{862.299 \times \sin(80°18'22.6'')}{\sin(40°39'47.8'')}$ = 1304.437 m

Slope $LI = \dfrac{1304.437}{\cos(46'27'')}$ = 1304.556 m

Horizontal $KL = \dfrac{1134.678 \times \sin(16°45'59'')}{\sin(29°42'59.8'')}$ = 660.306 m

*The average of measured length KL (check line) = $\dfrac{6597.695}{10} = 659.7695m$

Slope $KL = \dfrac{660.306}{\cos(1°5'37'')}$ = 660.426m

• Calculations Heights of Points (L, K).

* Height of Point L= 966.402+1.66-1304.437*tan 46′27"-1.1=949.336m
* Height of Point K= 966.402+1.66-1491.081*tan 10′17"-1.1= 962.502 m

  For Check
* Height of Point L=969.530+1.66-1134.678*tan 1°02′53"-1.1= 949.332m
* Height of Point K=969.530+1.66-1659.909*tan 15′43"-1.1= 962.501m
* Average Height of Point L= $\dfrac{949.336 + 949.332}{2} = 949.334m$
* Average Height of Point K= $\dfrac{962.502 + 962.501}{2} = 962.502m$

•Reduction Distances in Quadrilateral (G, H, I, J) to Mean Sea Level.

* Average Height for Distance IK = $\frac{966.402+962.502}{2}=964.452m$

*****Distance IK at mean sea level = $\frac{1491.081\times 6378137}{6378137+964.452}=1490.856m$

***** Average Height for Distance KJ = $\frac{969.530+962.502}{2}=966.016m$

***** Distance KJ at mean sea level = $\frac{1659.909\times 6378137}{6378137+966.016}=1659.658m$

***** Average Height for Distance JL = $\frac{969.530+949.334}{2}=959.432m$

***** Distance JL at mean sea level **=** $\frac{1134.678\times 6378137}{6378137+959.432}=1134.507m$

***** Average Height for Distance LI = $\frac{949.334+966.402}{2}=957.868m$

***** Distance LI at mean sea level **=** $\frac{1304.437\times 6378137}{6378137+957.868}=1304.241m$

***** Average Height for Distance LK = $\frac{949.334+962.502}{2}=955.918m$

***** Distance LK at mean sea level **=** $\frac{660.306\times 6378137}{6378137+955.918}=660.207m$

• Determination the Grid Distance.

*****Grid distance IK=$1490.856\times 1.000067=1490.956m$

*****Grid distance KJ=$1659.658\times 1.000067=1659.769m$

*****Grid distance JL=$1134.507\times 1.000067=1134.583m$

*****Grid distance LI=$1304.241\times 1.000067=1304.328m$

*****Grid distance LK=$660.207\times 1.000067=660.251m$

*** Determination the strength of figure**

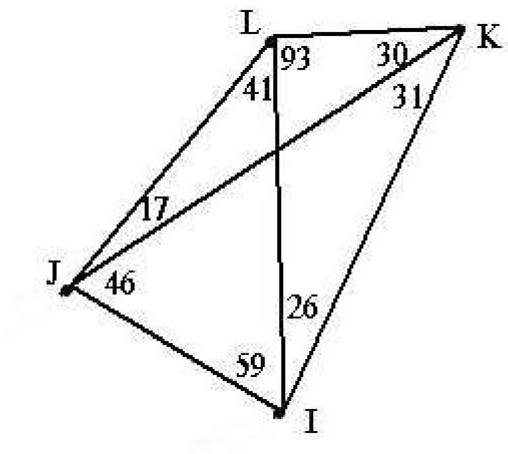

Figure 5.10 Fifth Quadrilateral (J,I,K,L)

* The route is chosen are triangles (JI K), (I K L).

*(D) =10, (C) = 4.

* $\frac{D-C}{D}=\frac{10-4}{10}=0.6$

*The first route is triangle (J I L), known side is JI and the side to be calculated is LI.

$A=46°+17°=63°$
$B=41°$

$B=40° \rightarrow A=60° \Rightarrow R=11$
$B=40° \rightarrow A=65° \Rightarrow R=10$

$65° - 60° \rightarrow 11 - 10$
$63° - 60° \rightarrow (R' - 10)$

$5 \rightarrow -1$
$3 \rightarrow (R' - 10)$

$-3 = 5(R' - 10) \Rightarrow (R' - 10) = -0.6$
$\Rightarrow R' = 9.4$

$B = 45° \rightarrow A = 60° \Rightarrow R = 9$
$B = 45° \rightarrow A = 65° \Rightarrow R = 7$

$65° - 60° \rightarrow 7 - 9$
$63° - 60° \rightarrow (R' - 9)$

$5 \rightarrow -2$
$3 \rightarrow (R' - 9) \Rightarrow R' = 7.8$

$A = 63° \rightarrow B = 40° \Rightarrow R' = 9.4$
$A = 63° \rightarrow B = 45° \Rightarrow R' = 7.8$

$45° - 40° \rightarrow 7.8 - 9.4$
$41° - 40° \rightarrow (R'' - 9.4)$

$5 \rightarrow -1.6$
$1 \rightarrow (R'' - 9.4) \Rightarrow R'' = 9.08$

*The second route is triangle (IKL), known side is IL and the side to be calculated is KL.

$A = 26°$
$B = 61°$

$A = 26° \rightarrow B = 60° \Rightarrow R = 25$
$A = 26° \rightarrow B = 65° \Rightarrow R = 24$

$65° - 60° \rightarrow 24 - 25$
$61° - 60° \rightarrow (R' - 25)$

$5 \rightarrow -1$
$1 \rightarrow (R' - 25)$

$-1 = 5(R' - 25) \Rightarrow R' = 24.8$

* The strength of figure (I, J, L, K) or $R''' = \frac{10-4}{10} \times (9.08 + 24.8) = 20.33$

* This quadrilateral is strong because the value of (R) is middle.

• **Calculations Coordinates for Points (L, K).**

$$AZ_{JI} = \tan^{-1}\frac{Y_I - Y_J}{X_I - X_J} = \tan^{-1}\frac{158970.972 - 158268.797}{103522.451 - 104022.837} = \tan^{-1}\frac{702.175}{-500.386}$$

$$AZ_{JI} = 125°28'28.3''$$

$$AZ_{JK} = AZ_{JI} - \angle(I\hat{J}K) = 125°28'28.3'' - 63°32'23.6'' = 61°56'4.76''$$

$$AZ_{JL} = AZ_{JI} - \angle(I\hat{J}K) - \angle(K\hat{J}L) = 61°56'4.76'' - 16°45'59'' = 45°10'5.76''$$

$$Y_K = Y_J + D_{JK} \times \sin AZ_{JK}$$
$$= 158268.797 + 1659.769 \times \sin 61°56'4.76'' = 159733.396$$

$$X_K = X_J + D_{JK} \times \cos AZ_{JK}$$
$$= 104022.837 + 1659.769 \times \cos 61°56'4.76'' = 104803.722$$

$$Y_L = Y_J + D_{JL} \times \sin AZ_{JL}$$
$$= 158268.797 + 1134.583 \times \sin 45°10'5.76'' = 159073.421$$

$$X_L = X_G + D_{GJ} \times \cos AZ_{GJ}$$
$$= 104022.837 + 1134.583 \times \cos 45°10'5.76'' = 104822.749$$

CHAPTER SIX

RECOMMENDATIONS AND CONCLUSIONS

6.1 Introduction

After our project had been completed, we have some conclusions and recommendations through working and problem that have been faced us in the project.

6.2 Conclusions

Our conclusions are summarized in the following proposals.

1- The control points had been applied on map of Hebron city using (Geographic Information System) GIS program and the results were very encouraged.

2- The equal shift method that used in calculation was easy and could be programmed on the computer easily.

3- The major figure and strength of figure for the network was found to be good.

4- We had good ideas about establishing geodesy networks using triangulation method.

5- The fruitful cooperation by the establishments and people had a big role in locating the control points.

6.3 Recommendations

Our recommendations are summarized in the following eight proposals.

1- To establish geodetic network points extends to Abu Ktelah region where Polytechnic buildings.

2- To intensify geodetic control points to include all parts of Hebron city.

3- To establish general geodetic network for Hebron governorate include all towns and villages, then to establish it for other governorate.

4- Providing the workers in such project many modern and precise types of equipments like total station, and using means of photogrammetry such as orthophoto.

5- Increasing number of the workers in geodesy project.

6- To make check on the geodesy network by using developed (Global Positioning System) GPS devices and other methods of calculations such as least square solution method.

7- Using Trilateration and Triangulataration methods to establish other control points.

8- To cooperate with the Palestine Geographic Center and other governmental establishment to make such control points.

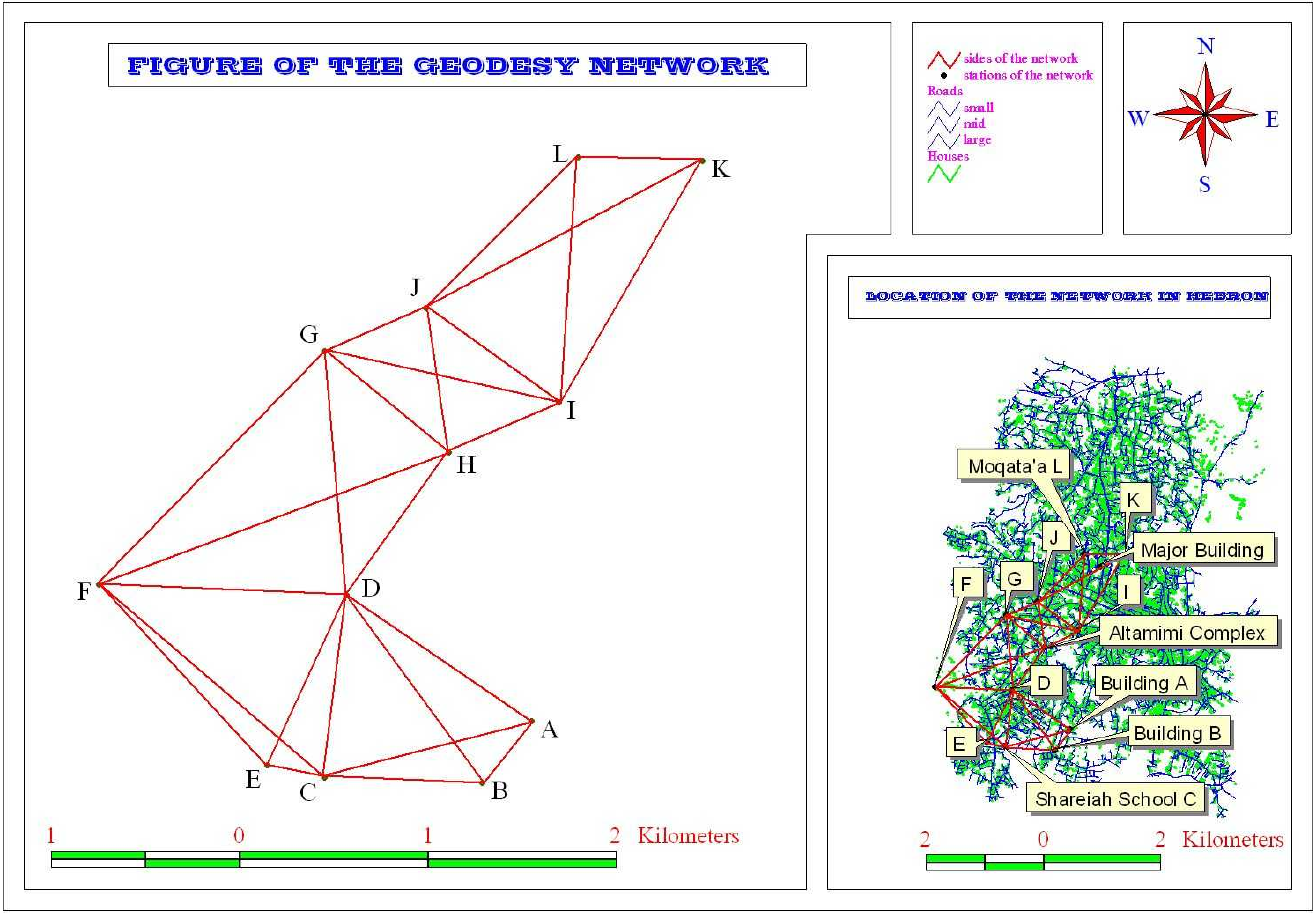
FIGURE OF THE GEODESY NETWORK
L
K
J
G
I
H
F
D
A
E
C
B
1
0
1
2
Kilometers
sides of the network
stations of the network
Roads
small
mid
large
Houses
N
W
E
S
LOCATION OF THE NETWORK IN HEBRON
Moqata'a L
K
J
Major Building
F
G
I
Altamimi Complex
D
Building A
E
Building B
Shareiah School C
2
0
2
Kilometers

