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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:

التاكيوميتري 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 البلانمترية ,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 مبادىء طريقة الستيديا والتي تتم بأستخدام اجهزة الترانست او الثيودولايت او جهاز المحطة الكاملة (Total Station Instrument) هي واحدة من الطرق الرئيسية للتاكيوميتري. ان هذا البحث يعرض مبادىء طريقة الستيديا وتم عمل برنامج حاسوب اسمه ((**MSM**) **M**odeling the **S**tadia **M**easurements). تم اعداد البرنامج بإستعمال لغة الفجوال بيسكِ، نسخة 6. هذه النسخةِ من اللغةِ موجهة ومجهزة بالأدواتِ الشاملةِ لتَبْسيط مهمّةِ البرمجة ولتَزويد المبرمجِ بتشكيلة واسعة من الخياراتِ لتصميمِ 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).

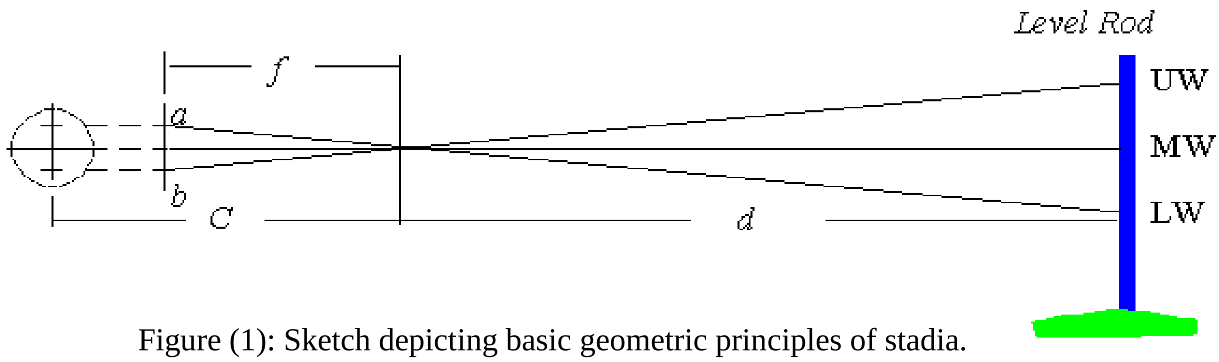


Figure (1): Sketch depicting basic geometric principles of stadia.

If we let

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

$$\frac{f}{ab} = \frac{d}{I} \Rightarrow d = \frac{f}{ab} I \quad \text{.......... (1)}$$

then

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

$$D = KI + C \quad \text{.......... (2)}$$

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.

f1= 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.

f2= distance from the center (actually the nodal point) of the objective lens to definite point when the telescope is focused on that point. When ***f2*** is infinite, or very large, *f1=f2*.

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.

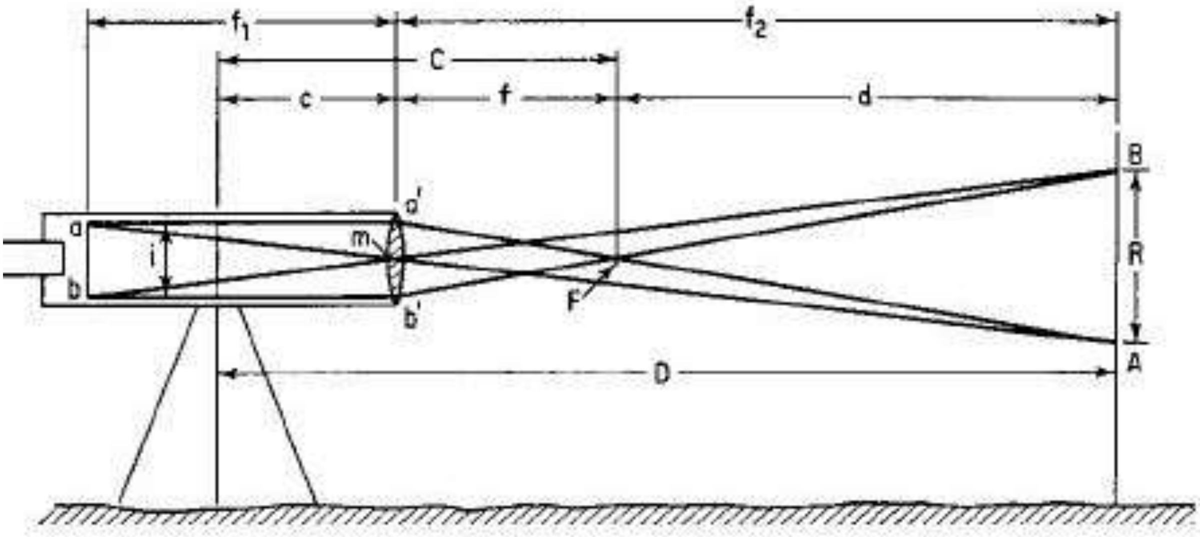


Figure (2): Principle of stadia, external-focusing telescope.

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 :

$I' = I \cos(\alpha)$ ………………………………………………………………………….......................... (3)

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

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

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

$H = KI \cos^2(\alpha) + C$ …………………….……………………………………………….….(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:

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

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

$V = KI \cos(\alpha) \sin(\alpha) = \mathrm{KI} \cos(z) \sin(z)$ ……………………..…………………….…..…(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]:

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

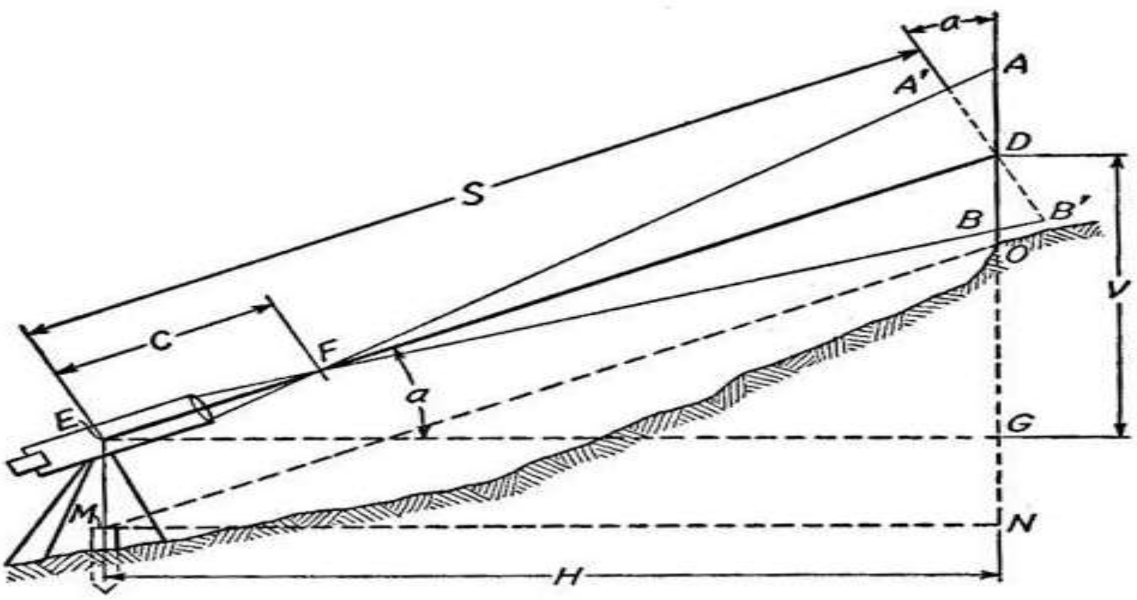


Figure (3): Inclined stadia measurement.

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 intial 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. I n 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 know 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 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. 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 are 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).

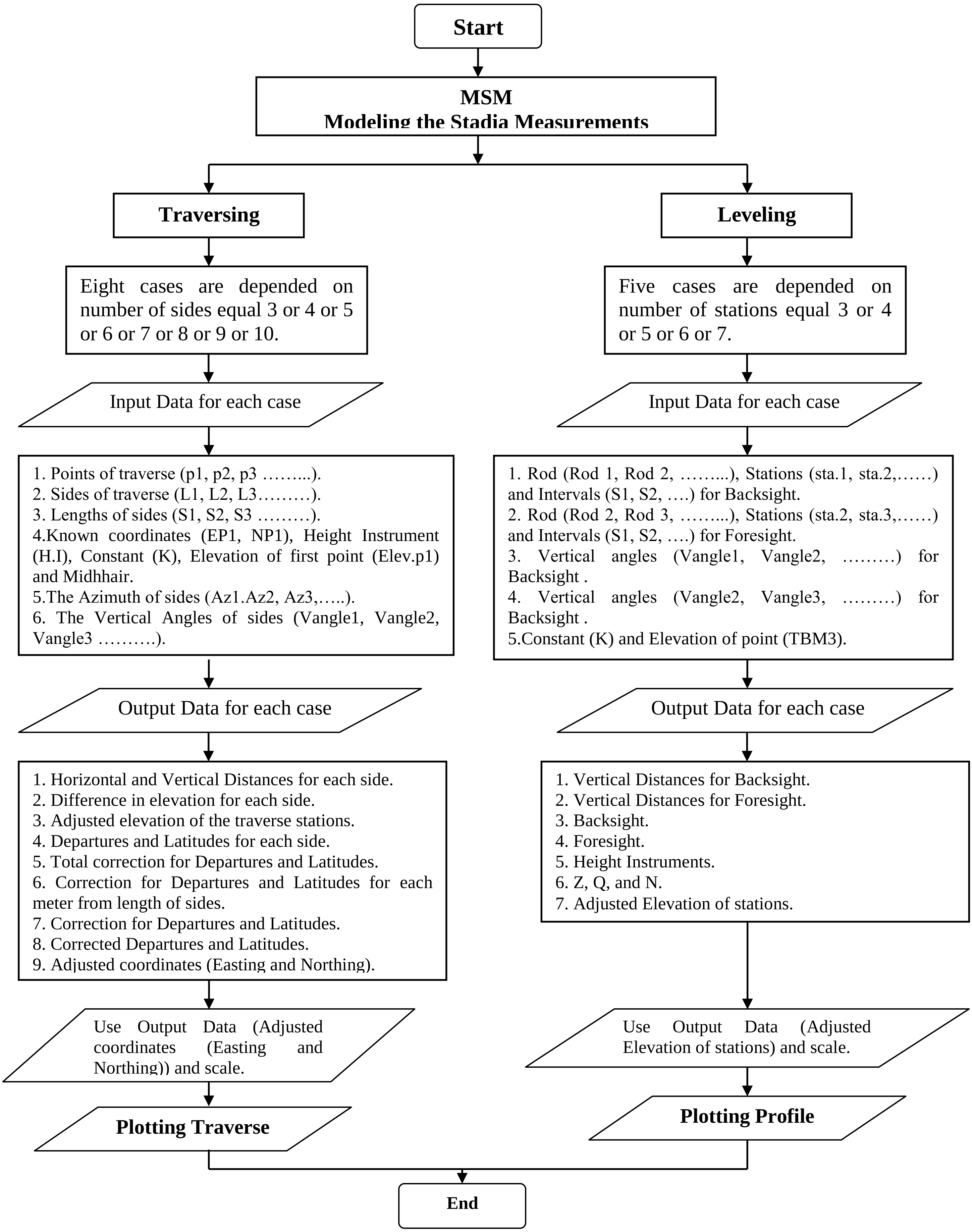


Figure (4): Flowchart of work steps.

