



DEVELOPING A COMPUTER PROGRAM FOR MODELING THE STADIA MEASUREMENTS FOR TACHEOMETRY WORKS

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ABSTRACT:

Tacheometry is used to measure the lengths of traverse sides, to check the more accurate taped distances in order to uncover gross errors or mistakes and to determine differences of elevation between points. It's most general use is found in the compilation of planimetric and topographic maps by field methods alone, by which distances, elevations and directions to points are to be determined from field control points whose positions have been established by a higher order of accuracy.

The principles of stadia measurement by use of the transit or theodolite or total station is one of the main method of tacheometry. This paper presents the principles of stadia measurement and a computer program **MSM** (**M**odeling the **S**tadia **M**easurements). The program is formulated and written by using the Visual Basic language, Version 6. This version of the language is objecting oriented provided with comprehensive tools to simplify the task of programming and to provide the programmer with wide range of options for design of the user interface system.

الخلاصة:

التاكيوميترية يستعمل لقياس اطوال اضلاع المضلع، لتدقيق المسافات المسجلة والاكثر دقة لكي تكشف الاخطاء الاجمالية وتعيين اختلاف الارتفاعات بين النقاط. ويعتبر استعمال عام جدا في تجميع الخرائط البلانومترية، الخرائط الطبوغرافية بواسطة طرق الحقل لوحدها، عن طريق قياس المسافات، والارتفاعات، وقياس الاتجاهات الى النقاط وذلك لتعيين نقاط الضبط الارضي التي اسست بدقة عالية.

ان مبادئ طريقة الستيديا والتي تتم باستخدام اجهزة الترانست او الثيودولايت او جهاز المحطة الكاملة (Total Station Instrument) هي واحدة من الطرق الرئيسية للتاكيوميترية. ان هذا البحث يعرض مبادئ طريقة الستيديا وتم عمل برنامج حاسوب اسمه ((**MSM**)) (**M**odeling the **S**tadia **M**easurements). تم اعداد البرنامج باستعمال لغة الفجوال بيسك، نسخة 6. هذه النسخة من اللغة موجهة ومجهزة بالادوات الشاملة لتبسيط مهمة البرمجة ولتزويد المبرمج بتشكيلة واسعة من الخيارات لتصميم واجهات البرامج.

Keyword:

Stadia Measurements, Measurement by stadia horizontal sights, Stadia Leveling, Applications of Stadia Measurement, Stadia Surveying, Horizontal Measurements Distances and Tacheometry.

1. INTRODUCTION

The term tacheometry in surveying is used to denote the procedures for obtaining horizontal distances and difference in elevation by rapid indirect methods. The procedure is sometimes referred to as stadia, optical distance measurement or telemetry [4].

The stadia method is a rapid and efficient way to measure distances accurately enough for trigonometric leveling, some traverse, and the location of topographic details. Furthermore, a two-or three-man party can replace the three-or four-man party required in transit-tape surveys. The term stadia comes from the Greek word for a unit of length originally applied in measuring distances for athletic contests. The word denoted 600 Greek feet, or 606 ft 9 in. by present-day American standards.

The term "Stadia" is now applied to the cross wires and rod used in making measurements, as well as to the stadia method itself. Stadia reading can be taken with modern transits, theodolites, levels, and Total Station [1].

2. BASIC PRINCIPLE:

Stadia is based on similar triangles between the object, the focal point of lens, and the reticle of the instrument. The relationship is shown in Figure (1).

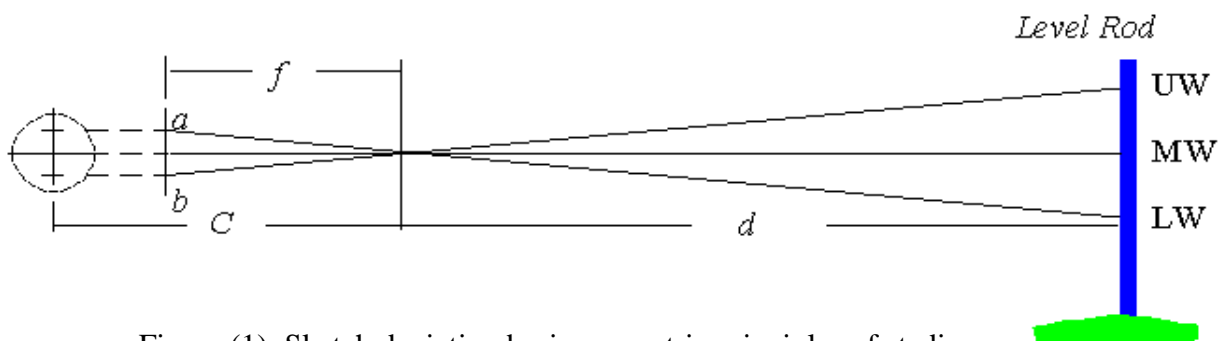


Figure (1): Sketch depicting basic geometric principles of stadia.

If we let

- $ab = i$, and
- $I = UW - LW$

$$\frac{f}{ab} = \frac{d}{I} \Rightarrow d = \frac{f}{ab} I \dots\dots\dots (1)$$

then

If $f/ab = K$, then $d = KI$ and the horizontal distance, D , from the instrument to the rod is:

$$D = KI + C \dots\dots\dots (2)$$

3. MEASUREMENT BY STADIA FOR HORIZONTAL SIGHTS

The stadia method is based upon the principle that in similar triangles homologous sides are proportional. Thus in Figure (2), which shows an external-focusing telescope, light rays from points A and B passing through the center of the lens the form a pair of similar triangles AmB

and amb . Here $Ab=R$ is the rod intercept (stadia interval) and ab is the interval between the stadia wires [4].

Standard symbols used in stadia measurements, and their definition, are as follows:

f = focal length of the lens (a constant for any particular compound objective lens). It can be determined by focusing upon a distant object and measuring the distance between the center (actually the *nodal point*) of the objective lens and the reticle.

f_1 = distance from the center (actually the nodal point) of the objective lens to the plane of the cross hairs when the telescope is focused on some definite point.

f_2 = distance from the center (actually the nodal point) of the objective lens to definite point when the telescope is focused on that point. When f_2 is infinite, or very large, $f_1=f_2$.

i = interval between the stadia wires (ab in figure (2)).

f/i = stadia interval factor, usually 100.

c = distance from the center of the instrument (spindle) to the center of the objective lens. It varies as the objective lens moves in and out for different sight lengths but is generally considered to be a constant [3].

$C=c+f$. C is called the stadia constant although it varies slightly with c .

d = distance from the focal point in front of the telescope to the face of the rod.

$D=C+d$ = distance from the center of the instrument to the face of the rod.

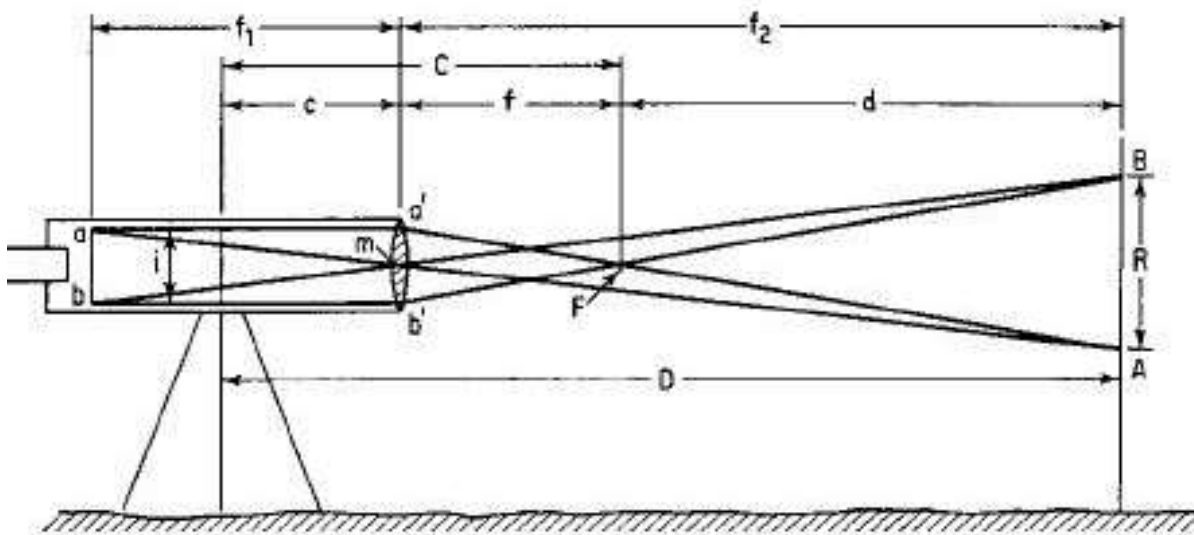


Figure (2): Principle of stadia, external-focusing telescope.

4. INCLINED MEASUREMENT

When collecting measurements using stadia as presented earlier, the requirement of having horizontal sights is limiting in normal terrain. Thus, the stadia formulas need to be developed for inclined measurements. In Figure (3), the geometric relationships of an inclined stadia measurement can be seen. In this figure, the desired position of the rod is perpendicular to the line of sight as shown by r' . Since it is impractical in the field to hold the rod in this manner, a correction to the readings on the level rod r must be determined. From simple geometric relationships, it can be shown that the altitude angle of the line of sight, α , is the same as the angle between positions of r' and r . For small vertical angles, we can make the assumption that the angle at the intersection of the upper wire line of sight and r' is 90° , and thus a simple right triangle relationship can be developed between the reading on the rod r and the corrected reading on the rod r' as :

$$I' = I \cos(\alpha) \dots\dots\dots (3)$$

Making this correction to Equation (1), the slope distance between the instrument and the rod is [4]:

$$S = KI \cos(\alpha) + C \dots\dots\dots (4)$$

The Equation (3) can now be used to compute the horizontal distance between the instrument and the rod as [5]:

$$H = KI \cos^2(\alpha) + C \dots\dots\dots (5)$$

Since theodolites and total stations read zenith angles, we can use the trigonometric relationships of $\sin(a) = \cos(90-a)$ to derive a similar equation for zenith angle reading instruments as:

$$H = KI \sin^2(z) + C \dots\dots\dots (6)$$

where z is the zenith angle of the line of sight. Similarly an equation for computing V is:

$$V = KI \cos(\alpha) \sin(\alpha) = KI \cos(z) \sin(z) \dots\dots\dots (7)$$

Note that in Equation (6), the term $C \sin(\alpha)$, or alternatively $C \cos(z)$ has been dropped since for small altitude angle or large zenith angles the value of the trigonometric functions is very small, and thus so is their product with C [4].