بسم الله الرحمن الرحيم

University Graduates Union
Palestine Polytechnic University
(PPU)

رابطة الجامعيين / محافظة الخليل
جامعـــة بوليتكنك فلســطين

التاريخ: 2003/11/10م

السيد مدير الجمعية الخيرية الإسلامية المحترم

<u>الموضوع: مشاريع تخرج الطلبة</u>

تحيه طيبه وبعد ،،،

يقوم الطلبة التالية اسماؤهم:

1) محمد عيسى عبد العزيز
2) إبراهيم منير أبو عرام
3) محمد سليم غانم

وهم من طلاب السنة الخامسة تخصص هندسة المساحة والجيوماتكس بعمل مشروع تخرج بعنوان: (إنشاء شبكة جيوديسية بين مباني جامعة البوليتكنك)، بإشراف المهندس فيضي شبانة وهم بحاجة خلال عملهم هذا بالصعود إلى اسطح بعض المباني العالية للاستعانة بها في عملهم.

نرجو منكم التكرم بالسماح لهم بالصعود على اسطح الأبنية الخاصة بالجمعية والواقعة في منطقة الحرايق والحاووز الأول وشارع السلام.

هذا مع تعهدهم بأن يكون ذلك في أوقات الدوام الرسمي لكم وأن يحافظو على ممتلكاتكم.

وتفضلوا بقبول فائق الاحترام،،،

9/11/03

د. جمال زلاطيمو

رئيس دائرة الهندسة المدنية والمعمارية

بسم الله الرحمن الرحيم

University Graduates Union

Palestine Polytechnic University

(PPU)

رابطة الجامعيين / محافظة الخليل

جامعــة بوليتكنك فلســطين

التاريخ: **2004/01/04م**

حضرة السيد مدير التربية والتعليم المحترم / محافظة الخليل

الموضوع: مشاريع التخرج للطلبة

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يقوم الطلبة التالية اسماؤهم:

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نرجو منكم التكرم بالسماح لهم بذلك مع تعهدهم بالمحافظة عليها.

وتفضلوا بقبول فائق الاحترام،،،

د. جمال زلاطيمو

رئيس دائرة الهندسة المدنية والمعمارية

بسم الله الرحمن الرحيم

University Graduates Union
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رابطة الجامعيين / محافظة الخليل
جامعـــة بوليتكنك فلســطين

التاريخ: **2004/01/04م**

السيد مدير المديرية العامة للأوقاف في الجنوب المحترم

الموضوع: مشاريع التخرج للطلبة

تحيه طيبه وبعد ،،،

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2) إبراهيم منير أبو عرام
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نرجو منكم التكرم بالسماح لهم بذلك مع تعهدهم بالمحافظة عليها.

وتفضلوا بقبول فائق الاحترام،،،

د. جمال زلاطيمو

رئيس دائرة الهندسة المدنية والمعمارية

بسم الله الرحمن الرحيم

السلطـــــة الوطنيـــــة الفلسطينيـــة
وزارة الأوقــاف والشؤون الدينية
الإدارة العامـــة لمديريـــات الجنوب-الخليل
تلفكس: ٢٢٢٣٠٠٥

الرقــم : ج/ ٣ / ١ / ١ / ٢٥٨ح
التاريـخ : ٢٥/ ٩ / ١٤٢٤هـ
الموافــق : ١٩/ ١١ /٢٠٠٣م

السيد/امام مسجد .... المحترم

السلام عليكم ورحمة الله وبركاته

يقوم الطلاب التالية أسماؤهم :

١. محمد عيسى عبد العزيز.
٢. إبراهيم منير أبو عزام.
٣. محمد سليم غانم.

من جامعة بوليتكنك فلسطين الخليل قسم الهندسة بعمل مشروع تخرج بعنوان (إنشاء شبكة جيوديسيه)بين مباني جامعة البوليتكنك وهم بحاجة خلال عملهم بالصعود على سطح المسجد من اجل الاستعانة بهـــا في عملهم.

أرجو تسهيل مهمتهم بالسماح لهم بالصعود على السطح.

شاكرين لكم حسن تعاونكم.

والســــــلام عليـــــكم ،،،

تيسير أبو سنينه
مدير عام مديريات الجنوب

السلطة الوطنية الفلسطينية
فرع الوزارة - الخليل
وزارة الأوقاف والشؤون الدينية

نسخه /المدير الإداري
=/الملف العام

ب.ب/ا.د.ي الثلاثاء، ١٨ تشرين الثاني، ٢٠٠٣

Table 10.3 Factors for Determining Strength of Figure (*Courtesy U.S. National Ocean Survey*)
Values of $(\delta_A^2 + \delta_A\delta_B + \delta_B^2)$ for various combinations of distance angles *A* and *B* of a triangle

	10°	12°	14°	16°	18°	20°	22°	24°	26°	28°	30°	35°	40°	45°	50°	55°	60°	65°	70°	75°	80°	85°	90°
10°	428	359																					
12	359	295	253																				
14	315	253	214	187																			
16	284	225	187	162	143																		
18	262	204	168	143	126	113																	
20°	245	189	153	130	113	100	91																
22	232	177	142	119	103	91	81	74															
24	221	167	134	111	95	83	74	67	61														
26	213	160	126	104	89	77	68	61	56	51													
28	206	153	120	99	83	72	63	57	51	47	43												
30°	199	148	115	94	79	68	59	53	48	43	40	33											
35	188	137	106	85	71	60	52	46	41	37	33	27	23										
40	179	129	99	79	65	54	47	41	36	32	29	23	19	16									
45	172	124	93	74	60	50	43	37	32	28	25	20	16	13	11								
50°	167	119	89	70	57	47	39	34	29	26	23	18	14	11	9	8							
55	162	115	86	67	54	44	37	32	27	24	21	16	12	10	8	7	5						
60	159	112	83	64	51	42	35	30	25	22	19	14	11	9	7	5	4	4					
65	155	109	80	62	49	40	33	28	24	21	18	13	10	7	6	5	4	3	2				
70°	152	106	78	60	48	38	32	27	23	19	17	12	9	7	5	4	3	2	2	1			
75	150	104	76	58	46	37	30	25	21	18	16	11	8	6	4	3	2	2	1	1	1		
80	147	102	74	57	45	36	29	24	20	17	15	10	7	5	4	3	2	1	1	1	0	0	
85	145	100	73	55	43	34	28	23	19	16	14	10	7	5	3	2	2	1	1	0	0	0	0

90°	143	98	71	54	42	33	27	22	19	16	13	9	6	4	3	2	1	1	1	0	0	0	0
95°	140	96	70	53	41	32	26	22	18	15	13	9	6	4	3	2	1	1	0	0	0	0	
100	138	95	68	51	40	31	25	21	17	14	12	8	6	4	3	2	1	1	0	0	0		
105	136	93	67	50	39	30	25	20	17	14	12	8	5	4	2	2	1	1	0	0			
110	134	91	65	49	38	30	24	19	16	13	11	7	5	3	2	2	1	1	1				
115°	132	89	64	48	37	29	23	19	15	13	11	7	5	3	2	2	1	1					
120	129	88	62	46	36	28	22	18	15	12	10	7	5	3	2	2	1						
125	127	86	61	45	35	27	22	18	14	12	10	7	5	4	3	2							
130	125	84	59	44	34	26	21	17	14	12	10	7	5	4	3								
135°	122	82	58	43	33	26	21	17	14	12	10	7	5	4									
140	119	80	56	42	32	25	20	17	14	12	10	8	6										
145	116	77	55	41	32	25	21	17	15	13	11	9											
150	112	75	54	40	32	26	21	18	16	15	13												
152°	111	75	53	40	32	26	22	19	17	16													
154	110	74	53	41	33	27	23	21	19														
156	108	74	54	42	34	28	25	22															
158	107	74	54	43	35	30	27																
160	107	74	56	45	38	33																	
162°	107	76	59	48	42																		
164	109	79	63	54																			
166	113	86	71																				
168	122	98																					
170	143																						

C-1 Data for the First Quadrilateral (A, B, C, D)

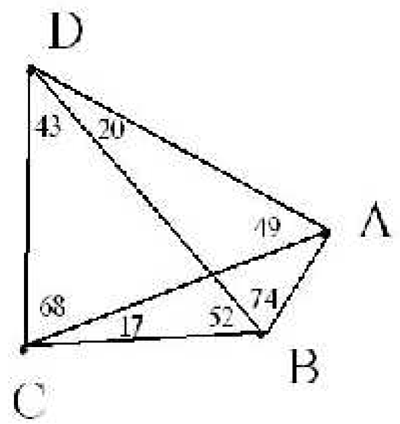


Figure C-1 Quadrilateral (A,B,C,D)

Station1 : Mosque (D)

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
A	00 00 00	91 53 32
B	19 46 08	91 54 38
A	00 00 00	91 53 34
B	19 46 04	91 54 40
A	00 00 00	91 53 32
B	19 46 06	91 54 38
A	00 00 00	91 53 34
B	19 46 04	91 54 40
A	00 00 00	91 53 32
B	19 46 06	91 54 38

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
B	00 00 00	91 54 38
A	340 13 54	91 53 34
B	00 00 00	91 54 40
A	340 13 52	91 53 32
B	00 00 00	91 54 38
A	340 13 56	91 53 34
B	00 00 00	91 54 40
A	340 13 54	91 53 32
B	00 00 00	91 54 38
A	340 13 55	91 53 34

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
B	00 00 00	91 54 40
C	42 52 34	93 49 48

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
C	00 00 00	93 49 50
B	317 07 26	91 54 38

B	00 00 00	91 54 38
C	42 52 32	93 49 50
B	00 00 00	91 54 40
C	42 52 34	93 49 48
B	00 00 00	91 54 38
C	42 52 36	93 49 50
B	00 00 00	91 54 40
C	42 52 34	93 49 48

C	00 00 00	93 49 48
B	317 07 24	91 54 40
C	00 00 00	93 49 50
B	317 07 22	91 54 38
C	00 00 00	93 49 48
B	317 07 25	91 54 40
C	00 00 00	93 49 50
B	317 07 24	91 54 38

Station2: Building A (A).