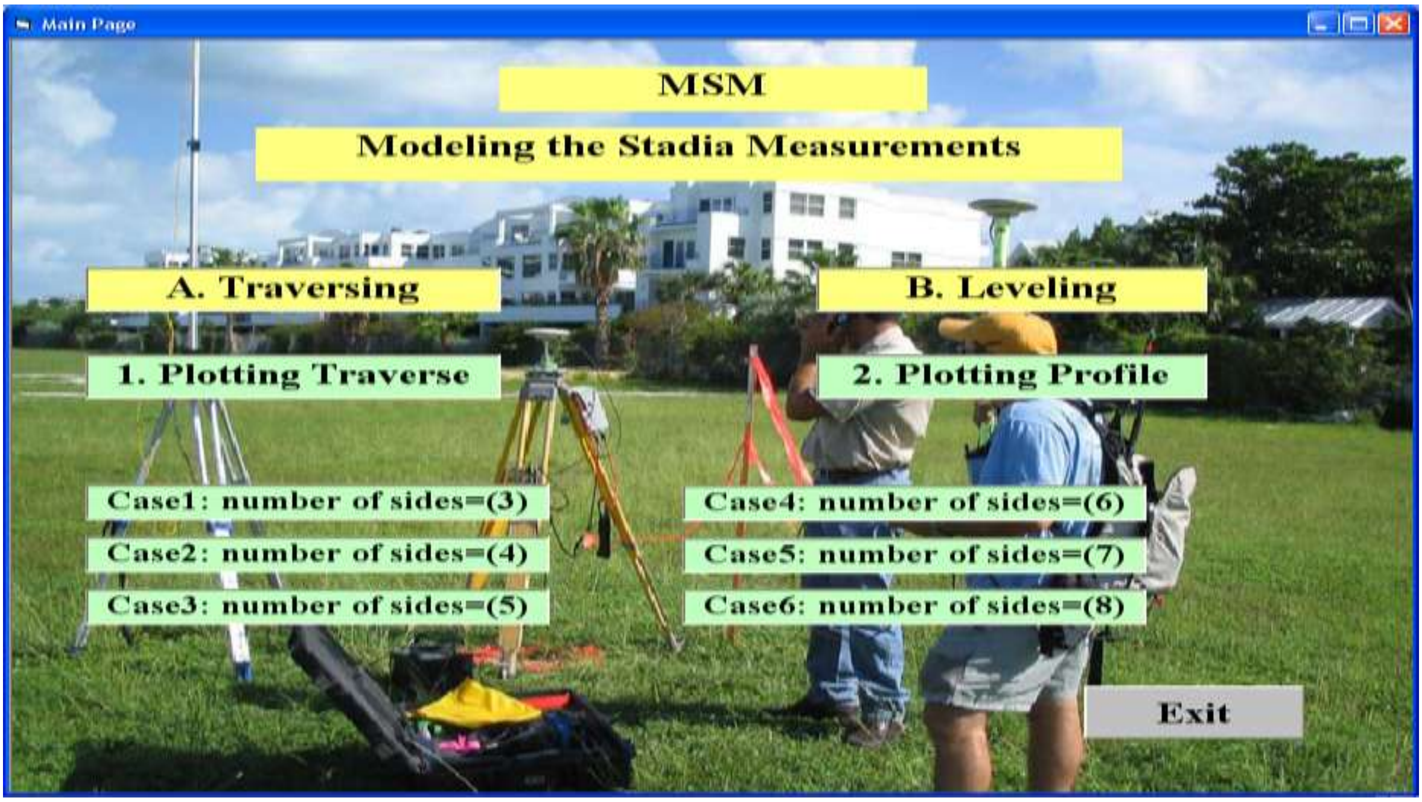


Figure (5): The main page of (MSM).