Using Equations (2) and (6), an expression for the elevation difference between ground at the instrument station and at the rod can be derived as [5]:

$$\Delta Elev = hi + V - MW \dots\dots\dots (8)$$

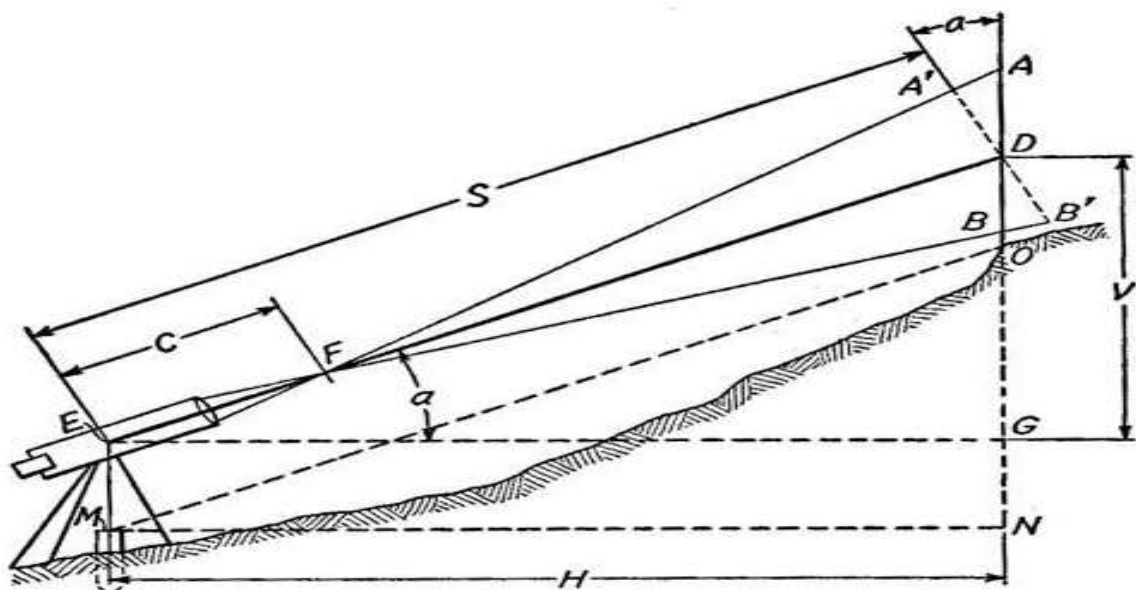


Figure (3): Inclined stadia measurement.



4.1 STADIA TRAVERSES

In a transit-stadia traverse, distances, horizontal angles, and vertical angles are measured at each corner. Reduction of stadia notes as the survey progresses provides elevations to be carried from hub to hub. Average values of stadia distances and differences in elevation are obtained from a foresight and a backsight on each line. An elevation check should be secured by closing on the initial point, or on bench marks near both ends for an open traverse [1].

4.2 TOPOGRAPHY

The stadia method is most useful in locating numerous topographic details, both horizontally and vertically, by transit or plane table. In urban areas, angle and distance readings can be taken faster than a notekeeper is able to record the measurements and prepare a sketch [4].

4.3 STADIA LEVELING

The stadia method is adaptable to trigonometric leveling. The h.i. is determined by sighting on a point of known elevation, or by setting the instrument over such a point and measuring the height of the horizontal axis above it with a stadia rod [2]. The elevation of any point can then be found by computation from the rod intercept and the vertical angle. If desirable a leveling circuit can be run to establish and check the elevations of two or more points [6].

5. PRECISION

A ratio of error of 1/500 can be obtained for a transit-stadia traverse run with ordinary care. Short sights, a long traverse, and careful work may give ratios up to 1/100. Errors in stadia work are usually the result of poor rod readings rather than incorrect angles. An error of 1 min in reading a vertical angle does not appreciably affect the horizontal distance. The same 1-min error produces a difference in elevation of less than 0.1 ft on a 300 ft sight for any vertical angle [4].

6. MODELING THE STADIA MEASUREMENT

The stadia measurement is modeled by Visual Basic language as software named **MSM** (**M**odeling the **S**tadia **M**easurements). The program is formulated and written by using Visual Basic, Version 6. This version of the language is object oriented provided with comprehensive tools to simplify the task of programming and to provide the programmer with wide range of options for design of the user interface system. Figure (4) shows the flowchart of this software.

The input data for each one of these forms and the link between these forms are described in the following sections with the aid of flowcharts, which provide description for the logic and the steps followed in the development of the program.

7. PROGRAM MENUS AND INPUT FORMS

In Visual Basic programming the term FORM is usually used to refer to the graphical area appeared on the screen, which is used to hold objects that may be fields or tables containing values, graphics or text boxes for input the required data values. The form interface is used because most people are familiar with paper form. These forms are written in such away to be user friendly and allow the data input to the program interactively. When the program (MSM) is run, the user presented with the form shown in figure (5).

This form displays program name and version, if the user select "Traverse and Leveling" from the main program menu interface displayed on the screen. The main Form of (MSM) also contains the cases of plotting the traverse and the cases of the plotting profile, as shown in figure (5).

The cases of plotting the traverse are classified into eight cases (number of sides = (3), number of sides = (4), number of sides = (5), number of sides = (6), number of sides = (7), number of sides = (8)), as it is clear in figure (5) and the cases of plotting profile classified into five cases (number of stations = (3), number of stations = (4), number of stations = (5), number of stations = (6), number of stations = (7).), as shown in figure (6).

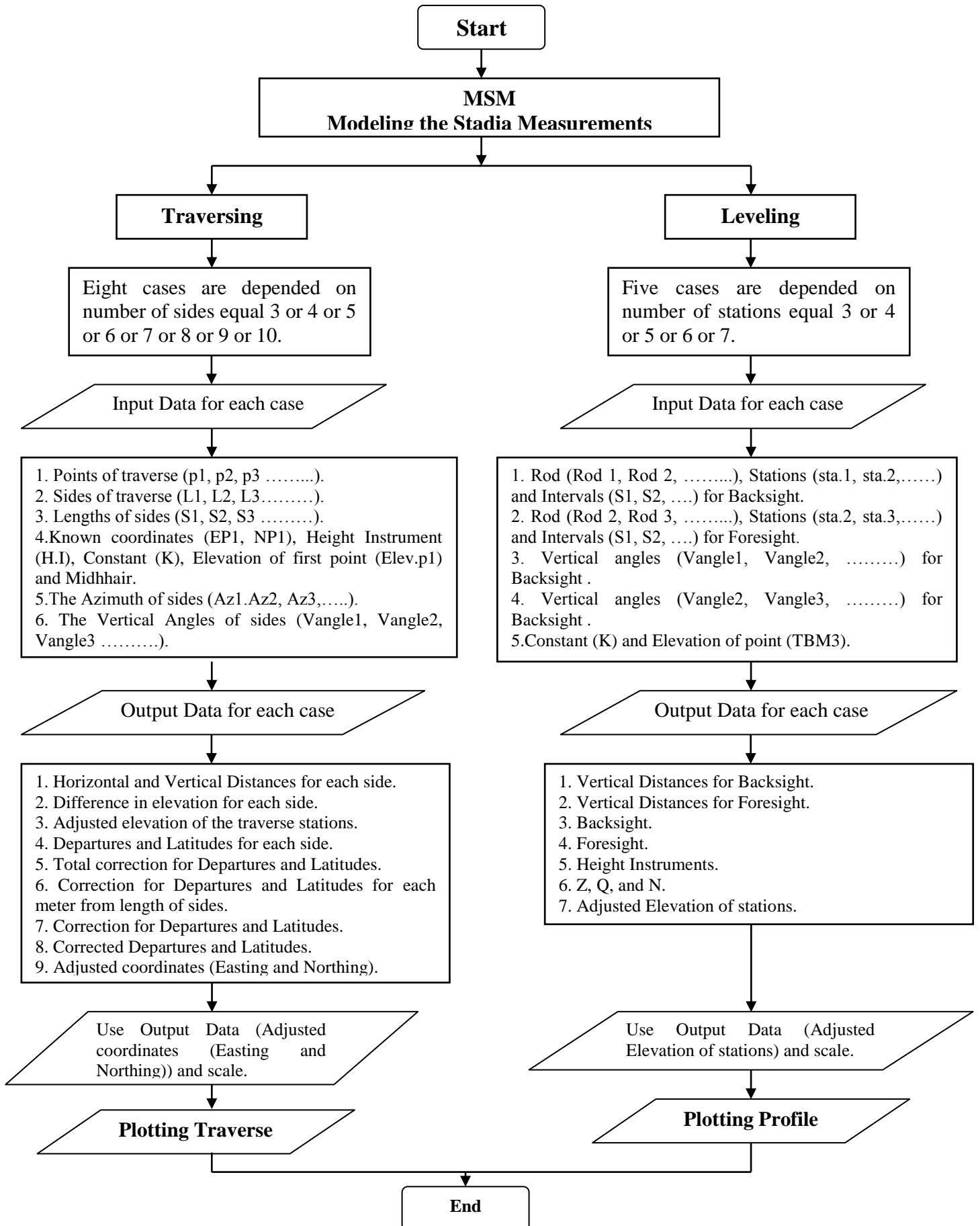


Figure (4): Flowchart of work steps.