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
C	00 00 00	91 19 59
D	49 25 12	88 06 26
C	00 00 00	91 19 57
D	49 25 14	88 06 28
C	00 00 00	91 19 59
D	49 25 12	88 06 26
C	00 00 00	91 19 57
D	49 25 13	88 06 28
C	00 00 00	91 19 59
D	49 25 11	88 06 26

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	88 06 28
C	310 34 48	91 19 57
D	00 00 00	88 06 26
C	310 34 46	91 19 59
D	00 00 00	88 06 28
C	310 34 47	91 19 57
D	00 00 00	88 06 26
C	310 34 48	91 19 59
D	00 00 00	88 06 28
C	310 34 49	91 06 57

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
B	00 00 00	90 10 38
C	36 32 46	91 19 57
B	00 00 00	90 10 40
C	36 32 48	91 19 59
B	00 00 00	90 10 38
C	36 32 45	91 19 57
B	00 00 00	90 10 40
C	36 32 47	91 19 59
B	00 00 00	90 10 38
C	36 32 44	91 19 57

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
C	00 00 00	91 19 59
B	323 27 14	90 10 38
C	00 00 00	91 19 57
B	323 27 16	90 10 40
C	00 00 00	91 19 59
B	323 27 12	90 10 40
C	00 00 00	91 19 57
B	323 27 16	90 10 38
C	00 00 00	91 19 59
B	323 27 14	90 10 40

Station3: Building B (B)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
C	00 00 00	91 40 49
D	51 59 36	88 05 22
C	00 00 00	91 40 51
D	51 59 38	88 05 20
C	00 00 00	91 40 49
D	51 59 34	88 05 22
C	00 00 00	91 40 51
D	51 59 34	88 05 20
C	00 00 00	91 40 49
D	51 59 38	88 05 22

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	88 05 20
C	308 00 24	91 40 51
D	00 00 00	88 05 22
C	308 00 22	91 40 49
D	00 00 00	88 05 20
C	308 00 26	91 40 51
D	00 00 00	88 05 22
C	308 00 23	91 40 49
D	00 00 00	88 05 20
C	308 00 24	91 40 51

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	88 05 22
A	74 15 54	89 49 21
D	00 00 00	88 05 20
A	74 15 52	89 49 23
D	00 00 00	88 05 22
A	74 15 54	89 49 21
D	00 00 00	88 05 20
A	74 15 53	89 49 23
D	00 00 00	88 05 22
A	74 15 57	89 49 21

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
A	00 00 00	89 49 21
D	285 44 06	88 05 22
A	00 00 00	89 49 23
D	285 44 08	88 05 20
A	00 00 00	89 49 21
D	285 44 04	88 05 22
A	00 00 00	89 49 23
D	285 44 07	88 05 20
A	00 00 00	89 49 21
D	285 44 05	88 05 22

Station4: Shareiah School (C)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	86 10 10
A	67 55 58	88 40 01
D	00 00 00	86 10 12
A	67 55 56	88 40 03
D	00 00 00	86 10 10
A	67 55 54	88 40 01
D	00 00 00	86 10 12
A	67 55 59	88 40 03
D	00 00 00	86 10 10
A	67 55 57	88 40 01

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
A	00 00 00	88 40 01
D	292 04 02	86 10 12
A	00 00 00	88 40 03
D	292 04 01	86 10 10
A	00 00 00	88 40 03
D	292 04 03	86 10 12
A	00 00 00	88 40 01
D	292 04 04	86 10 10
A	00 00 00	88 40 03
D	292 04 02	86 10 12

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
A	00 00 00	88 40 03
B	17 11 42	88 19 09
A	00 00 00	88 40 01
B	17 11 41	88 19 11
A	00 00 00	88 40 03
B	17 11 43	88 19 09
A	00 00 00	88 40 01
B	17 11 44	88 19 11
A	00 00 00	88 40 03
B	17 11 42	88 19 09

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
B	00 00 00	88 19 11
A	342 48 18	88 40 01
B	00 00 00	88 19 09
A	342 48 16	88 40 03
B	00 00 00	88 19 11
A	342 4815	88 40 01
B	00 00 00	88 19 09
A	342 48 19	88 40 03
B	00 00 00	88 19 11
A	342 48 20	88 40 01

C-2 Data for the Second Quadrilateral (C, D, E, F)

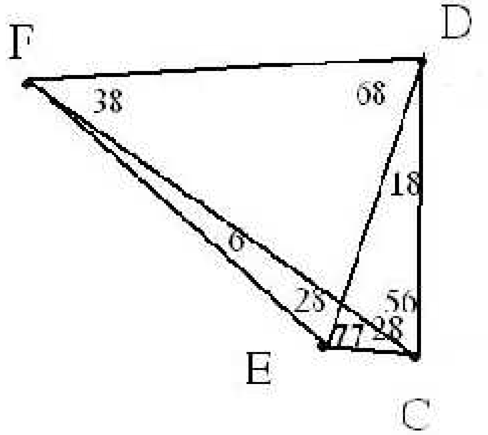


Figure C-2 Quadrilateral (C,D,E,F)

Station1: the Mosque (D).

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
C	00 00 00	93 49 48
E	18 01 18	93 31 30
C	00 00 00	93 49 50
E	18 01 16	93 31 32
C	00 00 00	93 49 48
E	18 01 14	93 31 30
C	00 00 00	93 49 50
E	18 01 18	93 31 32
C	00 00 00	93 49 48
E	18 01 16	93 31 30

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
E	00 00 00	93 31 32
C	341 58 42	93 49 50
E	00 00 00	93 31 30
C	341 58 46	93 49 48
E	00 00 00	93 31 32
C	341 58 44	93 49 50
E	00 00 00	93 31 30
C	341 58 42	93 49 48
E	00 00 00	93 31 30
C	341 58 46	93 49 50

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
E	00 00 00	93 31 30
F	67 32 14	92 37 04
E	00 00 00	93 31 32
F	67 32 16	92 37 06
E	00 00 00	93 31 30
F	67 32 18	92 37 04
E	00 00 00	93 31 32
F	67 32 20	92 37 06

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
F	00 00 00	92 37 06
E	292 27 44	93 31 32
F	00 00 00	92 37 04
E	292 27 42	93 31 30
F	00 00 00	92 37 06
E	292 27 40	93 31 32
F	00 00 00	92 37 04
E	292 27 44	93 31 30

E	00 00 00	93 31 30
F	67 32 14	92 37 04

F	00 00 00	92 37 06
E	292 27 42	93 31 32

Station2: Abu-Znad's Building (E)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	89 58 19
D	67 55 08	86 28 28
F	00 00 00	89 58 19
D	67 55 10	86 28 30
F	00 00 00	89 58 19
D	67 55 12	86 28 28
F	00 00 00	89 58 19
D	67 55 08	86 28 30
F	00 00 00	89 58 19
D	67 55 10	86 28 28

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	86 28 30
F	292 04 52	89 58 19
D	00 00 00	86 28 28
F	292 04 50	89 58 19
D	00 00 00	86 28 30
F	292 04 48	89 58 19
D	00 00 00	86 28 28
F	292 04 52	89 58 19
D	00 00 00	86 28 30
F	292 04 50	89 58 19

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	86 28 28
C	77 10 24	90 49 52
D	00 00 00	86 28 30
C	77 10 22	90 49 54
D	00 00 00	86 28 28
C	77 10 24	90 49 52
D	00 00 00	86 28 30
C	77 10 20	90 49 54
D	00 00 00	86 28 28
C	77 10 24	90 49 52

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
C	00 00 00	90 49 54
D	282 49 36	86 28 30
C	00 00 00	90 49 52
D	282 49 38	86 28 28
C	00 00 00	90 49 54
D	282 49 40	86 28 30
C	00 00 00	90 49 52
D	282 49 36	86 28 28
C	00 00 00	90 49 54
D	282 49 38	86 28 30

Station3: Hospital of Handicapped (F).

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
E	00 00 00	90 01 41
C	06 26 40	90 12 25
E	00 00 00	90 01 41

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
C	00 00 00	90 12 25
E	353 33 20	90 01 41
C	00 00 00	90 12 25

C	06 26 42	90 12 25	E	353 33 18	90 01 41
E	00 00 00	90 01 41	C	00 00 00	90 12 25
C	06 26 40	90 12 25	E	353 33 16	90 01 41
E	00 00 00	90 01 41	C	00 00 00	90 12 25
C	06 26 44	90 12 25	E	353 33 20	90 01 41
E	00 00 00	90 01 41	C	00 00 00	90 12 25
C	06 26 40	90 12 25	E	353 33 18	90 01 41

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″	Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	87 22 54	C	00 00 00	90 12 25
C	38 06 10	90 12 25	D	321 53 46	87 22 56
D	00 00 00	87 22 56	C	00 00 00	90 12 25
C	38 06 12	90 12 25	D	321 53 48	87 22 54
D	00 00 00	87 22 54	C	00 00 00	90 12 25
C	38 06 14	90 12 25	D	321 53 50	87 22 56
D	00 00 00	87 22 56	C	00 00 00	90 12 25
C	38 06 10	90 12 25	D	321 53 46	87 22 54
D	00 00 00	87 22 54	C	00 00 00	90 12 25
C	38 06 12	90 12 25	D	321 53 48	87 22 56

Station4: Shareiah School (C).