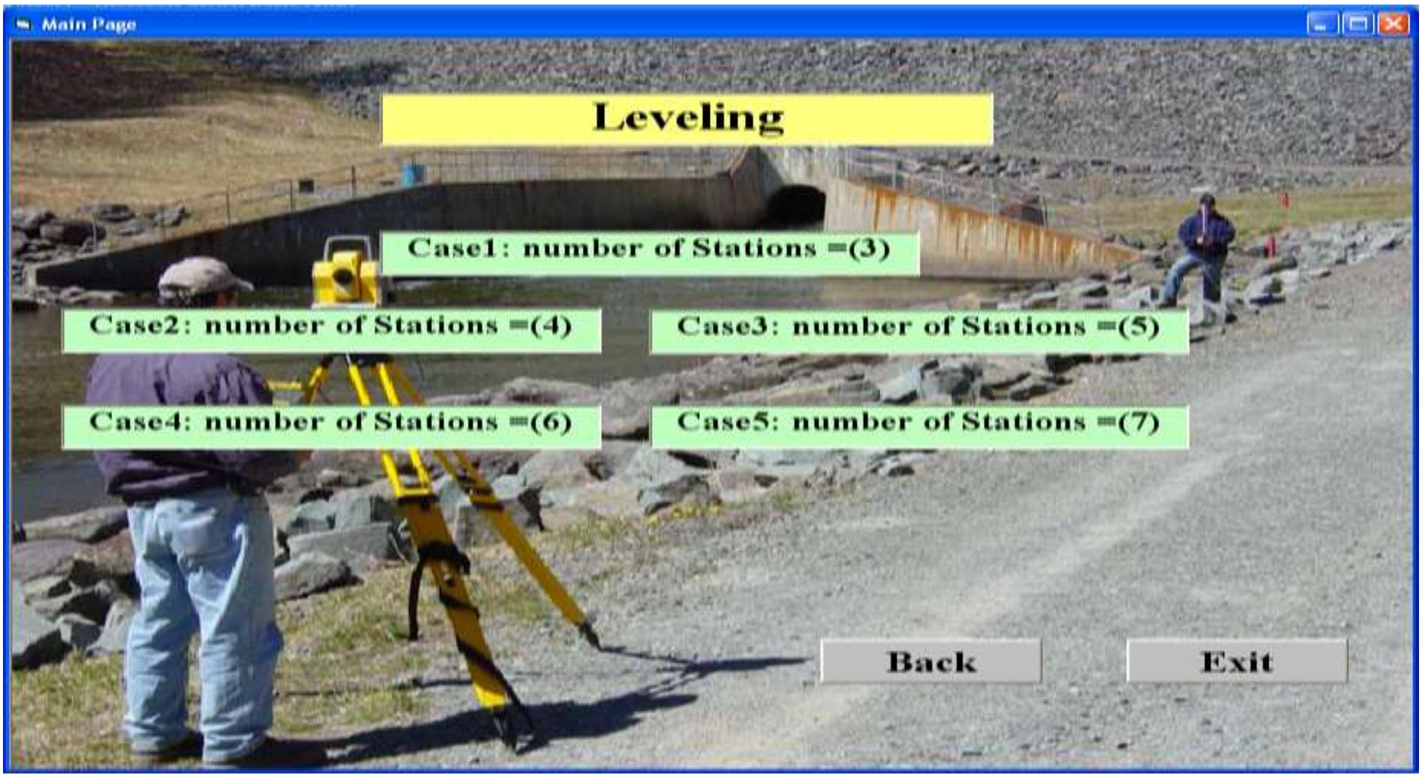


Figure (6): The main page of Leveling.

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).

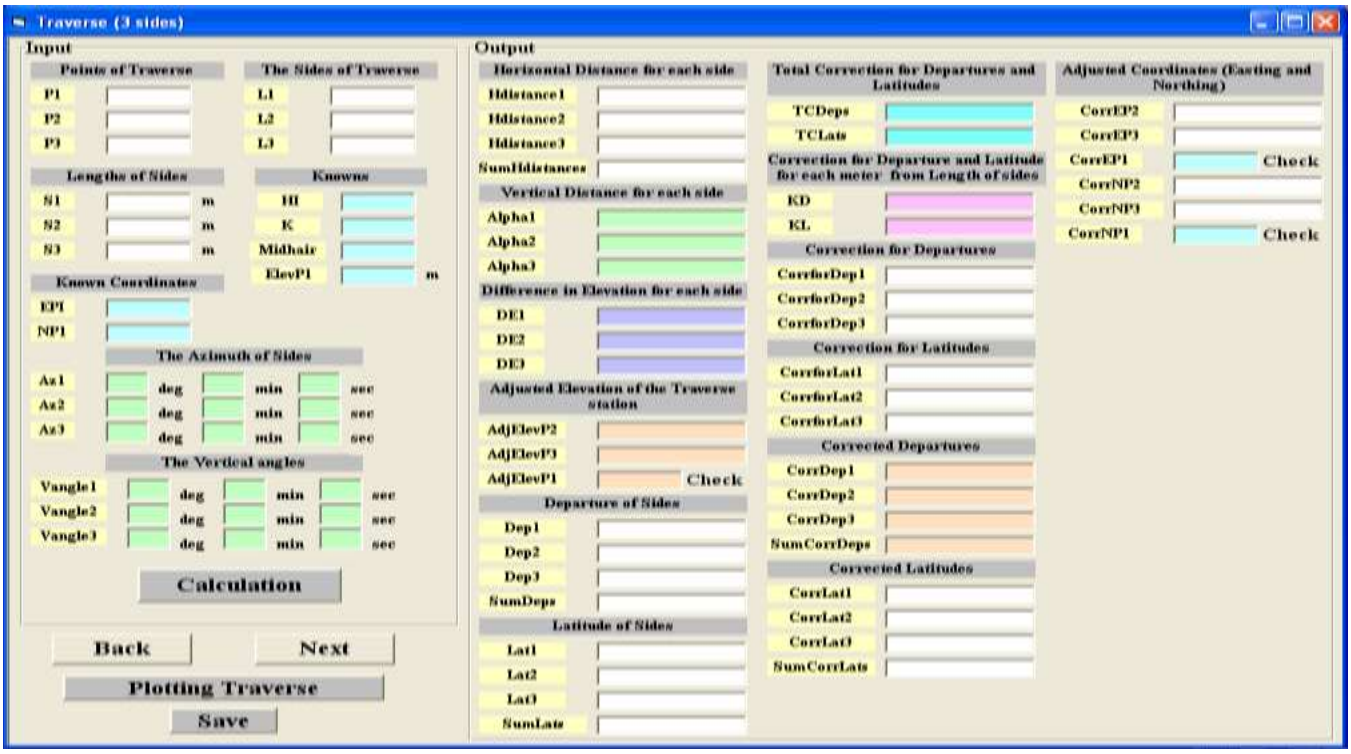


Figure (7/a): Traverse (3 Sides).