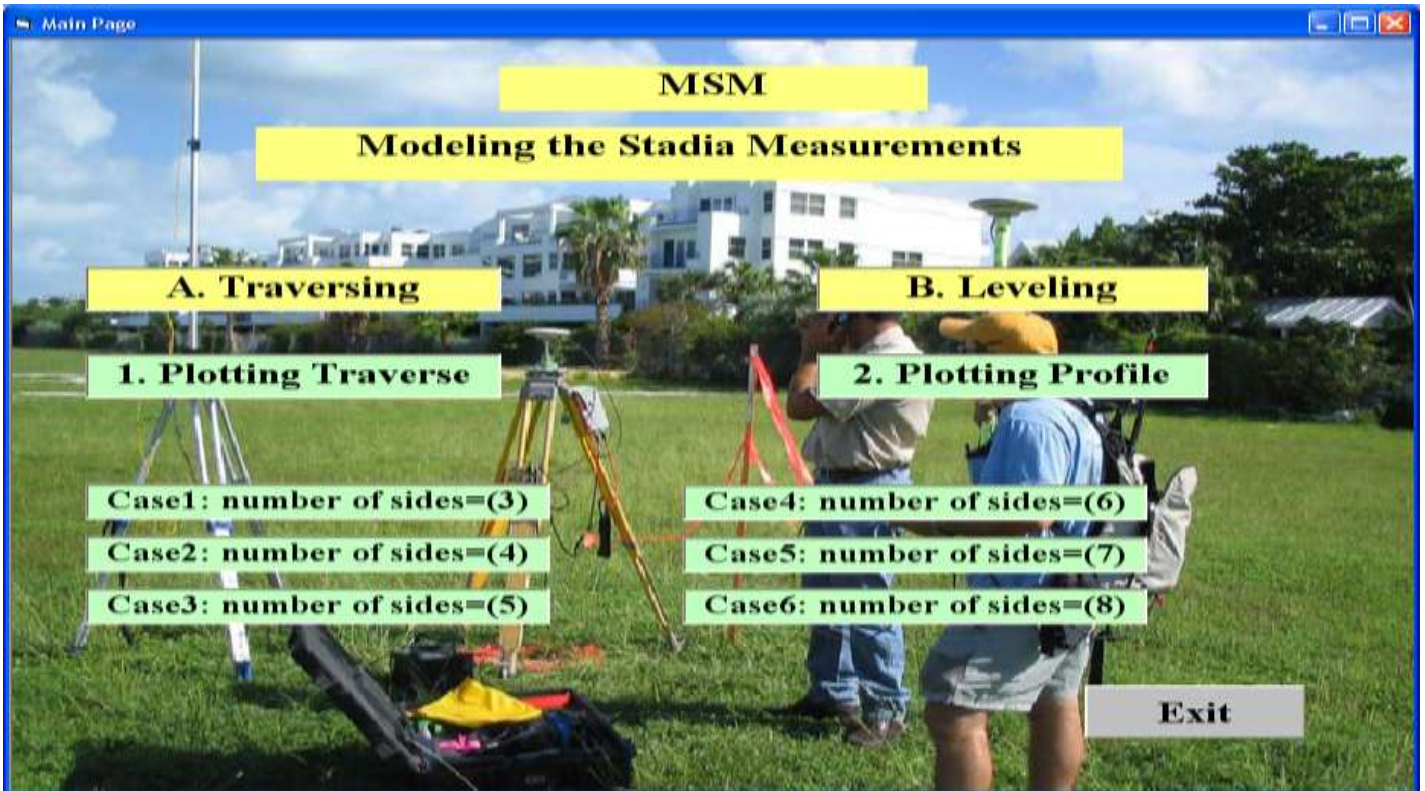


Figure (5): The main page of (MSM).

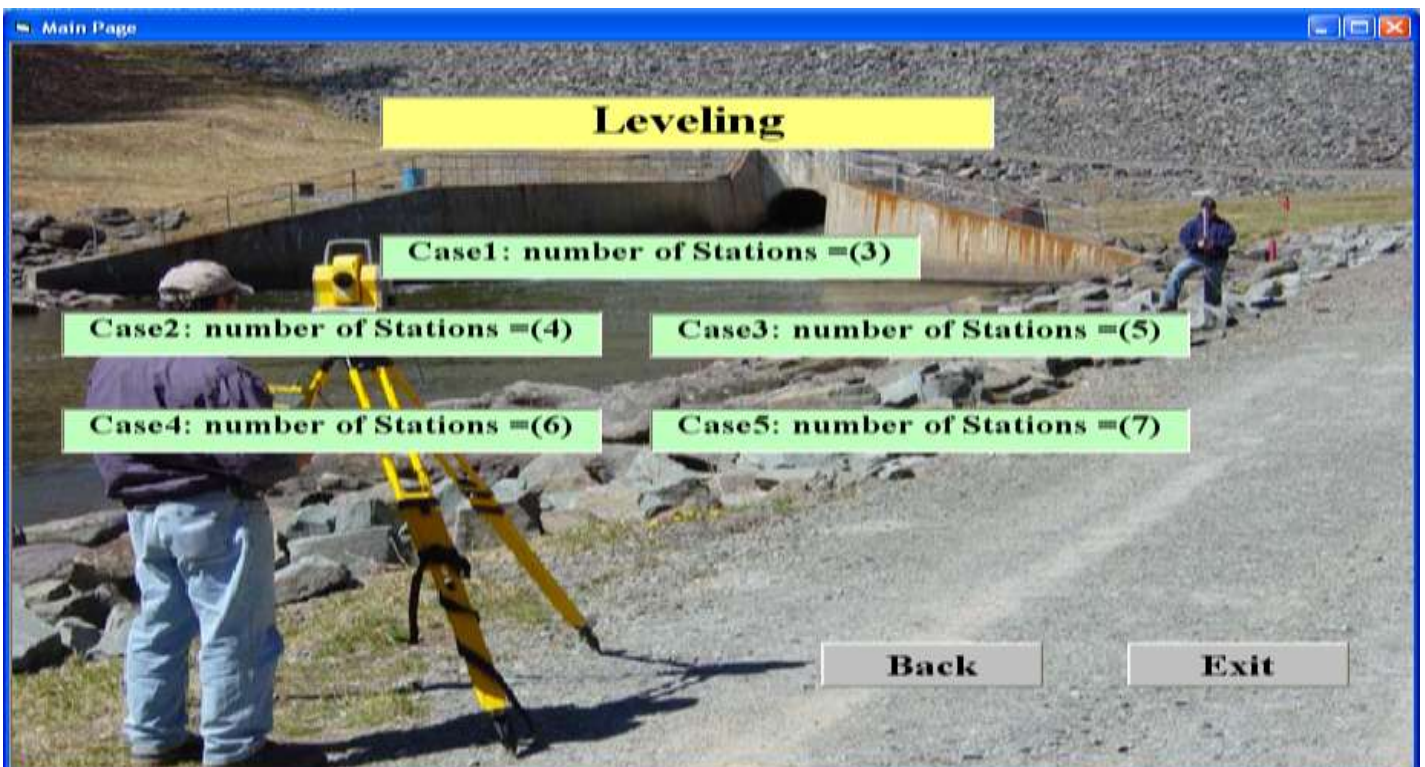


Figure (6): The main page of Leveling.

7.1 TRAVERSING

Traversing design is described in eight cases of the following:

1. Case1: number of sides = (3).
2. Case2: number of sides = (4).
3. Case3: number of sides = (5).
4. Case4: number of sides = (6).
5. Case5: number of sides = (7).
6. Case6: number of sides = (8).
7. Case7: number of sides = (9).
8. Case8: number of sides = (10).

These menu items are described in the following sections.

Case1: number of Sides = (3)

If the user selects this option, the form shown in figure (5) is displayed on the screen. First the user input information's the requirements of the first traverse and is listed below:

1. Points of traverse (P1, P2, P3,).
2. The sides of traverse (L1, L2, L3).
3. Lengths of sides (S1 S2, S3).
4. Known coordinates (EP1, NP1), Height Instrument (HI), Constant (K), Elevation of first point (Elev.p1) and Midhair.
5. The Azimuth of sides (Az1, Az2, Az3).
6. The Vertical angles (Vangle1, Vangle2, Vangle3)

When the user input the required data as displayed in figure (7/a), the program begins the calculation of the elements (Horizontal Distance for each side, Vertical Distance for each side, Difference in Elevation for each side, Adjusted Elevation of the Traverse Stations, Departure of Sides, Sum of Departures, Latitude of Sides, Sum of Latitudes, Total Correction for Departures and Latitudes, Correction for Departure and Latitude for each meter from Length of Sides, Correction for Departures, Correction for Latitudes, Sum Correction for Departures and Latitudes, Corrected Departures, Corrected Latitudes, Sum Corrected Departures, Sum Corrected Latitudes and Adjusted Coordinates (Easting and Northing of Points)) as shown in figure (7/b).

Figure (7/a): Traverse (3 Sides).



Traverse (3 sides)

Input				Output					
Points of Traverse		The Sides of Traverse		Horizontal Distance for each side		Total Correction for Departures and Latitudes		Adjusted Coordinates (Easting and Northing)	
P1	A	L1	AB	Hdistance1	324.957174152038	TCDepts	28.1053191848234	CorrEP2	531.210069725095
P2	B	L2	BC	Hdistance2	621.186758317448	TCLats	-598.257652579774	CorrEP3	698.396794028879
P3	C	L3	CA	Hdistance3	508.272472028533	SumHdistances	1454.41640449802	CorrEP1	200 Check
Lengths of Sides		Knowns		Vertical Distance for each side		Correction for Departure and Latitude for each meter from Length of sides		CorrNP2	70.4916011597747
S1	3.27 m	HI	1.52	Alpha1	25.76491635613	KD	1.93241214124807E-0	CorrNP3	416.464368307102
S2	6.24 m	K	100	Alpha2	41.8036898030274	KL	-0.411338630896602	CorrNP1	200 Check
S3	5.09 m	Midhair	1.52	Alpha3	-19.2297280409172	Correction for Departures			
Known Coordinates		ElevP1	300 m	Difference in Elevation for each side		CorrforDep1	6.27951188717063		
EPI	200			DE1	25.76491635613	CorrforDep2	12.0038883375517		
NP1	200			DE2	41.8036898030274	CorrforDep3	9.82191896010107		
The Azimuth of Sides				Adjusted Elevation of the Traverse station		Correction for Latitudes			
Az1	89 deg 16 min 00 sec			AdjElevP2	325.76491635613	CorrforLat1	-133.667439115728		
Az2	14 deg 28 min 00 sec			AdjElevP3	367.568606159157	CorrforLat2	-255.518110697398		
Az3	269 deg 10 min 00 sec			AdjElevP1	348 Check	CorrforLat3	-209.072102766648		
The Vertical angles				Departure of Sides		Corrected Departures			
Vangle1	+4 deg 32 min 00 sec			Dep1	324.930557837925	CorrDep1	331.210069725095		
Vangle2	+3 deg 51 min 00 sec			Dep2	155.182835966232	CorrDep2	167.186724303783		
Vangle3	-2 deg 10 min 00 sec			Dep3	-508.21871298898	CorrDep3	-498.396794028879		
Calculation				SumDepts		SumCorrDepts	0		
Back Next				Latitude of Sides		Corrected Latitudes			
Plotting Traverse				Lat1	4.15904027550286	CorrLat1	-129.508398840225		
Save				Lat2	601.490877844725	CorrLat2	345.972767147327		
				Lat3	-7.39226554045352	CorrLat3	-216.464368307102		
				SumLats	598.257652579774	SumCorrLats	0		

Figure (7/b): Traverse (3 Sides) Input and Computation [4].