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″	Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
E	00 00 00	89 10 06	F	00 00 00	89 47 35
F	28 27 44	89 47 35	E	331 32 18	89 10 08
E	00 00 00	89 10 08	F	00 00 00	89 47 35
F	28 27 46	89 47 35	E	331 32 16	89 10 06
E	00 00 00	89 10 06	F	00 00 00	89 47 35
F	28 27 42	89 47 35	E	331 32 14	89 10 08
E	00 00 00	89 10 08	F	00 00 00	89 47 35
F	28 27 44	89 47 35	E	331 32 18	89 10 06
E	00 00 00	89 10 06	F	00 00 00	89 47 35
F	28 27 46	89 47 35			

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	89 47 35
D	56 20 12	86 10 10
F	00 00 00	89 47 35
D	56 20 10	86 10 12
F	00 00 00	89 47 35
D	56 20 14	86 10 10
F	00 00 00	89 47 35
D	56 20 12	86 10 12
F	00 00 00	89 47 35
D	56 20 10	86 10 10

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	89 47 35
D	303 39 46	86 10 12
F	00 00 00	89 47 35
D	303 39 48	86 10 10
F	00 00 00	89 47 35
D	303 39 50	86 10 12
F	00 00 00	89 47 35
D	303 39 46	86 10 10
F	00 00 00	89 47 35
D	303 39 48	86 10 12

C-3 Data for the Third Quadrilateral (F, D, H, G)

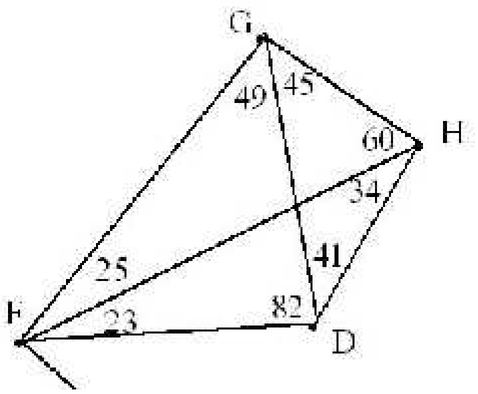


Figure C-3 Quadrilateral (F,D,G,H)

Station1: The Mosque (D).

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
H	00 00 00	89 52 40
G	40 41 26	89 27 10
H	00 00 00	89 52 42

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
G	00 00 00	89 27 10
H	319 18 34	89 52 42
G	00 00 00	89 27 12

G	40 41 24	89 27 12
H	00 00 00	89 52 40
G	40 41 22	89 27 10
H	00 00 00	89 52 42
G	40 41 24	89 27 12
H	00 00 00	89 52 40
G	40 41 26	89 27 10

H	319 18 38	89 52 40
G	00 00 00	89 27 10
H	319 18 34	89 52 42
G	00 00 00	89 27 12
H	319 18 36	89 52 40
G	00 00 00	89 27 10
H	319 18 34	89 52 42

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	92 37 04
G	82 23 20	89 27 12
F	00 00 00	92 37 06
G	82 23 22	89 27 10
F	00 00 00	92 37 04
G	82 23 24	89 27 12
F	00 00 00	92 37 06
G	82 23 22	89 27 10
F	00 00 00	92 37 04
G	82 23 20	89 27 12

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
G	00 00 00	89 27 10
F	277 36 40	92 37 06
G	00 00 00	89 27 12
F	277 36 36	92 37 04
G	00 00 00	89 27 10
F	277 36 40	92 37 06
G	00 00 00	89 27 12
F	277 36 38	92 37 04
G	00 00 00	89 27 10
F	277 36 40	92 37 06

Station2: Hospital of Handicaps (F)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
G	00 00 00	87 36 42
H	25 19 44	88 13 26
G	00 00 00	87 36 44
H	25 19 46	88 13 28
G	00 00 00	87 36 42
H	25 19 48	88 13 26
G	00 00 00	87 36 44
H	25 19 44	88 13 28
G	00 00 00	87 36 44
H	25 19 46	88 13 26

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
H	00 00 00	88 13 28
G	334 40 12	87 36 42
H	00 00 00	88 13 26
G	334 40 14	87 36 44
H	00 00 00	88 13 28
G	334 40 16	87 36 42
H	00 00 00	88 13 26
G	334 40 12	87 36 44
H	00 00 00	88 13 28
G	334 40 12	87 36 42

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
H	00 00 00	88 13 26
D	23 09 22	87 22 54
H	00 00 00	88 13 28
D	23 09 24	87 22 56
H	00 00 00	88 13 26
D	23 09 26	87 22 54
H	00 00 00	88 13 28
D	23 09 28	87 22 56
H	00 00 00	88 13 26
D	23 09 22	87 22 54

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	87 22 54
H	336 50 36	88 13 28
D	00 00 00	87 22 56
H	336 50 34	88 13 26
D	00 00 00	87 22 54
H	336 50 32	88 13 28
D	00 00 00	87 22 56
H	336 50 36	88 13 26
D	00 00 00	87 22 54
H	336 50 34	88 13 28

Station3: AL-Tamimi Complex (H)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	90 07 18
F	33 45 22	91 46 32
D	00 00 00	90 07 20
F	33 45 24	91 46 34
D	00 00 00	90 07 18
F	33 45 26	91 46 32
D	00 00 00	90 07 20
F	33 45 22	91 46 34
D	00 00 00	90 07 18
F	33 45 24	91 46 32

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	91 46 34
D	326 14 38	90 07 20
F	00 00 00	91 46 32
D	326 14 34	90 07 18
F	00 00 00	91 46 34
D	326 14 38	90 07 20
F	00 00 00	91 46 32
D	326 14 36	90 07 18
F	00 00 00	91 46 34
D	326 14 38	90 07 20

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	91 46 32
G	60 04 20	89 50 06
F	00 00 00	91 46 34
G	60 04 18	89 50 08
F	00 00 00	91 46 32
G	60 04 22	89 50 06

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
G	00 00 00	89 50 08
F	299 55 38	91 46 34
G	00 00 00	89 50 06
F	299 55 40	91 46 32
G	00 00 00	89 50 08
F	299 55 42	91 46 34

F	00 00 00	91 46 34
G	60 04 20	89 50 08
F	00 00 00	91 46 32
G	60 04 18	89 50 06

G	00 00 00	89 50 06
F	299 55 38	91 46 32
G	00 00 00	89 50 08
F	299 55 40	91 46 34

Station4: Natsheh's Building (G)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
H	00 00 00	90 09 52
D	45 28 48	90 32 48
H	00 00 00	90 09 54
D	45 28 50	90 32 50
H	00 00 00	90 09 52
D	45 28 46	90 32 48
H	00 00 00	90 09 54
D	45 28 48	90 32 50
H	00 00 00	90 09 52
D	45 28 50	90 32 48

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	90 32 50
H	314 31 08	90 09 54
D	00 00 00	90 32 48
H	314 31 10	90 09 52
D	00 00 00	90 32 50
H	314 31 14	90 09 54
D	00 00 00	90 32 48
H	314 31 12	90 09 52
D	00 00 00	90 32 50
H	314 31 08	90 09 54

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
F	00 00 00	92 23 16
D	49 06 38	90 32 48
F	00 00 00	92 23 18
D	49 06 40	90 32 50
F	00 00 00	92 23 16
D	49 06 38	90 32 48
F	00 00 00	92 23 18
D	49 06 42	90 32 50
F	00 00 00	92 23 16
D	49 06 38	90 32 48

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
D	00 00 00	90 32 50
F	310 53 22	92 23 18
D	00 00 00	90 32 48
F	310 53 20	92 23 16
D	00 00 00	90 32 50
F	310 53 18	92 23 18
D	00 00 00	90 32 48
F	310 53 22	92 23 16
D	00 00 00	90 32 50
F	310 53 20	92 23 18

C-4 Data for the Fourth Quadrilateral (G, H, I, J)

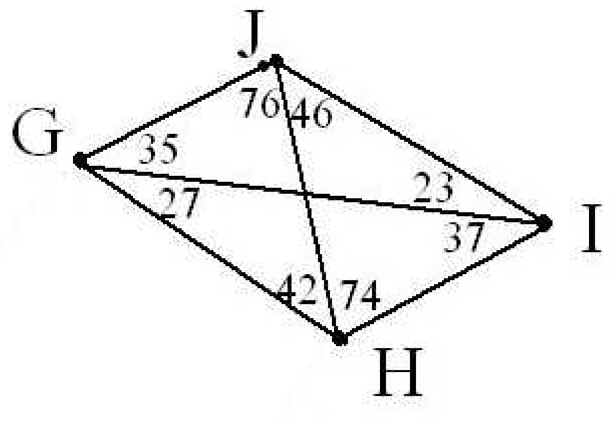


Figure C-4 Quadrilateral (G,H,I,J)

Station1: AL-Sharbate's Building (I)

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
H	00 00 00	90 28 22
G	36 56 12	89 46 08
H	00 00 00	90 28 24
G	36 56 10	89 46 10
H	00 00 00	90 28 22
G	36 56 12	89 46 08
H	00 00 00	90 28 24
G	36 56 08	89 46 10
H	00 00 00	90 28 22
G	36 56 12	89 46 08

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
G	00 00 00	89 46 10
H	323 03 48	90 28 24
G	00 00 00	89 46 08
H	323 03 50	90 28 22
G	00 00 00	89 46 10
H	323 03 52	90 28 24
G	00 00 00	89 46 08
H	323 03 48	90 28 22
G	00 00 00	89 46 10
H	323 03 50	90 28 24

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
G	00 00 00	89 46 08
J	23 01 32	89 49 46
G	00 00 00	89 46 10
J	23 01 34	89 49 48

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
J	00 00 00	89 49 48
G	336 58 26	89 46 10
J	00 00 00	89 49 46
G	336 58 28	89 46 08

G	00 00 00	89 46 08
J	23 01 32	89 49 46
G	00 00 00	89 46 10
J	23 01 30	89 49 48
G	00 00 00	89 46 08
J	23 01 32	89 49 46

J	00 00 00	89 49 48
G	336 58 30	89 46 10
J	00 00 00	89 49 46
G	336 58 26	89 46 08
J	00 00 00	89 49 48
G	336 58 28	89 46 10

Station2: Building of Essa Region (J)

Station	Horizontal angle. ○ ′ ”	Vertical angle ○ ′ ”
H	00 00 00	90 37 20
G	75 55 18	89 48 16
H	00 00 00	90 37 22
G	75 55 16	89 48 18
H	00 00 00	90 37 20
G	75 55 20	89 48 16
H	00 00 00	90 37 22
G	75 55 18	89 48 18
H	00 00 00	90 37 20
G	75 55 16	89 48 16

Station	Horizontal angle. ○ ′ ”	Vertical angle ○ ′ ”
G	00 00 00	89 48 18
H	284 04 42	90 37 22
G	00 00 00	89 48 16
H	284 04 44	90 37 20
G	00 00 00	89 48 18
H	284 04 42	90 37 22
G	00 00 00	89 48 16
H	284 04 44	90 37 20
G	00 00 00	89 48 18
H	284 04 42	90 37 22

Station	Horizontal angle. ○ ′ ”	Vertical angle ○ ′ ”
H	00 00 00	90 37 20
I	45 45 22	90 10 12
H	00 00 00	90 37 22
I	45 45 20	90 10 14
H	00 00 00	90 37 20
I	45 45 22	90 10 12
H	00 00 00	90 37 22
I	45 45 24	90 10 14
H	00 00 00	90 37 20
I	45 45 22	90 10 12

Station	Horizontal angle. ○ ′ ”	Vertical angle ○ ′ ”
I	00 00 00	90 10 14
H	314 14 36	90 37 22
I	00 00 00	90 10 12
H	314 14 40	90 37 20
I	00 00 00	90 10 14
H	314 14 38	90 37 22
I	00 00 00	90 10 12
H	314 14 36	90 37 20
I	00 00 00	90 10 14
H	314 14 40	90 37 22