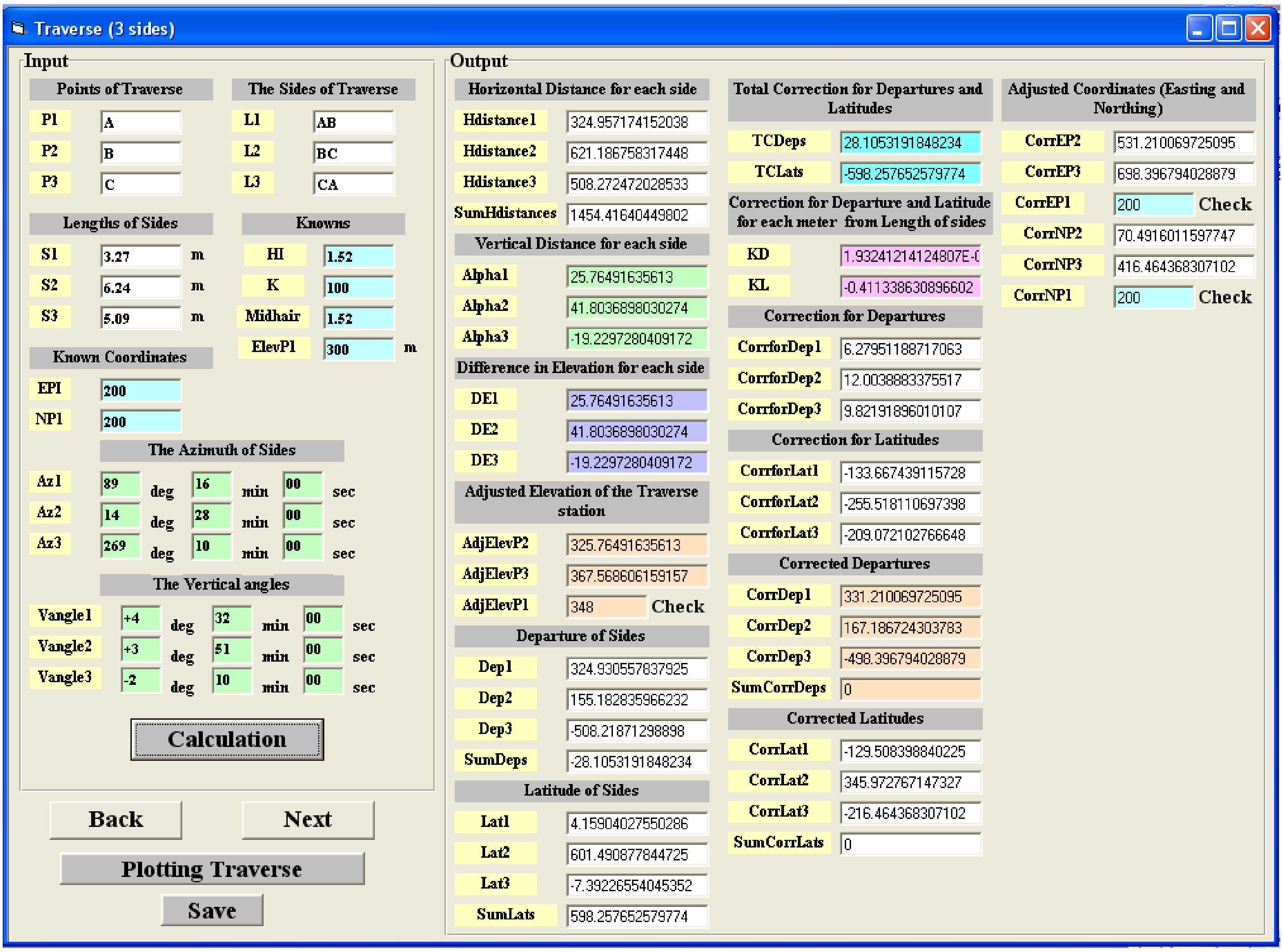


Figure (7/b): Traverse (3 Sides) Input and Computation [4].

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.

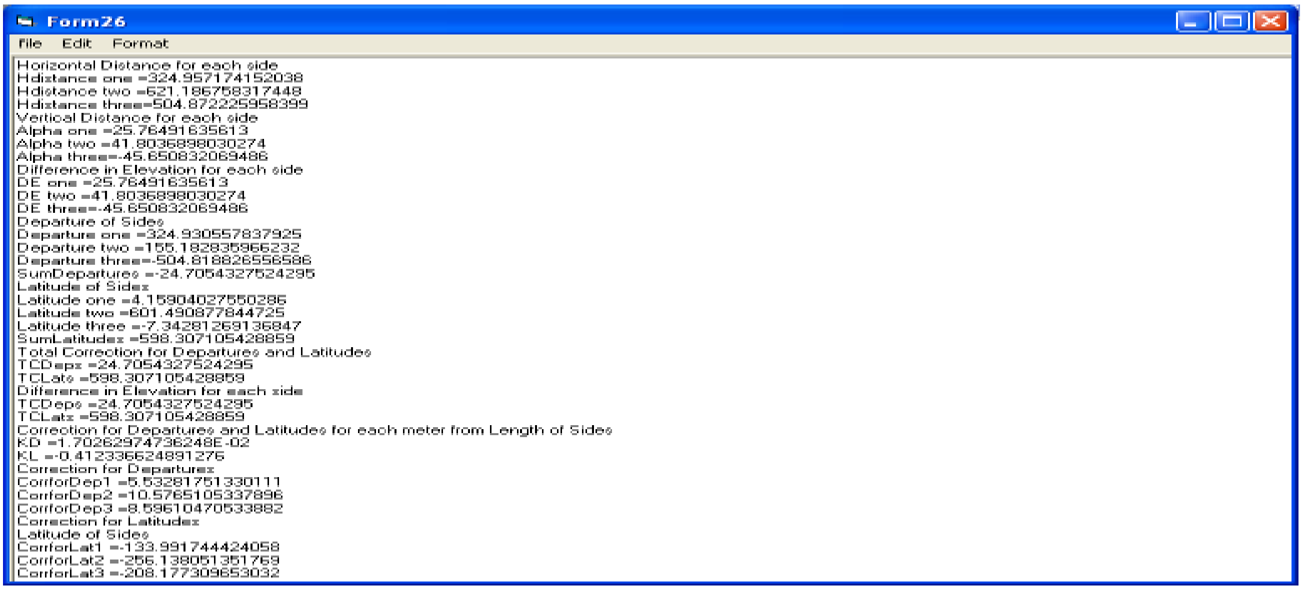


Figure (7/c): The Result of the Output.