The results of all elements (Horizontal Distance for each side, Vertical Distance for each side, Difference in Elevation for each side, Adjusted Elevation of the Traverse Stations, Departure of Sides, Sum of Departures, Latitude of Sides, Sum of Latitudes, Total Correction for Departures and Latitudes, Correction for Departure and Latitude for each meter from Length of Sides, Correction for Departures, Correction for Latitudes, Sum Correction for Departures and Latitudes, Corrected Departures, Corrected Latitudes, Sum Corrected Departures, Sum Corrected Latitudes and Adjusted Coordinates (Easting and Northing of Points)) are saved in a text file as shown figure (7/c). Following that the transition traverse design process is considered completed the program enabled the user to go to the design of the next traverse in the alignment irrespective of its case (3 sides or 4sides or 5 sides or 6 sides or 7 sides or 8 sides or 9 sides or 10 sides) or can exit the traverse design if it is the last traverse in the alignment.

File Menu

The menu items available under the file menu are **Open, Save as, Save, Close, Print, and Exit.**

- When "Open" is selected, an existing design text file can be selected to open and made available to the user for seeing the calculated results or edit an existing file as shown in figure (7/d).

- When "Save As" is selected, a new file is created. The current file is then copied to the new file on the disk or location specified by the user.
- When "Save" is selected, an edited open file can be saved at any existing disk drive as shown in Figure (7/e).
- When "Close" is selected, to close opened text file.
- When "Print" is selected, to print text file.
- When "Exit" is selected, the program terminates, and the user is returned to the operating system level.

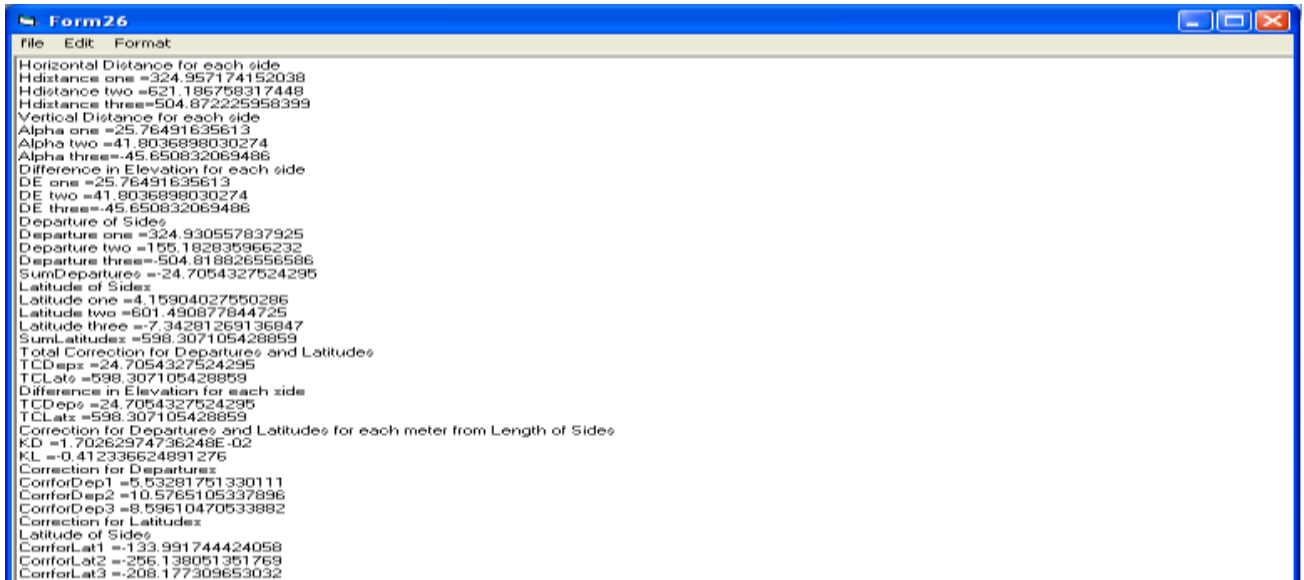


Figure (7/c): The Result of the Output.

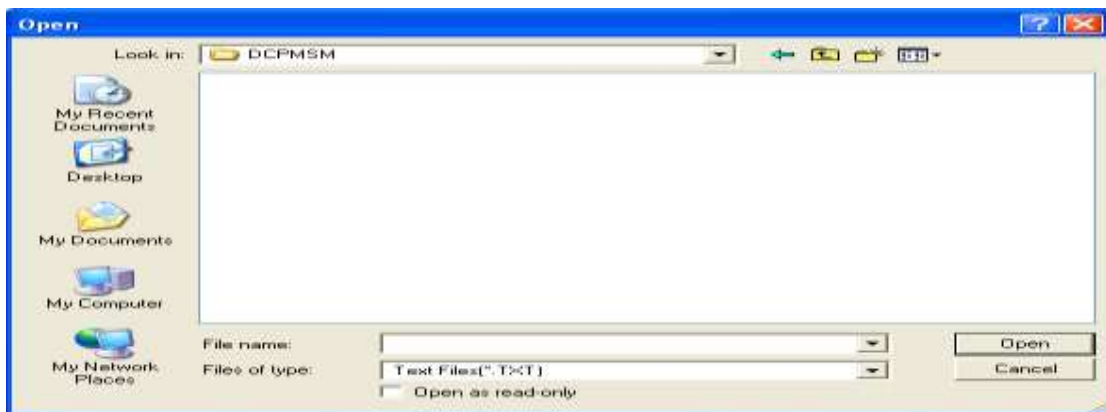


Figure (7/d): Open file dialog box.



Figure (7/e): Save file dialog box.



Case2: number of Sides = (4)

If the user selects this option, the form shown in figure (5) is displayed on the screen. First the user input information's the requirements of the second traverse and is listed below:

1. Points of traverse (P1, P2, P3, P4).
2. The Sides of traverse (L1, L2, L3, L4).
3. Lengths of sides (S1, S2, S3, S4).
4. Known coordinates (EP1, NP1), Height Instrument (HI), Constant (K), Elevation of first Point (Elev.p1), Midhair.
5. The Azimuth of sides (Az1, Az2, Az3, Az4).
6. The Vertical angles (Vangle1, Vangle2, Vangle3, Vangle4).

When the user input the required data as displayed in figure (8/a), the program begins the calculation of the elements (Horizontal Distance for each side, Vertical Distance for each side, Difference in Elevation for each side, Adjusted Elevation of the Traverse Stations, Departure of Sides, Sum of Departures, Latitude of Sides, Sum of Latitudes, Total Correction for Departures and Latitudes, Correction for Departure and Latitude for each meter from Length of Sides, Correction for Departures, Correction for Latitudes, Sum Correction for Departures and Latitudes, Corrected Departures, Corrected Latitudes, Sum Corrected Departures, Sum Corrected Latitudes and Adjusted Coordinates (Easting and Northing of Points)) as shown in figure (8/b).

The screenshot shows a software window titled "Traverse (4 sides)". It is divided into two main sections: "Input" and "Output".

Input Section:

- Points of Traverse:** P1, P2, P3, P4 (text boxes).
- The Sides of Traverse:** L1, L2, L3, L4 (text boxes).
- Lengths of Sides:** S1, S2, S3, S4 (text boxes with "m" unit).
- Knowns:** HI, K, Midhair, ElevP1 (text boxes).
- Known Coordinates:** EPI, NP1 (text boxes).
- The Azimuth of Sides:** Az1, Az2, Az3, Az4 (text boxes with "deg", "min", "sec" units).
- The Vertical angles:** Vangle1, Vangle2, Vangle3, Vangle4 (text boxes with "deg", "min", "sec" units).

Output Section:

- Horizontal Distance for each side:** Hdistance1, Hdistance2, Hdistance3, Hdistance4, SumHdistances.
- Vertical Distance for each side:** Alpha1, Alpha2, Alpha3, Alpha4.
- Difference in Elevation for each side:** DE1, DE2, DE3, DE4.
- Adjusted Elevation of the Traverse station:** AdjElevP2, AdjElevP3, AdjElevP4, AdjElevP1 (with "Check" button).
- Departure of Sides:** Dep1, Dep2, Dep3, Dep4, SumDeps.
- Latitude of Sides:** Lat1, Lat2, Lat3, Lat4, SumLats.
- Correction for Departures and Latitudes:** TCDeps, TCLats.
- Correction for Departure and Latitude for each meter from Length of sides:** KD, KL.
- Correction for Departures:** CorrforDep1, CorrforDep2, CorrforDep3, CorrforDep4.
- Correction for Latitudes:** CorrforLat1, CorrforLat2, CorrforLat3, CorrforLat4.
- Corrected Departures:** CorrDep1, CorrDep2, CorrDep3.
- Adjusted Coordinates (Easting and Northing):** CorrEP2, CorrEP3, CorrEP4, CorrNP2, CorrNP3, CorrNP4, CorrNP1 (with "Check" buttons).

Buttons: "Calculation", "Back", "Next", "Plotting Traverse", "Save".

Figure (8/a): Traverse (4 Sides).