Station3: AL-Tamimi Complex (H)

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
J	00 00 00	89 22 38
G	41 47 30	89 50 06
J	00 00 00	89 22 40
G	41 47 28	89 50 08
J	00 00 00	89 22 38
G	41 47 30	89 50 06
J	00 00 00	89 22 40
G	41 47 32	89 50 08
J	00 00 00	89 22 38
G	41 47 30	89 50 06

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
G	00 00 00	89 50 08
J	318 12 28	89 22 40
G	00 00 00	89 50 06
J	318 12 32	89 22 38
G	00 00 00	89 50 08
J	318 12 30	89 22 40
G	00 00 00	89 50 06
J	318 12 28	89 22 38
G	00 00 00	89 50 08
J	318 12 32	89 22 40

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
J	00 00 00	89 22 38
I	74 16 56	89 31 36
J	00 00 00	89 22 40
I	74 16 54	89 31 38
J	00 00 00	89 22 38
I	74 16 52	89 31 36
J	00 00 00	89 22 40
I	74 16 54	89 31 38
J	00 00 00	89 22 38
I	74 16 56	89 31 36

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
I	00 00 00	89 31 38
J	285 43 04	89 22 40
I	00 00 00	89 31 36
J	285 43 06	89 22 38
I	00 00 00	89 31 38
J	285 43 04	89 22 40
I	00 00 00	89 31 36
J	285 43 06	89 22 38
I	00 00 00	89 31 38
J	285 43 04	89 22 40

Station4: Natsheh's Building (G)

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
J	00 00 00	90 11 42
I	35 17 52	90 13 50
J	00 00 00	90 11 44
I	35 17 54	90 13 52
J	00 00 00	90 11 42

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
I	00 00 00	90 13 52
J	324 42 04	90 11 44
I	00 00 00	90 13 50
J	324 42 06	90 11 42
I	00 00 00	90 13 52

I	35 17 56	90 13 50
J	00 00 00	90 11 44
I	35 17 58	90 13 52
J	00 00 00	90 11 42
I	35 17 52	90 13 50

J	324 42 02	90 11 44
I	00 00 00	90 13 50
J	324 42 04	90 11 42
I	00 00 00	90 13 52
J	324 42 06	90 11 44

Station	Horizontal angle. ° ′ ”	Vertical angle ° ′ ”
I	00 00 00	90 13 50
H	26 59 14	90 09 52
I	00 00 00	90 13 52
H	26 59 12	90 09 54
I	00 00 00	90 13 50
H	26 59 16	90 09 52
I	00 00 00	90 13 52
H	26 59 10	90 09 54
I	00 00 00	90 13 50
H	26 59 14	90 09 52

Station	Horizontal angle. ° ′ ”	Vertical angle ° ′ ”
H	00 00 00	90 09 54
I	333 00 48	90 13 52
H	00 00 00	90 09 52
I	333 00 50	90 13 50
H	00 00 00	90 09 54
I	333 00 48	90 13 52
H	00 00 00	90 09 52
I	333 00 44	90 13 50
H	00 00 00	90 09 54
I	333 00 48	90 13 52

C-5 Data for the Fifth Quadrilateral (J, I, K, L).

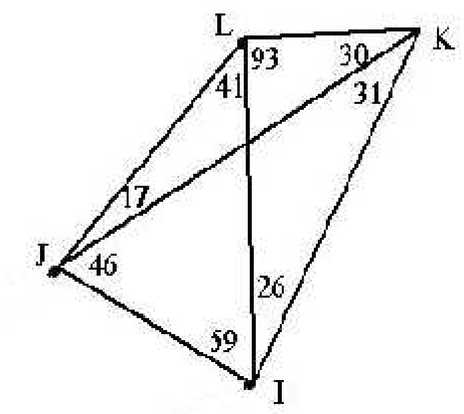


Figure C-5 Quadrilateral (J,I,K,L)

Station1: AL-Moqata'a (L)

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
K	00 00 00	88 54 22
I	92 51 24	89 13 32
K	00 00 00	88 54 24
I	92 51 26	89 13 34
K	00 00 00	88 54 22
I	92 51 22	89 13 32
K	00 00 00	88 54 24
I	92 51 24	89 13 34
K	00 00 00	88 54 22
I	92 51 26	89 13 32

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
I	00 00 00	89 13 34
K	265 08 36	88 54 22
I	00 00 00	89 13 32
K	265 08 38	88 54 24
I	00 00 00	89 13 34
K	265 08 34	88 54 22
I	00 00 00	89 13 32
K	265 08 36	88 54 24
I	00 00 00	89 13 34
K	265 08 38	88 54 22

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
I	00 00 00	89 13 32
J	40 39 40	88 57 06
I	00 00 00	89 13 34
J	40 39 42	88 57 08
I	00 00 00	89 13 32
J	40 39 40	88 57 06
I	00 00 00	89 13 34
J	40 39 38	88 57 08
I	00 00 00	89 13 32
J	40 39 40	88 57 06

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
J	00 00 00	88 57 08
I	319 20 20	89 13 34
J	00 00 00	88 57 06
I	319 20 22	89 13 32
J	00 00 00	88 57 08
I	319 20 18	89 13 34
J	00 00 00	88 57 06
I	319 20 20	89 13 32
J	00 00 00	88 57 08
I	319 20 22	89 13 34

Station2: Building of Nimra Region (K)

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
I	00 00 00	89 49 42
J	31 10 56	89 44 16
I	00 00 00	89 49 44
J	31 10 58	89 44 18
I	00 00 00	89 49 42
J	31 10 56	89 44 16
I	00 00 00	89 49 44

Station	Horizontal angle. ° ' "	Vertical angle ° ' "
J	00 00 00	89 44 18
I	328 49 02	89 49 44
J	00 00 00	89 44 16
I	328 49 04	89 49 42
J	00 00 00	89 44 18
I	328 49 02	89 49 44
J	00 00 00	89 44 16

J	31 10 58	89 44 18
I	00 00 00	89 49 42
J	31 10 56	89 44 16

I	328 49 04	89 49 42
J	00 00 00	89 44 18
I	328 49 02	89 49 44

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
J	00 00 00	89 44 16
L	29 42 56	91 05 36
J	00 00 00	89 44 18
L	29 42 58	91 05 38
J	00 00 00	89 44 16
L	29 42 54	91 05 36
J	00 00 00	89 44 18
L	29 42 56	91 05 38
J	00 00 00	89 44 16
L	29 42 58	91 05 36

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
L	00 00 00	91 05 38
J	330 17 02	89 44 18
L	00 00 00	91 05 36
J	330 17 04	89 44 16
L	00 00 00	91 05 38
J	330 17 06	89 44 18
L	00 00 00	91 05 36
J	330 17 02	89 44 16
L	00 00 00	91 05 38
J	330 17 06	89 44 18

Station3: AL-Sharbate's Building (I)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
J	00 00 00	89 49 46
L	59 01 54	90 46 26
J	00 00 00	89 49 48
L	59 01 56	90 46 28
J	00 00 00	89 49 46
L	59 01 54	90 46 26
J	00 00 00	89 49 48
L	59 01 56	90 46 28
J	00 00 00	89 49 46
L	59 01 54	90 46 26

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
L	00 00 00	90 46 28
J	300 58 04	89 49 48
L	00 00 00	90 46 26
J	300 58 06	89 49 46
L	00 00 00	90 46 28
J	300 58 04	89 49 48
L	00 00 00	90 46 26
J	300 58 06	89 49 46
L	00 00 00	90 46 28
J	300 58 04	89 49 48

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
L	00 00 00	90 46 26
K	26 14 54	90 10 16
L	00 00 00	90 46 28

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
K	00 00 00	90 10 18
L	333 45 04	90 46 28
K	00 00 00	90 10 16

K	26 14 56	90 10 18
L	00 00 00	90 46 26
K	26 14 58	90 10 16
L	00 00 00	90 46 28
K	26 14 54	90 10 18
L	00 00 00	90 46 26
K	26 14 56	90 10 16

L	333 45 02	90 46 26
K	00 00 00	90 10 18
L	333 45 06	90 46 28
K	00 00 00	90 10 16
L	333 45 04	90 46 26
K	00 00 00	90 10 18
L	333 45 02	90 46 28

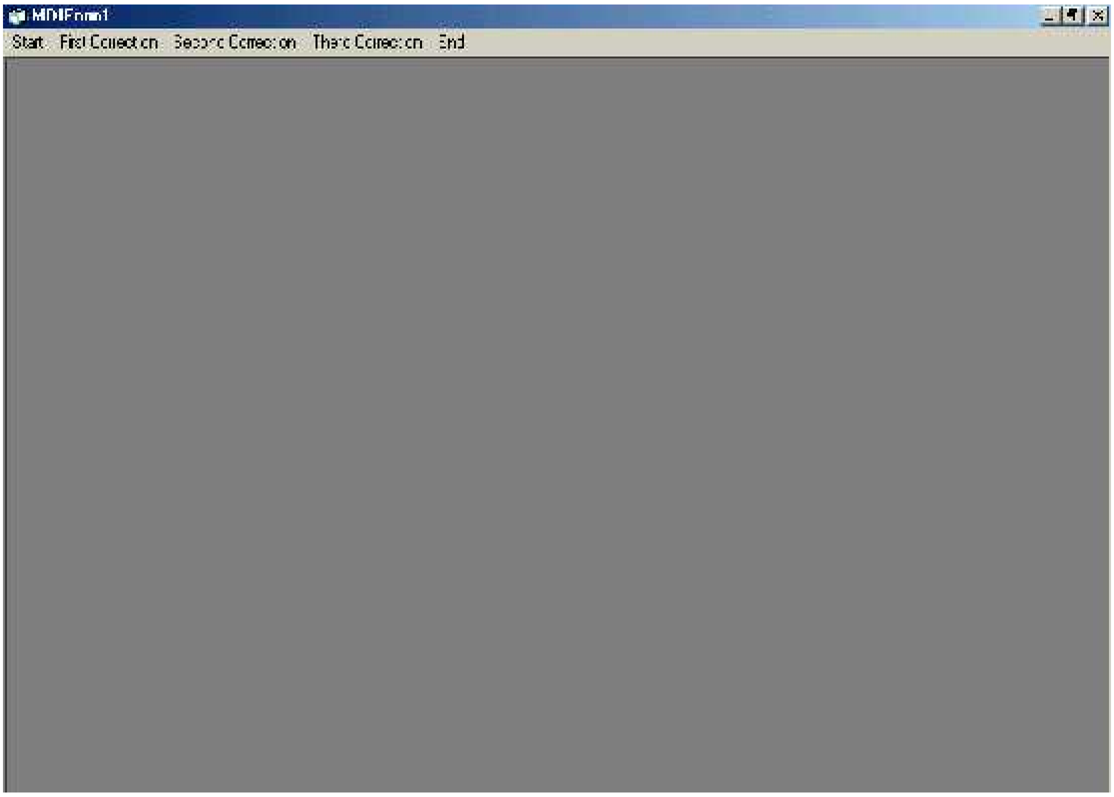
Station4: Building of Essa Region (J)