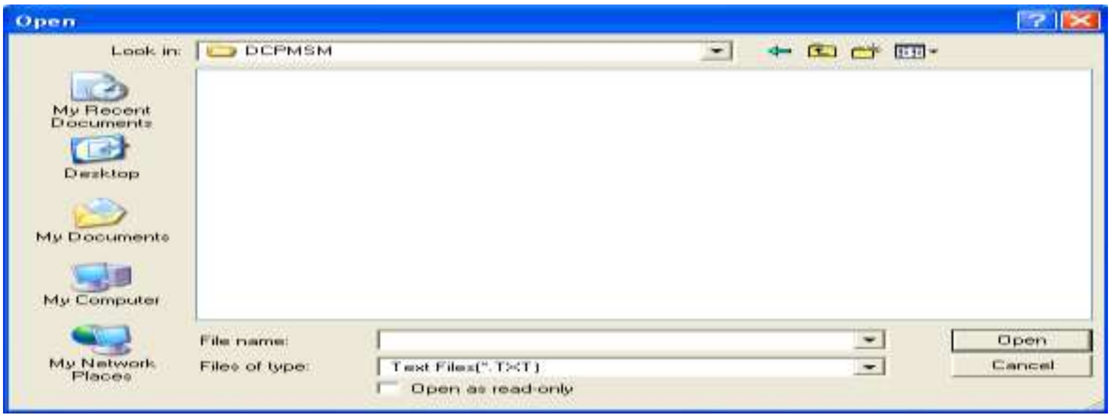


Figure (7/d): Open file dialog box.

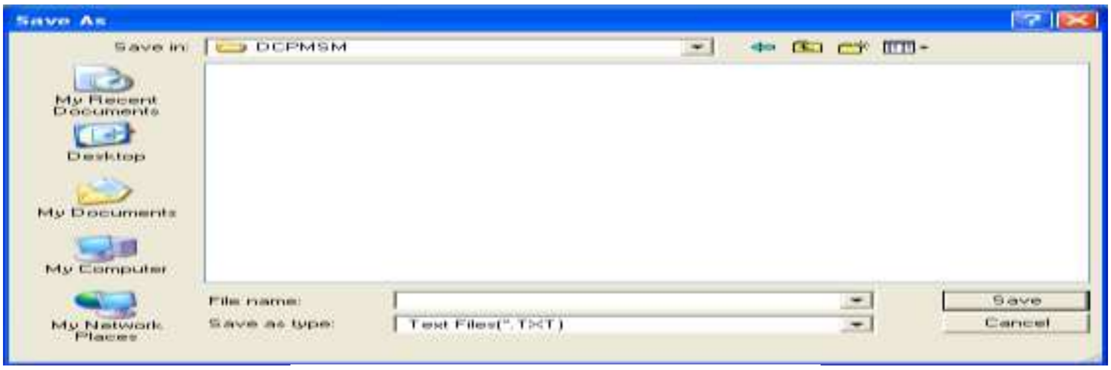


Figure (7/e): Save file dialog box.

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).

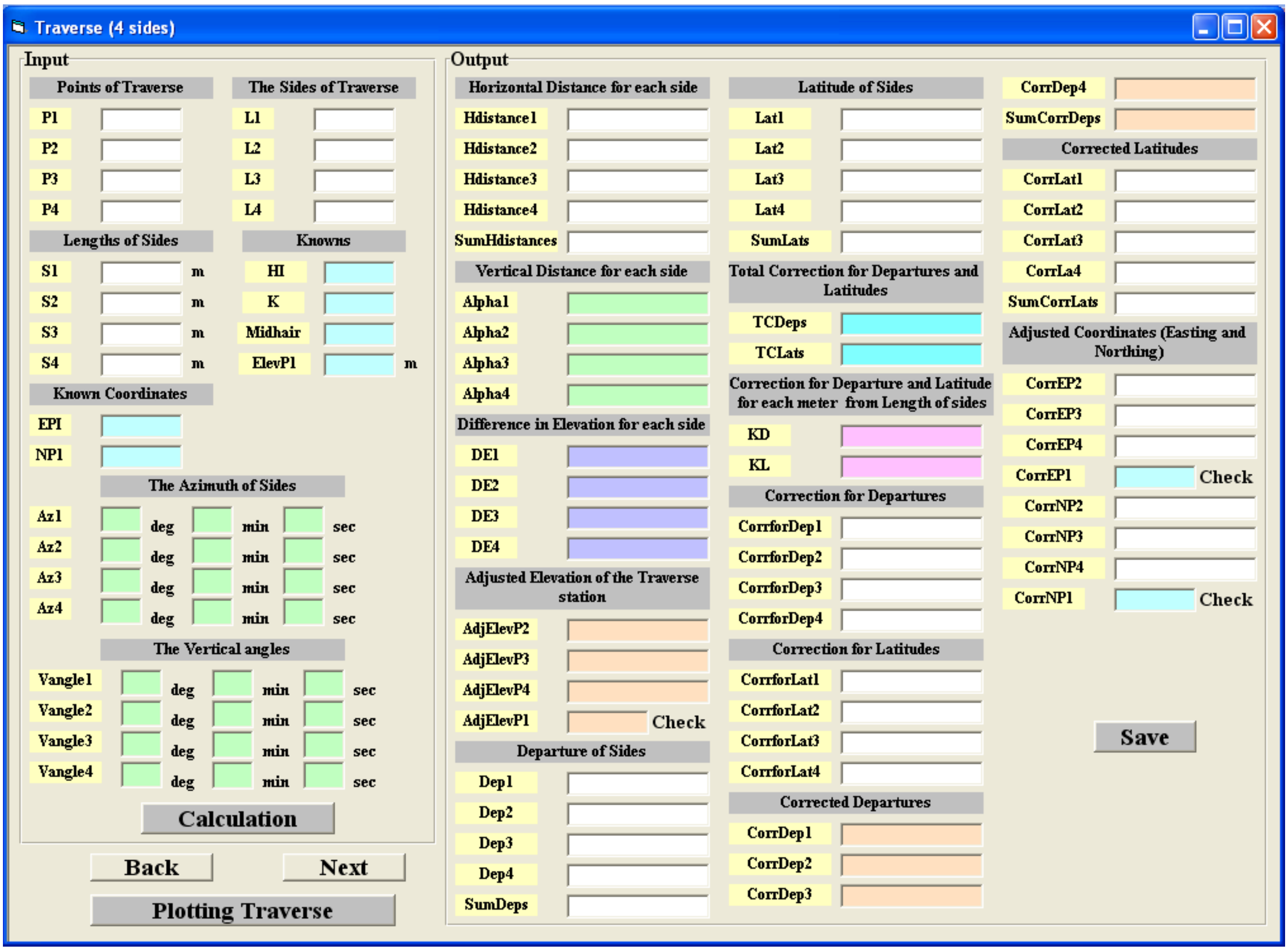


Figure (8/a): Traverse (4 Sides).