The result of all elements (Horizontal Distance for each side, Vertical Distance for each side, Difference in Elevation for each side, Adjusted Elevation of the Traverse Stations, Departure

of Sides, Sum of Departures, Latitude of Sides, Sum of Latitudes, Total Correction for Departures and Latitudes, Correction for Departure and Latitude for each meter from Length of Sides, Correction for Departures, Correction for Latitudes, Sum Correction for Departures and Latitudes, Corrected Departures, Corrected Latitudes, Sum Corrected Departures, Sum Corrected Latitudes and Adjusted Coordinates (Easting and Northing of Points)) are saved in a text file. Following that the transition traverse design process is considered completed the program enabled the user to go to the design of the next traverse in the alignment irrespective of its case (3 sides or 4sides or 5 sides or 6 sides or 7 sides or 8 sides or 9 sides or 10 sides) or can exit the traverse design if it is the last traverse in the alignment.

The screenshot displays a software window titled "Traverse (4 sides)" with a blue title bar. The interface is divided into several sections:

- Input Section:**
 - Points of Traverse:** P1 (A), P2 (B), P3 (C), P4 (D).
 - The Sides of Traverse:** L1 (AB), L2 (BC), L3 (CD), L4 (DA).
 - Lengths of Sides:** S1 (3.27 m), S2 (6.24 m), S3 (5.09 m), S4 (6.11 m).
 - Knowns:** HI (1.52), K (100), Midhair (1.52), ElevP1 (300 m).
 - Known Coordinates:** EPI (200), NP1 (200).
 - The Azimuth of Sides:** Az1 (89 deg 16 min 00 sec), Az2 (14 deg 28 min 00 sec), Az3 (269 deg 10 min 00 sec), Az4 (177 deg 14 min 00 sec).
 - The Vertical angles:** Vangle1 (+4 deg 32 min 00 sec), Vangle2 (+3 deg 51 min 00 sec), Vangle3 (-5 deg 04 min 00 sec), Vangle4 (-2 deg 10 min 00 sec).
- Output Section:**
 - Horizontal Distance for each side:** Hdistance1 (324.957174152038), Hdistance2 (621.186758317448), Hdistance3 (505.03005174651), Hdistance4 (610.126680568631), SumHdistances (2061.30066478463).
 - Vertical Distance for each side:** Alpha1 (25.76491635613), Alpha2 (41.8036898030274), Alpha3 (-44.7765917851198), Alpha4 (-23.0832295343819).
 - Difference in Elevation for each side:** DE1 (25.76491635613), DE2 (41.8036898030274), DE3 (-44.7765917851198), DE4 (-23.0832295343819).
 - Adjusted Elevation of the Traverse station:** AdjElevP2 (325.76491635613), AdjElevP3 (367.568606159157), AdjElevP4 (322.792014374038), AdjElevP1 (300) with a "Check" button.
 - Departure of Sides:** Dep1 (324.930557837925), Dep2 (155.182835966232), Dep3 (-504.976635651754), Dep4 (29.4500114780522), SumDeps (4.58676963045401).
 - Latitude of Sides:** Lat1 (4.15904027550286), Lat2 (601.490877844725), Lat3 (-7.34510809432466), Lat4 (-609.415509456101), SumLats (-11.1106994301981).
 - Correction for Departures and Latitudes:** TCDEps (-4.58676963045401), TCLats (11.1106994301981).
 - Correction for Departure and Latitude for each meter from Length of sides:** KD (-2.22518223993939E-05), KL (5.3901401285188E-05).
 - Correction for Departures:** CorrforDep1 (-0.723088932664006), CorrforDep2 (-1.38225374229351), CorrforDep3 (-1.123783901782), CorrforDep4 (-1.35764305371449).
 - Correction for Latitudes:** CorrforLat1 (1.75156470444698), CorrforLat2 (3.34828367331139), CorrforLat3 (2.72218274802679), CorrforLat4 (3.28866830441295).
 - Corrected Departures:** CorrDep1 (324.207468905261), CorrDep2 (153.800582223938), CorrDep3 (-506.100419553536).
 - Corrected Latitudes:** CorrLat1 (5.91060497994983), CorrLat2 (604.839161518036), CorrLat3 (-4.62292534629787), CorrLat4 (-606.126841151688), SumCorrLats (0).
 - Adjusted Coordinates (Easting and Northing):** CorrEP2 (524.207468905261), CorrEP3 (678.008051129199), CorrEP4 (171.907631575662), CorrNP1 (200) with a "Check" button.
- Buttons:** "Calculation", "Back", "Next", "Plotting Traverse", and "Save".

Figure (8/b): Traverse (4 Sides) Input and Computation [4].

Plotting Traverse

When this option is selected the figure shown in (8/b) presented to the user. The user has to input the following information:

- Corrected Easting of points (EP1, CorrEp2, and CorrEp3,.....).
- Corrected Northing of points (NP1, CorrNp2, and CorrNp3,.....).
- Scale (S).



When these data are input the computer program and when the user selects "plotting traverse" button to begin by drawing the points are illustrated in the below figures (9/a),(9/b),(9/c),(9/d),(9/e),(9/f),(9/g) and figure (9/h) . The program output result is saved for later use by the user in a text file.

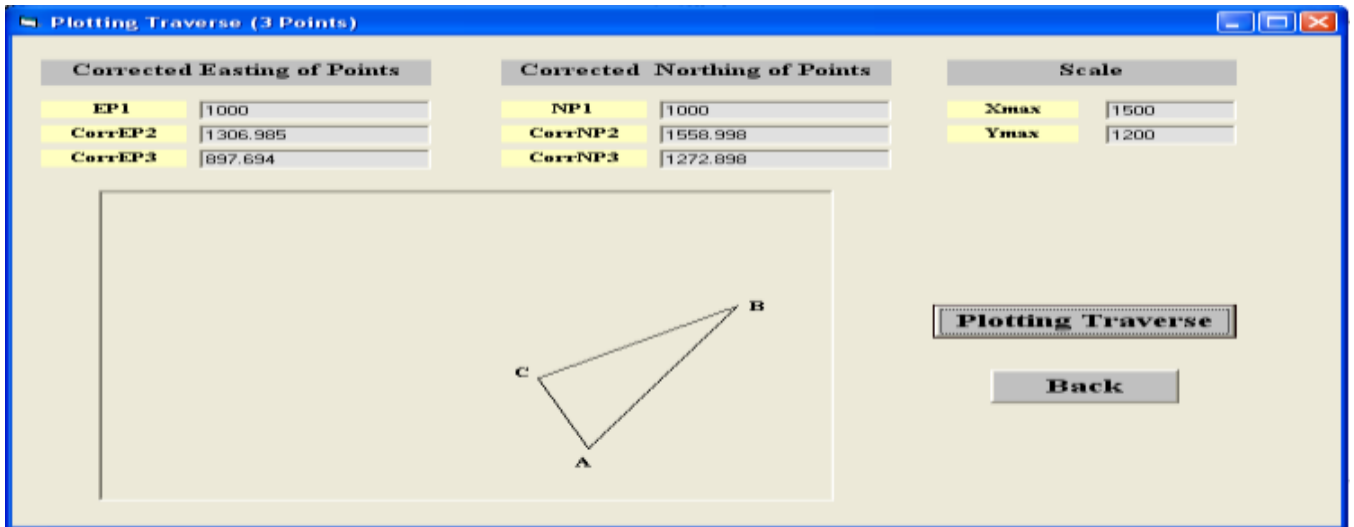


Figure (9/a): Plotting Traverse (3 points) Input and Plotting.

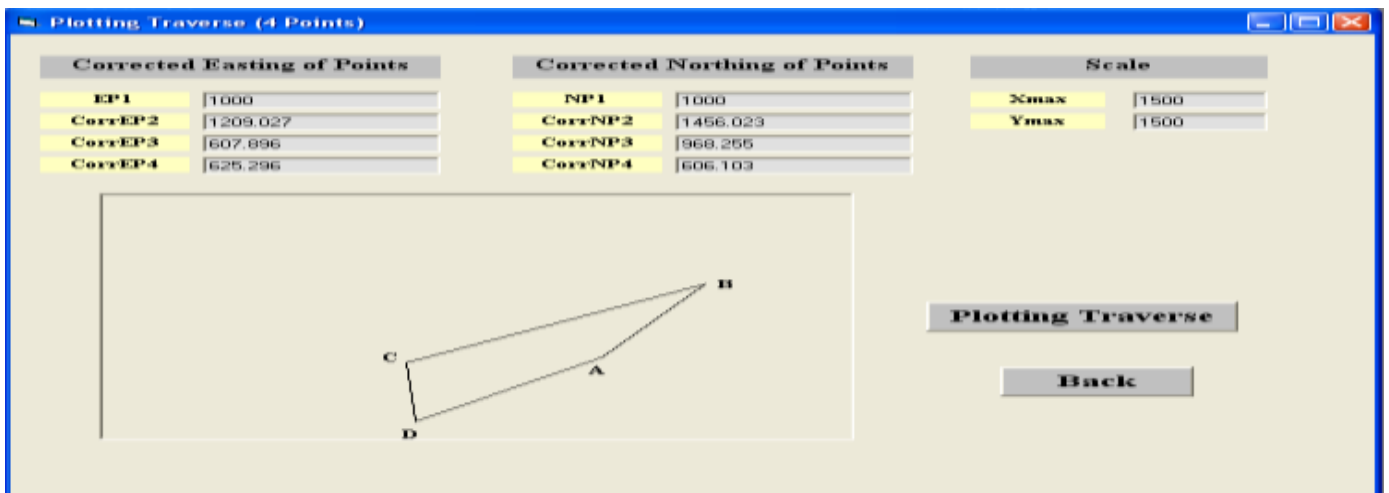


Figure (9/b): Plotting Traverse (4 points) Input and Plotting.