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
L	00 00 00	91 02 52
K	16 46 58	90 15 42
L	00 00 00	91 02 54
K	16 46 56	90 15 44
L	00 00 00	91 02 52
K	16 46 56	90 15 42
L	00 00 00	91 02 54
K	16 46 56	90 15 44
L	00 00 00	91 02 52
K	16 46 54	90 15 42

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
K	00 00 00	90 15 44
L	343 13 06	91 02 54
K	00 00 00	90 15 42
L	343 13 02	91 02 52
K	00 00 00	90 15 44
L	343 13 0	91 02 54
K	00 00 00	90 15 42
L	343 13 0	91 02 52
K	00 00 00	90 15 44
L	343 13 06	91 02 54

Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
K	00 00 00	90 15 42
I	62 31 14	90 10 12
K	00 00 00	90 15 44
I	62 31 16	90 10 14
K	00 00 00	90 15 42
I	62 31 12	90 10 12
K	00 00 00	90 15 44
I	62 31 14	90 10 14
K	00 00 00	90 15 42
I	62 31 16	90 10 12

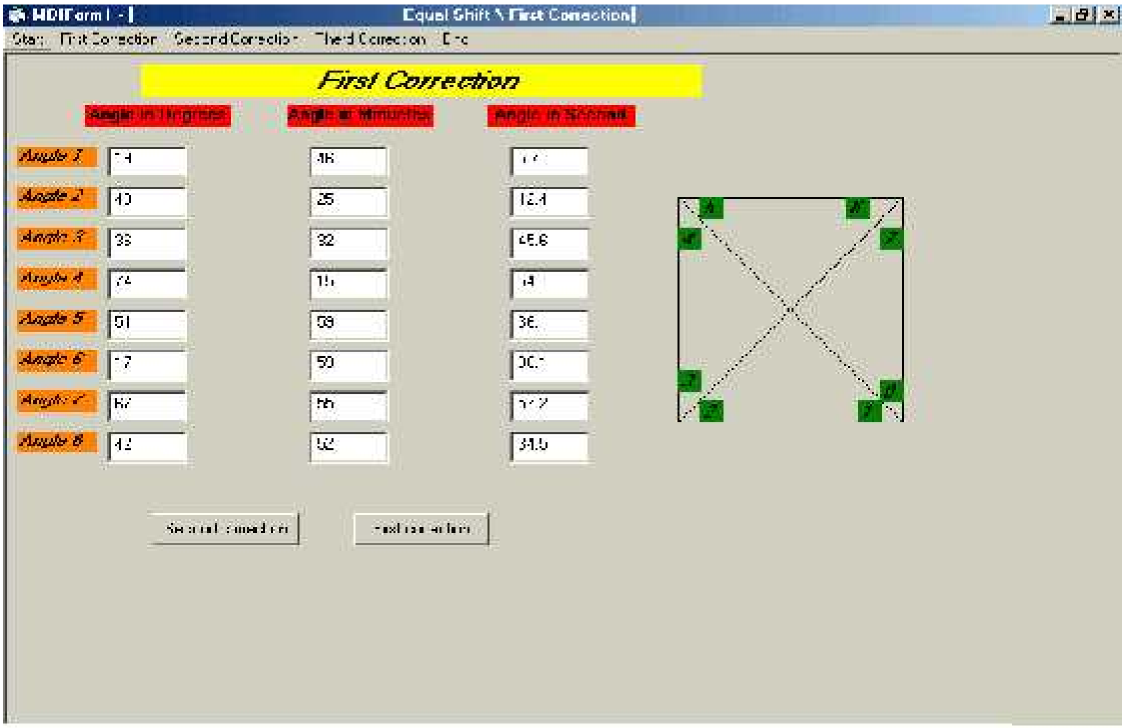
Station	Horizontal angle. ° ′ ″	Vertical angle ° ′ ″
I	00 00 00	90 10 14
K	297 27 42	90 15 44
I	00 00 00	90 10 12
K	297 27 44	90 15 42
I	00 00 00	90 10 14
K	297 27 42	90 15 44
I	00 00 00	90 10 12
K	297 27 46	90 15 42
I	00 00 00	90 10 14
K	297 27 48	90 15 44




```
Private Sub Command1_Click()
Dim s, s1, s2, s3, s4, s5, s6, s7, s8, e As Double

s1 = Val(Text1.Text) + Val(Text2.Text) / 60 + Val(Text3.Text) / 3600
s2 = Val(Text4.Text) + Val(Text5.Text) / 60 + Val(Text6.Text) / 3600
s3 = Val(Text7.Text) + Val(Text8.Text) / 60 + Val(Text9.Text) / 3600
s4 = Val(Text10.Text) + Val(Text11.Text) / 60 + Val(Text12.Text) / 3600
s5 = Val(Text13.Text) + Val(Text14.Text) / 60 + Val(Text15.Text) / 3600
s6 = Val(Text16.Text) + Val(Text17.Text) / 60 + Val(Text18.Text) / 3600
s7 = Val(Text19.Text) + Val(Text20.Text) / 60 + Val(Text21.Text) / 3600
s8 = Val(Text22.Text) + Val(Text23.Text) / 60 + Val(Text24.Text) / 3600

s = s1 + s2 + s3 + s4 + s5 + s6 + s7 + s8

  e = 360 - s
   s1 = (s1 + (e / 8))
   s2 = (s2 + (e / 8))
   s3 = (s3 + (e / 8))
   s4 = (s4 + (e / 8))
```

```
s5 = (s5 + (e / 8))
s6 = (s6 + (e / 8))
s7 = (s7 + (e / 8))
s8 = (s8 + (e / 8))

d1 = Fix(s1)
a1 = ((s1 - d1) * 60)
m1 = Fix(a1)
s1 = ((a1 - m1) * 60)
s1 = Format(s1, "##.00")

d2 = Fix(s2)
a2 = ((s2 - d2) * 60)
m2 = Fix(a2)
s2 = ((a2 - m2) * 60)
s2 = Format(s2, "##.00")

d3 = Fix(s3)
a3 = ((s3 - d3) * 60)
m3 = Fix(a3)
s3 = ((a3 - m3) * 60)
s3 = Format(s3, "##.00")

d4 = Fix(s4)
a4 = ((s4 - d4) * 60)
m4 = Fix(a4)
s4 = ((a4 - m4) * 60)
s4 = Format(s4, "##.00")

d5 = Fix(s5)
a5 = ((s5 - d5) * 60)
m5 = Fix(a5)
s5 = ((a5 - m5) * 60)
s5 = Format(s5, "##.00")

d6 = Fix (s6)
a6 = ((s6 - d6) * 60)
m6 = Fix (a6)
s6 = ((a6 - m6) * 60)
s6 = Format(s6, "##.00")

d7 = Fix (s7)
a7 = ((s7 - d7) * 60)
m7 = Fix (a7)
```

```
        s7 = ((a7 - m7) * 60)
        s7 = Format (s7, "##.00")

        d8 = Fix (s8)
        a8 = ((s8 - d8) * 60)
        m8 = Fix(a8)
        s8 = ((a8 - m8) * 60)
        s8 = Format(s8, "##.00")

        Text1.Text = d1
        Text2.Text = m1
        Text3.Text = s1
        Text4.Text = d2
        Text5.Text = m2
        Text6.Text = s2
        Text7.Text = d3
        Text8.Text = m3
        Text9.Text = s3
        Text10.Text = d4
        Text11.Text = m4
        Text12.Text = s4
        Text13.Text = d5
        Text14.Text = m5
        Text15.Text = s5
        Text16.Text = d6
        Text17.Text = m6
        Text18.Text = s6
        Text19.Text = d7
        Text20.Text = m7
        Text21.Text = s7
        Text22.Text = d8
        Text23.Text = m8
        Text24.Text = s8

        End Sub

Private Sub Command2_Click()
Form2.Visible = True
Form1.Visible = False

End Sub
```