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.

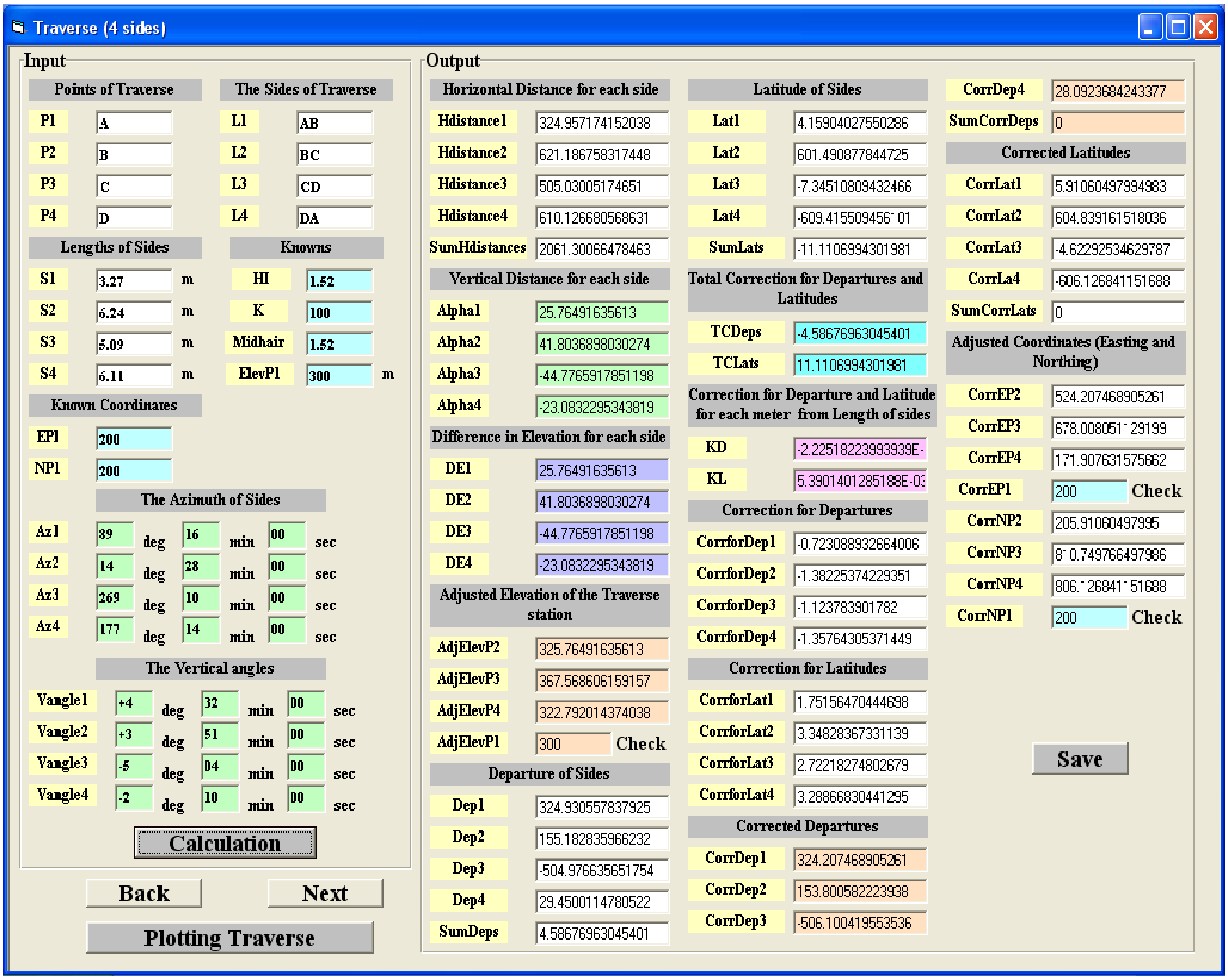


Figure (8/b): Traverse (4 Sides) Input and Computation [4].

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.