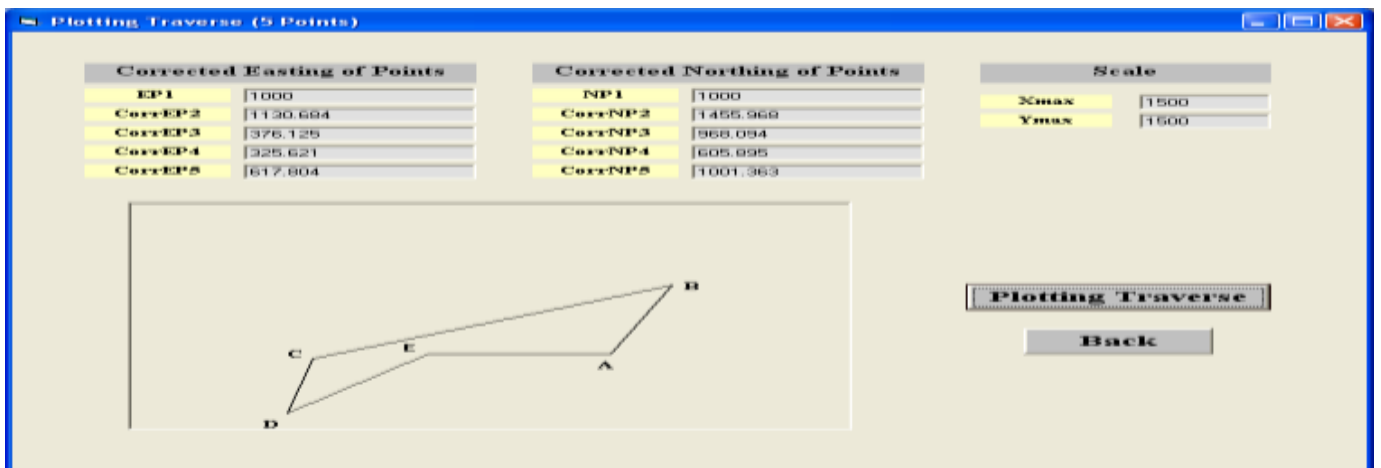


Figure (9/c): Plotting Traverse (5 points) Input and Plotting.

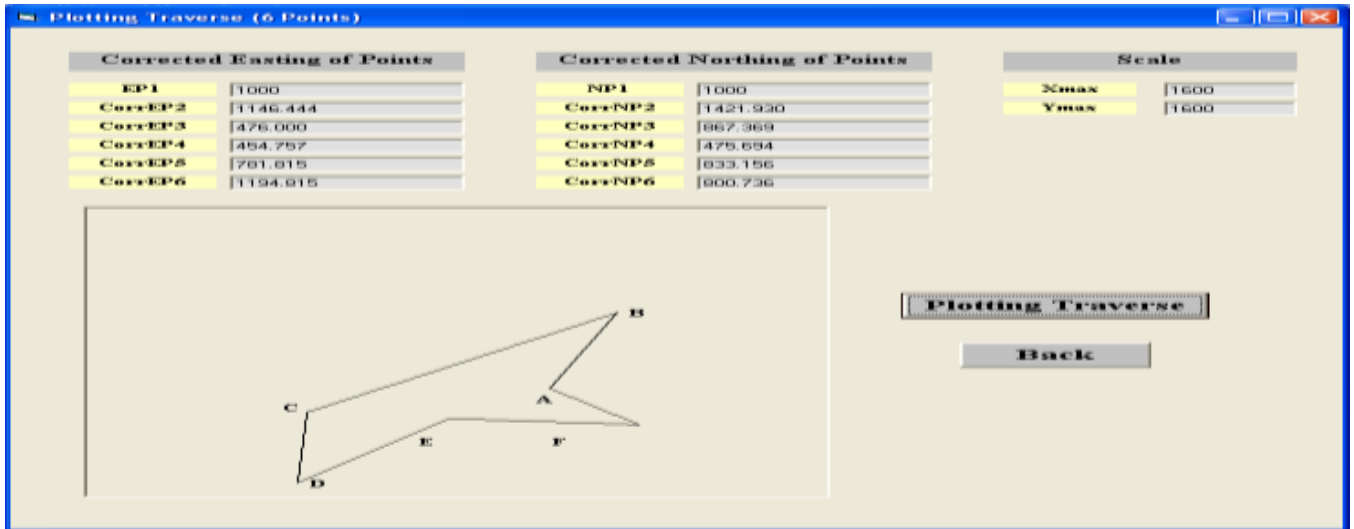


Figure (9/d): Plotting Traverse (6 points) Input and Plotting.

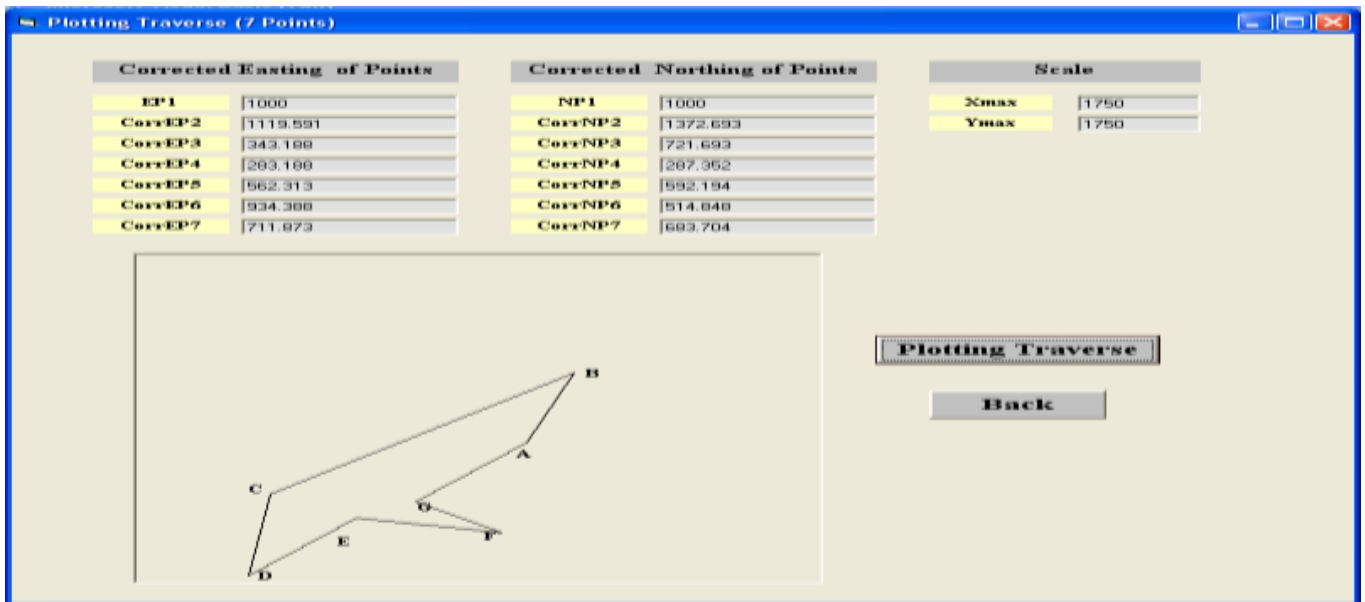


Figure (9/e): Plotting Traverse (7 points) Input and Plotting.

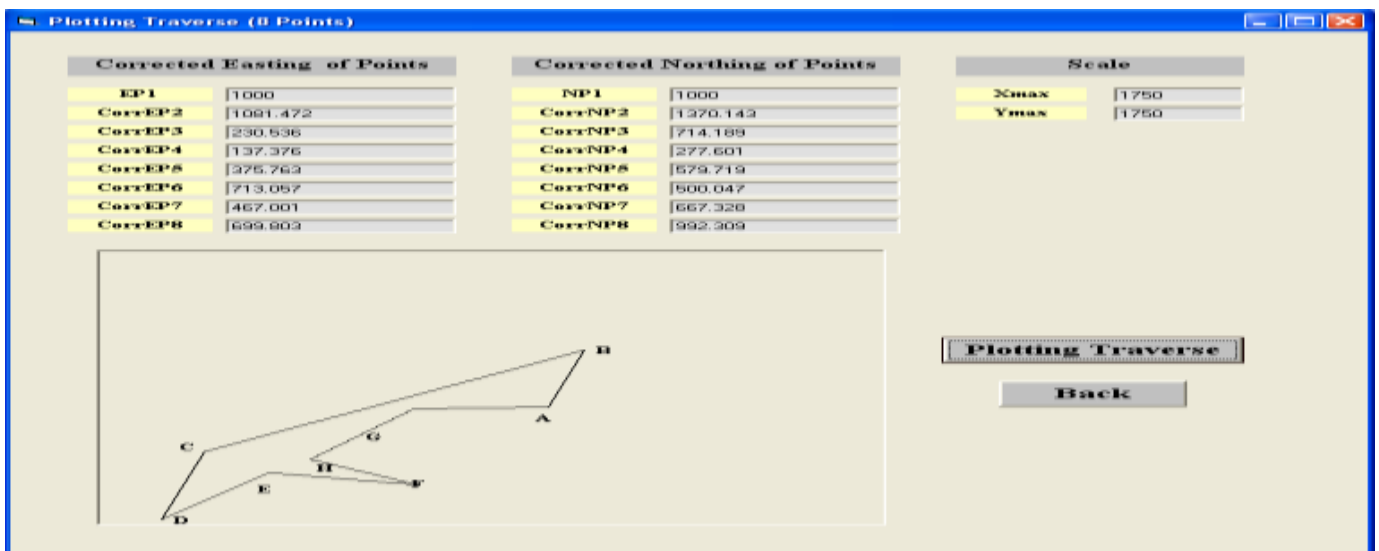


Figure (9/f): Plotting Traverse (8 points) Input and Plotting.