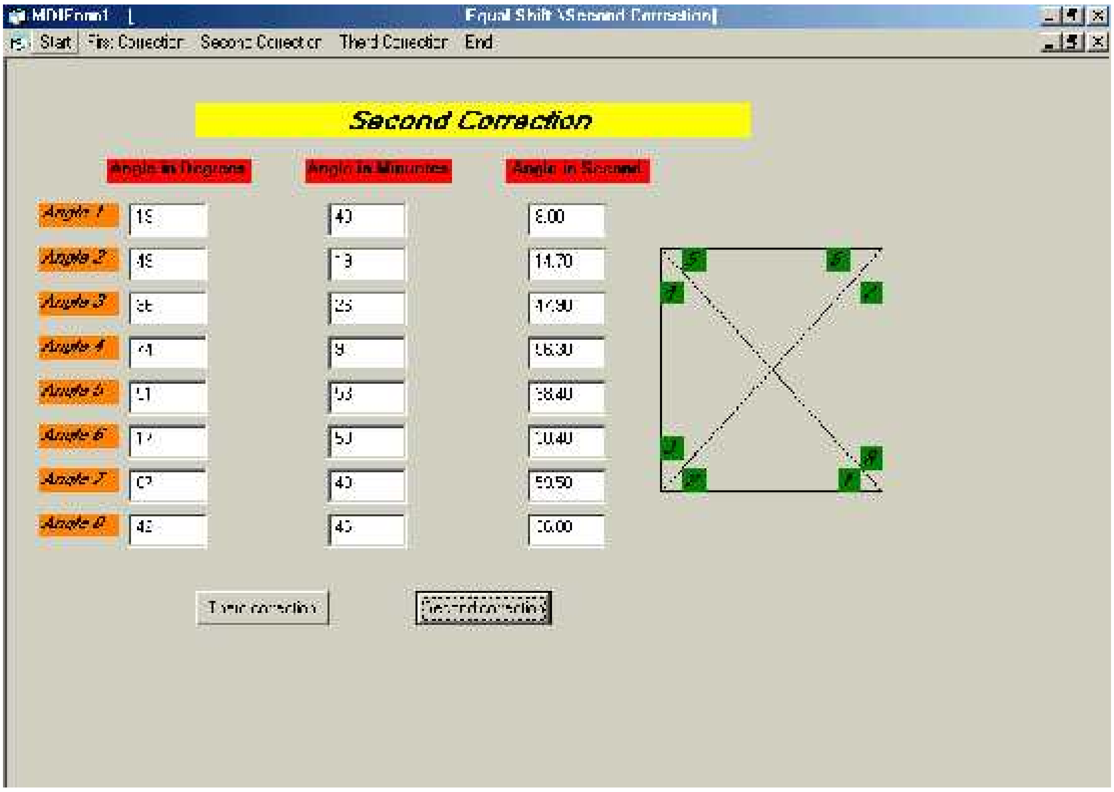

```
Private Sub Form_Load()
Dim s1, s2, s3, s4, s5, s6, s7, s8, e As Double
Dim r, r1, r2, c, c1, c2 As Double
Text1.Text = Form1.Text1.Text
Text2.Text = Form1.Text2.Text
Text3.Text = Form1.Text3.Text
Text4.Text = Form1.Text4.Text
Text5.Text = Form1.Text5.Text
Text6.Text = Form1.Text6.Text
Text7.Text = Form1.Text7.Text
Text8.Text = Form1.Text8.Text
Text9.Text = Form1.Text9.Text
Text10.Text = Form1.Text10.Text
Text11.Text = Form1.Text11.Text
Text12.Text = Form1.Text12.Text
Text13.Text = Form1.Text13.Text
Text14.Text = Form1.Text14.Text
Text15.Text = Form1.Text15.Text
Text16.Text = Form1.Text16.Text
Text17.Text = Form1.Text17.Text
Text18.Text = Form1.Text18.Text
Text19.Text = Form1.Text19.Text
```

```
Text20.Text = Form1.Text20.Text
Text21.Text = Form1.Text21.Text
Text22.Text = Form1.Text22.Text
Text23.Text = Form1.Text23.Text
Text24.Text = Form1.Text24.Text

s1 = (Text1.Text) + (Text2.Text / 60) + (Text3.Text / 3600)
s2 = (Text4.Text) + (Text5.Text / 60) + (Text6.Text / 3600)
s3 = (Text7.Text) + (Text8.Text / 60) + (Text9.Text / 3600)
s4 = (Text10.Text) + (Text11.Text / 60) + (Text12.Text / 3600)
s5 = (Text13.Text) + (Text14.Text / 60) + (Text15.Text / 3600)
s6 = (Text16.Text) + (Text17.Text / 60) + (Text18.Text / 3600)
s7 = ((Text19.Text) + (Text20.Text / 60) + (Text21.Text / 3600))
s8 = (Text22.Text) + (Text23.Text / 60) + (Text24.Text / 3600)

End Sub

Private Sub Command1_Click()

Dim s1, s2, s3, s4, s5, s6, s7, s8, e As Double
Dim r, r1, r2, c, c1, c2 As Double
Text1.Text = Form1.Text1.Text
Text2.Text = Form1.Text2.Text
Text3.Text = Form1.Text3.Text
Text4.Text = Form1.Text4.Text
Text5.Text = Form1.Text5.Text
Text6.Text = Form1.Text6.Text
Text7.Text = Form1.Text7.Text
Text8.Text = Form1.Text8.Text
Text9.Text = Form1.Text9.Text
Text10.Text = Form1.Text10.Text
Text11.Text = Form1.Text11.Text
Text12.Text = Form1.Text12.Text
Text13.Text = Form1.Text13.Text
Text14.Text = Form1.Text14.Text
Text15.Text = Form1.Text15.Text
Text16.Text = Form1.Text16.Text
Text17.Text = Form1.Text17.Text
Text18.Text = Form1.Text18.Text
Text19.Text = Form1.Text19.Text
Text20.Text = Form1.Text20.Text
Text21.Text = Form1.Text21.Text
Text22.Text = Form1.Text22.Text
Text23.Text = Form1.Text23.Text
```

```
Text24.Text = Form1.Text24.Text

s1 = (Text1.Text) + (Text2.Text / 60) + (Text3.Text / 3600)
s2 = (Text4.Text) + (Text5.Text / 60) + (Text6.Text / 3600)
s3 = (Text7.Text) + (Text8.Text / 60) + (Text9.Text / 3600)
s4 = (Text10.Text) + (Text11.Text / 60) + (Text12.Text / 3600)
s5 = (Text13.Text) + (Text14.Text / 60) + (Text15.Text / 3600)
s6 = (Text16.Text) + (Text17.Text / 60) + (Text18.Text / 3600)
s7 = ((Text19.Text) + (Text20.Text / 60) + (Text21.Text / 3600))
s8 = (Text22.Text) + (Text23.Text / 60) + (Text24.Text / 3600)


  r1 = s1 + s2
  r2 = s5 + s6
  r = r1 - r2

  s1 = (s1 - (r / 4))
  s2 = (s2 - (r / 4))
  s5 = (s5 + (r / 4))
  s6 = (s6 + (r / 4))

  c1 = s3 + s4
  c2 = s7 + s8
  c = c1 - c2

  s3 = (s3 - (c / 4))
  s4 = (s4 - (c / 4))
  s7 = (s7 + (c / 4、))
  s8 = (s8 + (c / 4))

   d1 = Fix(s1)
   a1 = ((s1 - d1) * 60)
   m1 = Fix(a1)
   s1 = ((a1 - m1) * 60)
   s1 = Format(s1, "##.00")

   d2 = Fix(s2)
   a2 = ((s2 - d2) * 60)
   m2 = Fix(a2)
   s2 = ((a2 - m2) * 60)
   s2 = Format(s2, "##.00")

   d3 = Fix(s3)
   a3 = ((s3 - d3) * 60)
```

```
m3 = Fix(a3)
s3 = ((a3 - m3) * 60)
s3 = Format(s3, "##.00")

d4 = Fix(s4)
a4 = ((s4 - d4) * 60)
m4 = Fix(a4)
s4 = ((a4 - m4) * 60)
s4 = Format(s4, "##.00")

d5 = Fix(s5)
a5 = ((s5 - d5) * 60)
m5 = Fix(a5)
s5 = ((a5 - m5) * 60)
s5 = Format(s5, "##.00")

d6 = Fix(s6)
a6 = ((s6 - d6) * 60)
m6 = Fix(a6)
s6 = ((a6 - m6) * 60)
s6 = Format(s6, "##.00")

d7 = Fix(s7)
a7 = ((s7 - d7) * 60)
m7 = Fix(a7)
s7 = ((a7 - m7) * 60)
s7 = Format(s7, "##.00")

d8 = Fix(s8)
a8 = ((s8 - d8) * 60)
m8 = Fix(a8)
s8 = ((a8 - m8) * 60)
s8 = Format(s8, "##.00")

Text1.Text = d1
Text2.Text = m1
Text3.Text = s1
Text4.Text = d2
Text5.Text = m2
Text6.Text = s2
Text7.Text = d3
Text8.Text = m3
Text9.Text = s3
Text10.Text = d4
```

```
Text11.Text = m4
Text12.Text = s4
Text13.Text = d5
Text14.Text = m5
Text15.Text = s5
Text16.Text = d6
Text17.Text = m6
Text18.Text = s6
Text19.Text = d7
Text20.Text = m7
Text21.Text = s7
Text22.Text = d8
Text23.Text = m8
Text24.Text = s8
End Sub

Private Sub Command2_Click()
Form3.Visible = True
Form2.Visible = False
End Sub
```



```
Private Sub Form_Load()
Form3.Text1.Text = Form2.Text1.Text
Form3.Text2.Text = Form2.Text2.Text
Form3.Text3.Text = Form2.Text3.Text
Form3.Text4.Text = Form1.Text4.Text
Form3.Text5.Text = Form2.Text5.Text
Form3.Text6.Text = Form2.Text6.Text
Form3.Text7.Text = Form2.Text7.Text
Form3.Text8.Text = Form2.Text8.Text
Form3.Text9.Text = Form2.Text9.Text
Form3.Text10.Text = Form2.Text10.Text
Form3.Text11.Text = Form2.Text11.Text
Form3.Text12.Text = Form2.Text12.Text
Form3.Text13.Text = Form2.Text13.Text
Form3.Text14.Text = Form2.Text14.Text
Form3.Text15.Text = Form2.Text15.Text
Form3.Text16.Text = Form2.Text16.Text
Form3.Text17.Text = Form2.Text17.Text
Form3.Text18.Text = Form2.Text18.Text
Form3.Text19.Text = Form2.Text19.Text
Form3.Text20.Text = Form2.Text20.Text
Form3.Text21.Text = Form2.Text21.Text
Form3.Text22.Text = Form2.Text22.Text
Form3.Text23.Text = Form2.Text23.Text
Form3.Text24.Text = Form2.Text24.Text

s1 = Form3.Text1.Text + Form3.Text2.Text / 60 + Form3.Text3.Text / 3600
s2 = Form3.Text4.Text + Form3.Text5.Text / 60 + Form3.Text6.Text / 3600
s3 = Form3.Text7.Text + Form3.Text8.Text / 60 + Form3.Text9.Text / 3600
s4 = Form3.Text10.Text + Form3.Text11.Text / 60 + Form3.Text12.Text / 3600
s5 = Form3.Text13.Text + Form3.Text14.Text / 60 + Form3.Text15.Text / 3600
s6 = Form3.Text16.Text + Form3.Text17.Text / 60 + Form3.Text18.Text / 3600
s7 = Form3.Text19.Text + Form3.Text20.Text / 60 + Form3.Text21.Text / 3600
s8 = Form3.Text22.Text + Form3.Text23.Text / 60 + Form3.Text24.Text / 3600

End Sub

Private Sub Command1_Click()
Dim s, s1, s2, s3, s4, s5, s6, s7, s8 As Double
Dim l1, l2, l3, l4, l5, l6, l7, l8 As Double
Dim p1, p2, p3, p4, p5, p6, p7, p8 As Double
Dim t1, t2, t3, t4, t5, t6, t7, t8, n, y As Double

Form3.Text1.Text = Form2.Text1.Text
```