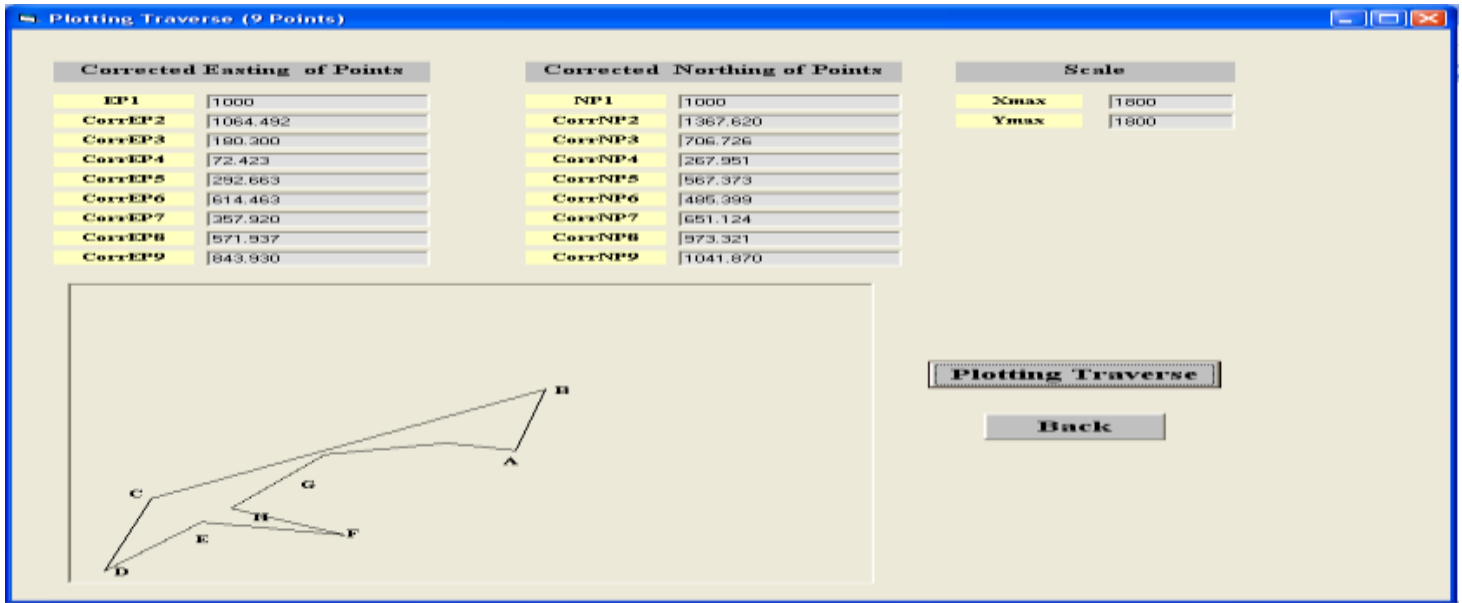


Figure (9/g): Plotting Traverse (9 points) Input and Plotting.

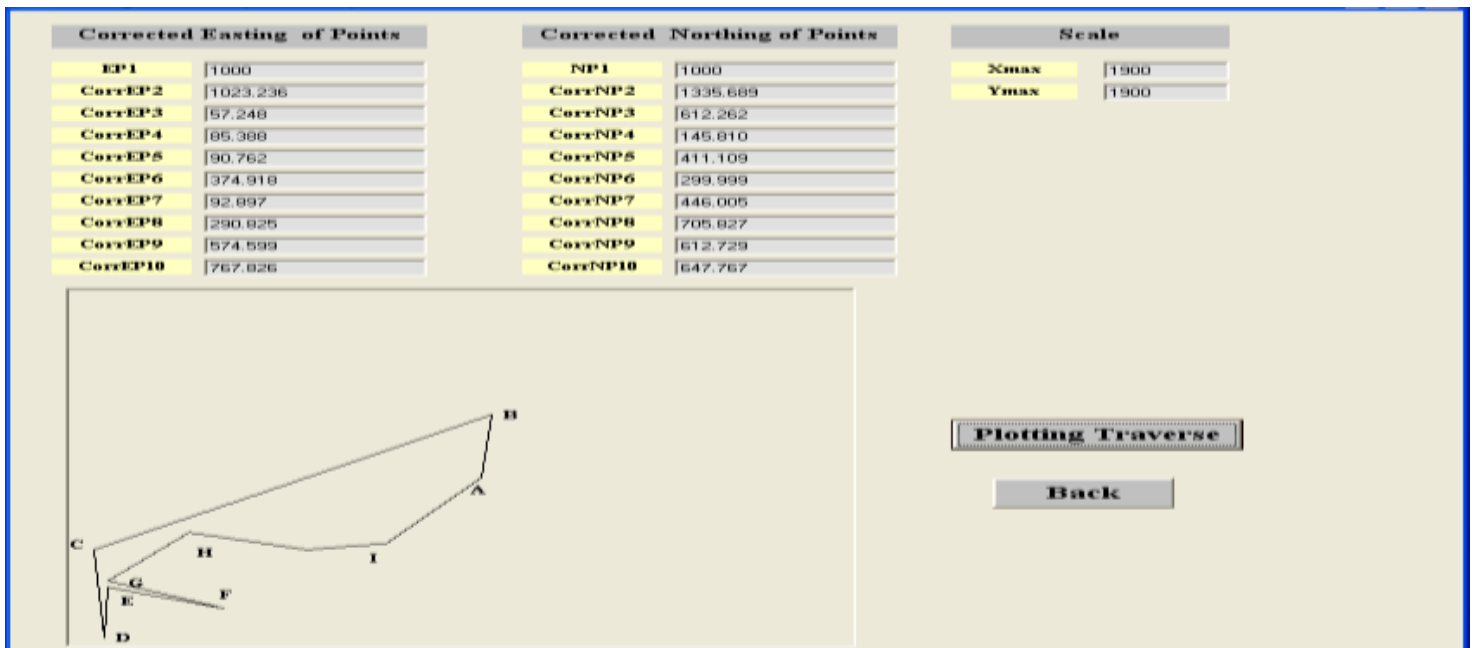


Figure (9/h): Plotting Traverse (10 points) Input and Plotting.

7.2 LEVELING

Leveling design is described in five cases of the following:

1. Case1: number of Stations = (3).
2. Case2: number of Stations = (4).
3. Case3: number of Stations = (5).
4. Case4: number of Stations = (6).
5. Case5: number of Stations = (7).

These menu items are described in the following sections.

Case1: number of Stations = (3)

If the user selects this option, the form shown in figure (6) is displayed on the screen. First the user input information's the requirements of the first leveling and is listed below:

1. Stations (Sta1, Sta2), Rod (Rod1, Rod2) and Interval (S1, S2) for Backsight.
2. The Vertical angles (Vangle1, Vangle2) for Backsight.
3. Stations (Sta2, Sta3), Rod (Rod2, Rod3) and Interval (S2, S3) for Foresight.
4. The Vertical angles (Vangle2, Vangle3) for Foresight.
5. Known Elevation of point (TBM2) and Constant (K).

When the user input the required data as displayed in figure (10/a), the program begins the calculation of the elements (Vertical Distances for Backsight, Vertical Distances for Foresight, Elevation of the Stations, Backsight and Sum of Backsight, Foresight and Sum of Foresight, Height Instrument, Z, Q and N) as shown in figure (10/b).

The screenshot shows a software window titled "Leveling (3 Stations)". It is divided into two main sections: "Input" and "Output".

Input Section:

- Backsight:** Fields for Station (Sta1, Sta2), Rod (Rod1, Rod2), and Interval (S1, S2) in feet. Below this are fields for vertical angles Vangle1 and Vangle2, each with sub-fields for degrees, minutes, and seconds.
- Foresight:** Fields for Station (Sta2, Sta3), Rod (Rod2, Rod3), and Interval (S2, S3) in feet. Below this are fields for vertical angles Vangle2 and Vangle3, each with sub-fields for degrees, minutes, and seconds.
- Knowns:** Fields for Constant (K) and Elevation of TBM2 (ElevTBM2) in feet.
- A "Calculation" button is located at the bottom right of the input section.

Output Section:

- Vertical Distances for Backsight:** Fields for Vd1 and Vd2 in feet.
- Vertical Distances for Foresight:** Fields for Vd2 and Vd3 in feet.
- Height Instrument:** Fields for HI1 and HI2 in feet.
- Elevation of Stations:** Fields for ElevTP1 and ElevTP2 in feet.
- Backsight:** Fields for BS1, BS2, and Sum BS (with a "Check" button).
- Foresight:** Fields for FS2, FS3, and Sum FS (with a "Check" button).
- Derived Values:**
 - Z = (SumBS - SumFS) with a "Check" button.
 - Q = Elev Final point (TBM3) - Elev First Point (TBM2) with a "Check" button.
 - N = (Z - Q) with a "Check" button.
- Buttons for "Back", "Next", and "Plotting Profile" are located at the bottom of the output section.

Figure (10/a): Leveling (3 Stations).

The results of all elements (Vertical Distances for Backsight, Vertical Distances for Foresight, Elevation of the Stations, Backsight and Sum of Backsight, Foresight and Sum of Foresight, Height Instrument, Z, Q and N) are saved in a text file. Following that the transition leveling design process is considered completed the program enabled the user to go to the design of the next leveling in the alignment irrespective of its case (3 stations or 4 stations or 5 stations or 6 stations or 7 stations) or can exit the leveling design if it is the last leveling in the alignment.



Leveling (3 Stations)

Input

Backsight

Station	Rod	Interval
Sta1 TBM2	Rod1 8.6 ft	S1 3.14 ft
Sta2 TP1	Rod2 4.5 ft	S2 6.32 ft

The Vertical angles

Vangle1 +0 deg 25 min 00 sec
 Vangle2 +3 deg 15 min 00 sec

Foresight

Station	Rod	Interval
Sta2 TP1	Rod2 6.3 ft	S2 4.62 ft
Sta3 TBM3	Rod3 2.2 ft	S3 5.04 ft

The Vertical angles

Vangle2 -1 deg 52 min 00 sec
 Vangle3 -6 deg 20 min 00 sec

Knowns

K 100
 ElevTBM2 1416.8 ft

Calculation

Output

Vertical Distances for Backsight		Height Instrument	
Vd1	2.28339192868951 ft	HI1	1410.48339192869 ft
Vd2	35.7722155099583 ft	HI2	1463.09667832923 ft

Vertical Distances for Foresight		Elevation of Stations	
Vd2	-15.0410708905804 ft	ElevTP1	1431.82446281927 ft
Vd3	-55.258213233242 ft	ElevIP2	1520.55489156247 ft

Backsight		Foresight	
BS1	-6.31660807131049 ft	FS2	-21.3410708905804 ft
BS2	31.2722155099583 ft	FS3	-57.458213233242 ft
Sum BS	24.9556074386478 Check	Sum FS	-78.799284123822 Check

Z = (SumBS - SumFS) 103.75489156247 Check
 Q = Elev Final point (TBM3) - Elev First Point (TBM2) 103.75489156247 Check
 N = (Z - Q) 0 Check

Back
Next

Plotting Profile

Save

Figure (10/b): Leveling (3 Stations) Input and Computation [4].

Case2: number of Stations = (4)

If the user selects this option, the form shown in figure (6) is displayed on the screen. First the user input information's the requirements of the second leveling and is listed below:

1. Stations (Sta1, Sta2, Sta3), Rod (Rod1, Rod2, Rod3) and Interval (S1, S2, S3) for Backsight.
2. The Vertical angles (Vangle1, Vangle2, Vangle3) for Backsight.
3. Stations (Sta2, Sta3, Sta4), Rod (Rod2, Rod3, Rod4) and Interval (S2, S3, S4) for Foresight.
4. The Vertical angles (Vangle2, Vangle3, Vangle4) for Foresight.
5. Known Elevation of point (TBM2) and Constant (K).

When the user input the required data as displayed in figure (11/a), the program begins the calculation of the elements (Vertical Distances for Backsight, Vertical Distances for Foresight, Elevation of the Stations, Backsight and Sum of Backsight, Foresight and Sum of Foresight, Height Instrument, Z, Q and N) as shown in figure (11/b).

Leveling (4 Stations)

Input

Backsight

Station	Rod	Interval	
Sta1	Rod1	S1	ft
Sta2	Rod2	S2	ft
Sta3	Rod3	S3	ft

The Vertical angles

Vangle1 deg min sec
Vangle2 deg min sec
Vangle3 deg min sec

Foresight

Station	Rod	Interval	
Sta2	Rod2	S2	ft
Sta3	Rod3	S3	ft
Sta4	Rod4	S4	ft

The Vertical angles

Vangle2 deg min sec
Vangle3 deg min sec
Vangle4 deg min sec

Knowns

K
ElevTBM3 ft

Calculation

Output

Vertical Distances for Backsight

Vd1 ft
Vd2 ft
Vd3 ft

Vertical Distances for Foresight

Vd2 ft
Vd3 ft
Vd4 ft

Backsight

BS1 ft
BS2 ft
BS3 ft
Sum BS Check

Foresight

FS2 ft
FS3 ft
FS4 ft
Sum FS Check

Z = (SumBS - SumFS) Check
Q = Elev Final point (TBM4) - Elev First Point (TBM3) Check
N = (Z - Q) Check

Height Instrument

HI1 ft
HI2 ft
HI3 ft

Elevation of Stations

ElevTP1 ft
ElevTP2 ft
ElevTP3 ft

Buttons:

Figure (11/a): Leveling (4 Stations).



Leveling (4 Stations)

Input

Backsight				
Station	Rod	Interval		
Sta1	TBM3	Rod1 8.6	S1	3.14 ft
Sta2	TP1	Rod2 4.5	S2	6.32 ft
Sta3	TP2	Rod3 10	S3	3.88 ft

The Vertical angles

Vangle1: +0 deg 25 min 00 sec
 Vangle2: +3 deg 15 min 00 sec
 Vangle3: -1 deg 02 min 00 sec

Foresight				
Station	Rod	Interval		
Sta2	TP1	Rod2 6.3	S2	4.62 ft
Sta3	TP2	Rod3 2.2	S3	5.04 ft
Sta4	TBM4	Rod4 5	S4	5.06 ft

The Vertical angles

Vangle2: -1 deg 52 min 00 sec
 Vangle3: -6 deg 20 min 00 sec
 Vangle4: -0 deg 13 min 00 sec

Knowns

K: 100
 ElevTBM3: 1416.8 ft

Calculation

Output

Vertical Distances for Backsight		Height Instrument	
Vd1	2.28339192868951 ft	HI1	1410.48339192869 ft
Vd2	35.7722155099583 ft	HI2	1463.09667832923 ft
Vd3	-6.99608946001652 ft	HI3	1503.55880210245 ft

Vertical Distances for Foresight		Elevation of Stations	
Vd2	-15.0410708905804 ft	ElevTP1	1431.82446281927 ft
Vd3	-55.258213233242 ft	ElevTP2	1520.55489156247 ft
Vd4	-1.91344439266989 ft	ElevTP3	1510.47224649512 ft

Backsight	
BS1	-6.31660807131049 ft
BS2	31.2722155099583 ft
BS3	-16.9960894600165 ft
Sum BS	7.9595179786313 Check

Foresight	
FS2	-21.3410708905804 ft
FS3	-57.458213233242 ft
FS4	-6.91344439266989 ft
Sum FS	-85.712728516492 Check

Z = (SumBS - SumFS) 93.6722464951236 Check
 Q = Elev Final point (TBM4) - Elev First Point (TBM3) 93.6722464951236 Check
 N = (Z - Q) 0 Check

Buttons: Save, Back, Next, Plotting Profile

Plotting Pro Figure (11/b): Leveling (4 Stations) Input and Computation [4].

When this option is selected the figure shown in figures (10/b) and (11/b) presented to the user. The user has to input the following information:

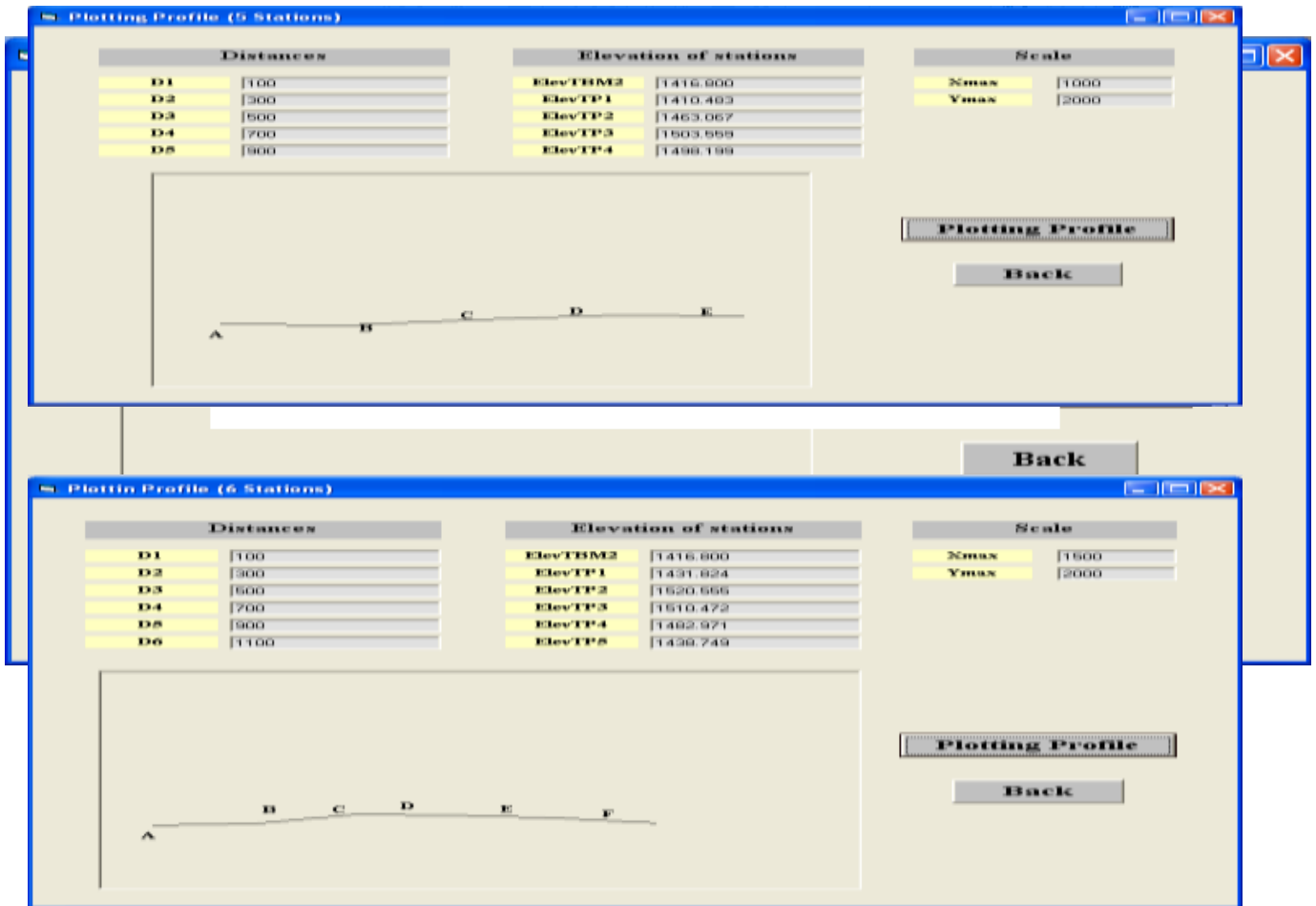
- Distances (D1, D2, and D3,.....).
- Elevation of Stations (ElevTBM2, ElevTP1, and ElevTP2,.....).
- Scale (S).

When these data are input the computer program and when the user selects "plotting profile" button to begin by drawing the points are illustrated in the below figures (12/a),(12/b),(12/c),and figure (12/d) . The program output result is saved for later use by the user in a text file.

Plotting Profile (3 Stations)

Distances		Elevation of stations		Scale	
D1	100	ElevTBM2	1416.800	Xmax	1000
D2	200	ElevTP1	1431.824	Ymax	2000
D3	300	ElevTP2	1520.555		

Buttons: Plotting Profile, Back



Conclusions:

From the results obtained in research, the following conclusions can be made:-

1. The stadia measurement is modeled by Visual Basic language as software named **MSM** (**M**odeling the **S**tadia **M**easurements). The program is formulated and written by using Visual Basic, Version 6.
2. The software that were developed in this research has been tested by performing the stadia measurements method and proved to be efficient.
3. The solution problems of traversing and leveling in manual method is more complex if compared to Figure (12/c): Plotting Leveling (5 Stations) Input and Plotting.
4. The developed program (**MSM**) needs less time as compared to the manual method in order to solve the problem.

Figure (12/d): Plotting Leveling (6 Stations) Input and Plotting.

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