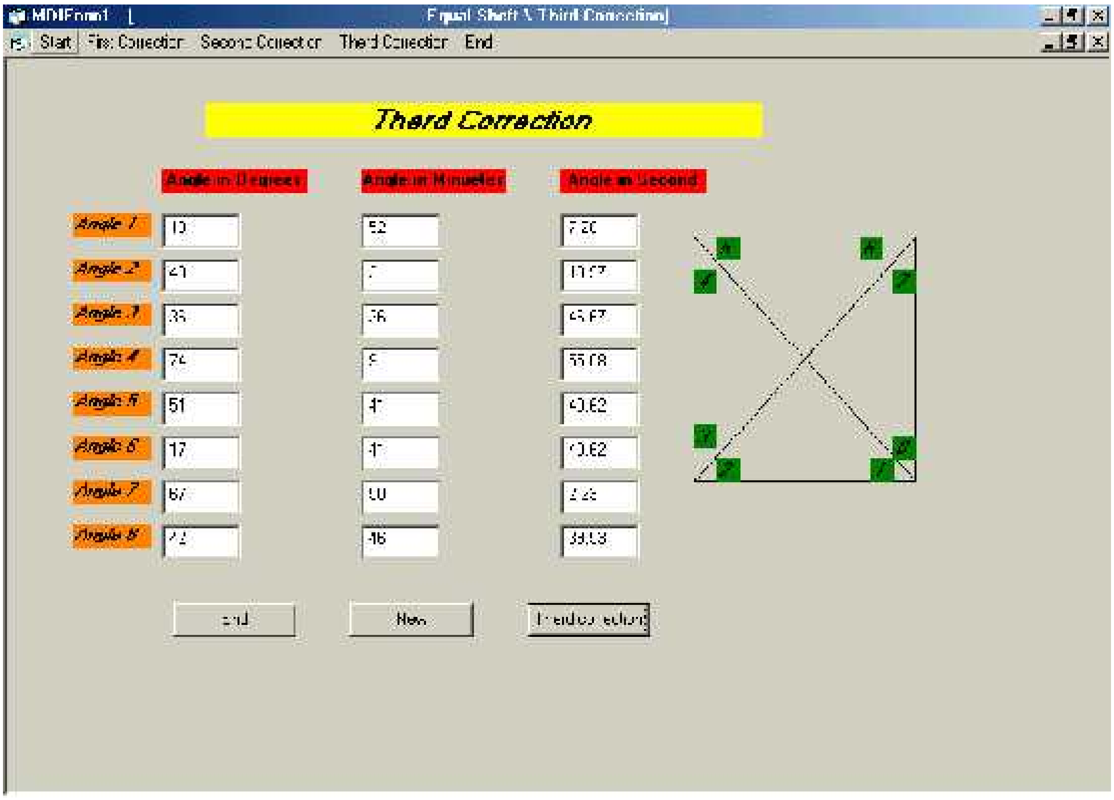
```
Form3.Text2.Text = Form2.Text2.Text
Form3.Text3.Text = Form2.Text3.Text
Form3.Text4.Text = Form1.Text4.Text
Form3.Text5.Text = Form2.Text5.Text
Form3.Text6.Text = Form2.Text6.Text
Form3.Text7.Text = Form2.Text7.Text
Form3.Text8.Text = Form2.Text8.Text
Form3.Text9.Text = Form2.Text9.Text
Form3.Text10.Text = Form2.Text10.Text
Form3.Text11.Text = Form2.Text11.Text
Form3.Text12.Text = Form2.Text12.Text
Form3.Text13.Text = Form2.Text13.Text
Form3.Text14.Text = Form2.Text14.Text
Form3.Text15.Text = Form2.Text15.Text
Form3.Text16.Text = Form2.Text16.Text
Form3.Text17.Text = Form2.Text17.Text
Form3.Text18.Text = Form2.Text18.Text
Form3.Text19.Text = Form2.Text19.Text
Form3.Text20.Text = Form2.Text20.Text
Form3.Text21.Text = Form2.Text21.Text
Form3.Text22.Text = Form2.Text22.Text
Form3.Text23.Text = Form2.Text23.Text
Form3.Text24.Text = Form2.Text24.Text

s1 = Form3.Text1.Text + Form3.Text2.Text / 60 + Form3.Text3.Text / 3600
s2 = Form3.Text4.Text + Form3.Text5.Text / 60 + Form3.Text6.Text / 3600
s3 = Form3.Text7.Text + Form3.Text8.Text / 60 + Form3.Text9.Text / 3600
s4 = Form3.Text10.Text + Form3.Text11.Text / 60 + Form3.Text12.Text / 3600
s5 = Form3.Text13.Text + Form3.Text14.Text / 60 + Form3.Text15.Text / 3600
s6 = Form3.Text16.Text + Form3.Text17.Text / 60 + Form3.Text18.Text / 3600
s7 = Form3.Text19.Text + Form3.Text20.Text / 60 + Form3.Text21.Text / 3600
s8 = Form3.Text22.Text + Form3.Text23.Text / 60 + Form3.Text24.Text / 3600

l1 = ((Log(Sin(s1 * (22 / (180 * 7))))))
l2 = ((Log(Sin(s2 * (22 / (180 * 7))))))
l3 = ((Log(Sin(s3 * (22 / (180 * 7))))))
l4 = ((Log(Sin(s4 * (22 / (180 * 7))))))
l5 = ((Log(Sin(s5 * (22 / (180 * 7))))))
l6 = ((Log(Sin(s6 * (22 / (180 * 7))))))
l7 = ((Log(Sin(s7 * (22 / (180 * 7))))))
l8 = ((Log(Sin(s8 * (22 / (180 * 7))))))

ld = l1 + l3 + l5 + l7
le = l2 + l4 + l6 + l8
```

```
l = ld - le
l = Format(l, "#.000000")

p1 = s1 + (10 / 3600)
p2 = s2 + (10 / 3600)
p3 = s3 + (10 / 3600)
p4 = s4 + (10 / 3600)
p5 = s5 + (10 / 3600)
p6 = s6 + (10 / 3600)
p7 = s7 + (10 / 3600)
p8 = s8 + (10 / 3600)

t1 = ((Log(Sin(p1 * (22 / (180 * 7))))))
t2 = ((Log(Sin(p2 * (22 / (180 * 7))))))
t3 = ((Log(Sin(p3 * (22 / (180 * 7))))))
t4 = ((Log(Sin(p4 * (22 / (180 * 7))))))
t5 = ((Log(Sin(p5 * (22 / (180 * 7))))))
t6 = ((Log(Sin(p6 * (22 / (180 * 7))))))
t7 = ((Log(Sin(p7 * (22 / (180 * 7))))))
t8 = ((Log(Sin(p8 * (22 / (180 * 7))))))

n = (t1 - l1) + (t2 - l2) + (t3 - l3) + (t4 - l4) + (t5 - l5) + (t6 - l6) + (t7 - l7) + (t8 - sl8)
y = (l * 10 / (3600 * n))
  y = Format(y, "#.000000")
  s1 = (s1 + y)
  s2 = (s2 + y)
  s3 = (s3 + y)
  s4 = (s4 + y)
  s5 = (s5 + y)
  s6 = (s6 + y)
  s7 = (s7 + y)
  s8 = (s8 + y)

    d1 = Fix(s1)
    a1 = ((s1 - d1) * 60)
    m1 = Fix(a1)
    s1 = ((a1 - m1) * 60)
    s1 = Format(s1, "##.00")
    d2 = Fix(s2)
    a2 = ((s2 - d2) * 60)
    m2 = Fix(a2)
    s2 = ((a2 - m2) * 60)
    s2 = Format(s2, "##.00")
    d3 = Fix(s3)
```

```
a3 = ((s3 - d3) * 60)
m3 = Fix(a3)
s3 = ((a3 - m3) * 60)
s3 = Format(s3, "##.00")
d4 = Fix(s4)
a4 = ((s4 - d4) * 60(
m4 = Fix(a4)
s4 = ((a4 - m4) * 60)
s4 = Format(s4, "##.00")
d5 = Fix(s5)
a5 = ((s5 - d5) * 60)
m5 = Fix(a5)
s5 = ((a5 - m5) * 60)
s5 = Format(s5, "##.00")
d6 = Fix(s6)
a6 = ((s6 - d6) * 60)
m6 = Fix(a6)
s6 = ((a6 - m6) * 60)
s6 = Format(s6, "##.00")

d7 = Fix(s7)
a7 = ((s7 - d7) * 60)
m7 = Fix(a7)
s7 = ((a7 - m7) * 60)
s7 = Format(s7, "##.00")
d8 = Fix(s8)
a8 = ((s8 - d8) * 60)
m8 = Fix(a8)
s8 = ((a8 - m8) * 60)
s8 = Format(s8, "##.00 ")

Text1.Text = d1
Text2.Text = m1
Text3.Text = s1
Text4.Text = d2
Text5.Text = m2
Text6.Text = s2
Text7.Text = d3
Text8.Text = m3
Text9.Text = s3
Text10.Text = d4
Text11.Text = m4
Text12.Text = s4
Text13.Text = d5
```

```
Text14.Text = m5
Text15.Text = s5
Text16.Text = d6
Text17.Text = m6
Text18.Text = s6
Text19.Text = d7
Text20.Text = m7
Text21.Text = s7
Text22.Text = d8
Text23.Text = m8
Text24.Text = s8

End Sub

Private Sub Command2_Click()
Form1.Visible = True
Form1.Visible = False
Form1.Text1.Text"" =
Form1.Text2.Text"" =
Form1.Text3.Text"" =
Form1.Text4.Text"" =
Form1.Text5.Text"" =
Form1.Text6.Text"" =
Form1.Text7.Text"" =
Form1.Text8.Text"" =
Form1.Text9.Text"" =
Form1.Text10.Text"" =
Form1.Text11.Text"" =
Form1.Text12.Text"" =
Form1.Text13.Text"" =
Form1.Text14.Text"" =
Form1.Text15.Text"" =
Form1.Text16.Text"" =
Form1.Text17.Text"" =
Form1.Text18.Text"" =
Form1.Text19.Text"" =
Form1.Text20.Text"" =
Form1.Text21.Text"" =
Form1.Text22.Text"" =
Form1.Text23.Text"" =
Form1.Text24.Text"" =

End Sub
```

```
Private Sub Command3_Click()
End
End Sub
```



Reference

1- W. Schofield; Engineering Surveying; Fifth edition, Linacre House, Jordan Hill, Oxford OX2 8DP, 2001

2- Maslov, Gordeev, Batrakov ; Geodetic Surveying ; 1972.

3- Raymond E. Davis, Francis S. Foote, James M. Anderson and Edward M. Mikhail; Surveying Theory and Practice; Impresora Donneco Internacional ; Mexico; 1981.

4- http://www.landservices-sa.gov.au

5- http://www.geo.tudelft.nl/fmr/deoslatter

6- http://www.answering-islam.org/scicnce/globecoins.html

Angle No	Observed anglw			1st Corr'n	1st corr'd angle			1+2 = 5+6 3+4 = 7+8			2nd Corr'n	2nd corr'd angle			Sin odd Angles product	Cot odd angles sum	Sin even angles product	Cot even angles sum	3rd Corr'n	Final corr'd angle		
	°	′	″	″	°	′	″	°	′	″	″	°	′	″						°	′	″
1	50	42	27	-1	50	42	26	117	30	19	+1	50	42	27	0.773923	0.8182703			+1	50	42	28
2	66	47	54	-1	66	47	53				+1	66	47	54	×	+	0.919124	0.4286344	-1	66	47	53
3	41	24	32	-1	41	24	31	62	29	36	+2	41	24	33	0.661432	1.1339115	×	+	+1	41	24	34
4	21	05	06	-1	21	05	05				+1	21	05	06	×	+	0.359753	2.593582.9	-1	21	05	05
5	74	13	36	-1	74	13	35	117	30	23	-1	74	13	34	0.962342	0.2824794	×	+	+1	74	13	35
6	43	16	49	-1	43	16	48				-1	43	16	47	×	+	0.685561	1.061927.3	-1	43	16	46
7	18	36	14	-1	18	36	13	62	29	42	-1	18	36	12	0.319014	2.9708676	×	+	+1	18	36	13
8	43	53	30	-1	43	53	29				-2	43	53	27			0.693287	1.039486.9	-1	43	53	26
Σ	360	00	08	-8	360	00	00					360	00	00	0.1571528	5.2055288	0.1571584	5.1236315		360	00	00
															A	B	C	D				

Table 4.6 Adjustment of braced quadrilateral by equal shift

$$3 \text{ rd correction} = \frac{206265(A-C)}{AB+CD}$$

$$= 0.7'' \approx 1''$$

If A > C then add to even angles and subtract from odd angles and vice versa