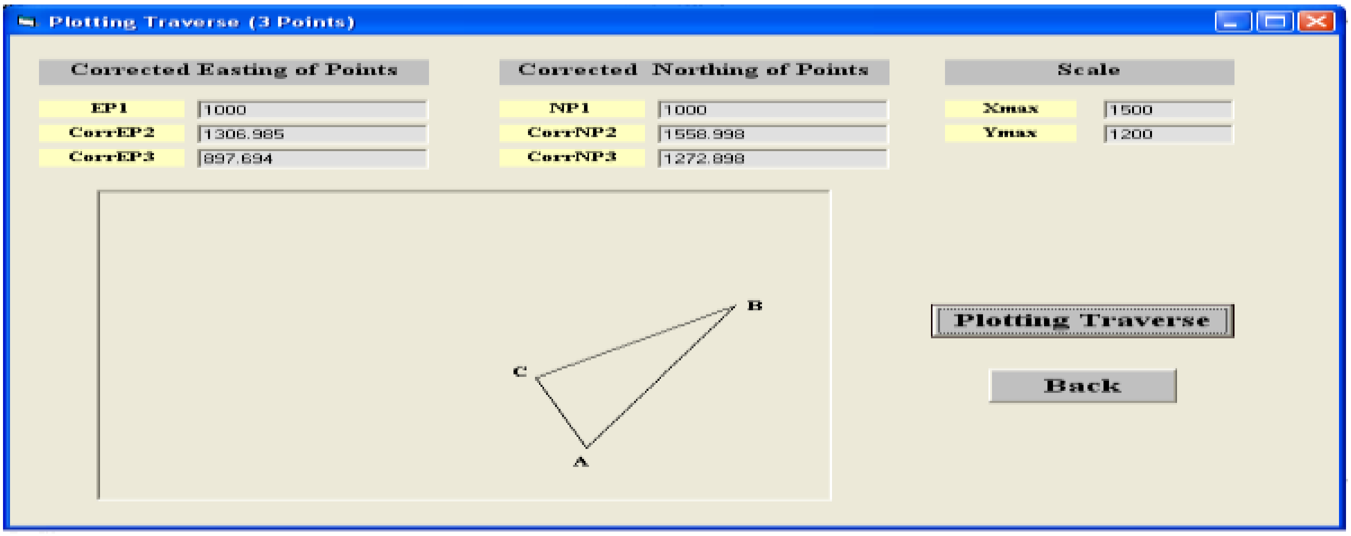


Figure (9/a): Plotting Traverse (3 points) Input and Plotting.

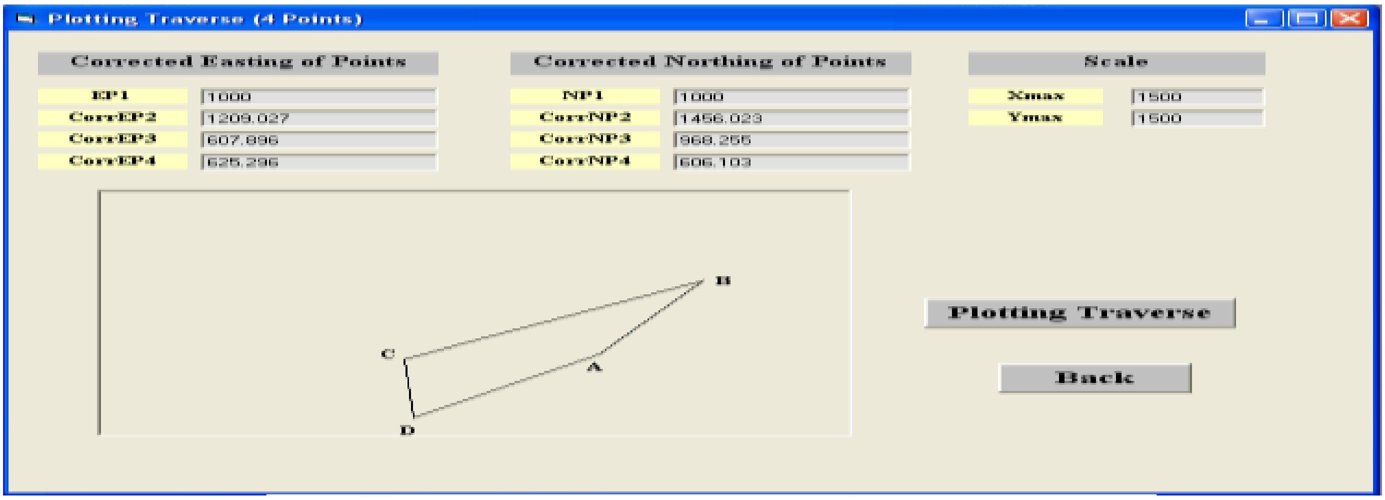


Figure (9/b): Plotting Traverse (4 points) Input and Plotting.

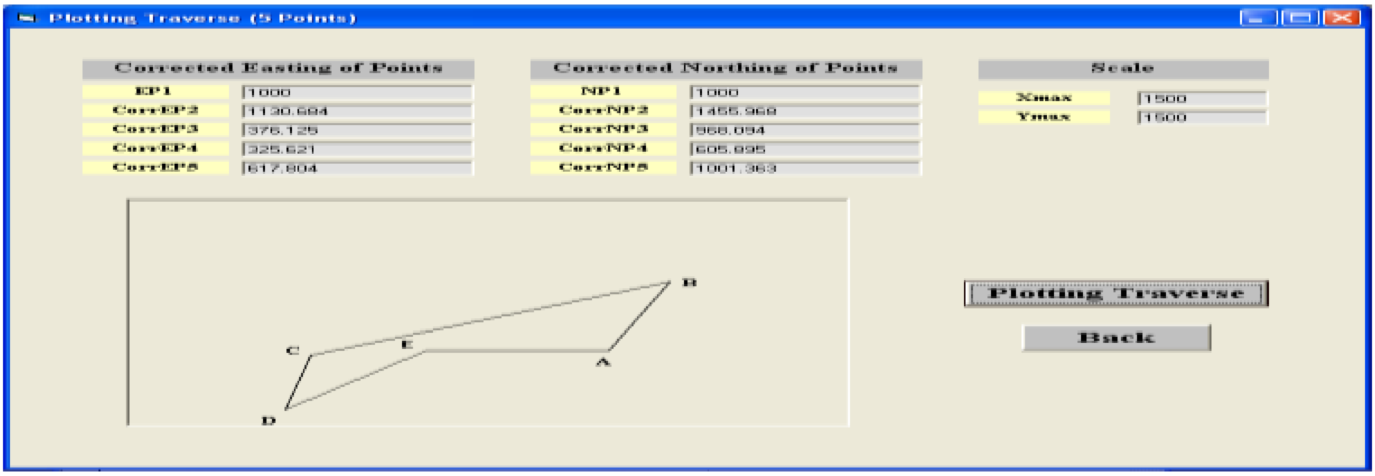


Figure (9/c): Plotting Traverse (5 points) Input and Plotting.

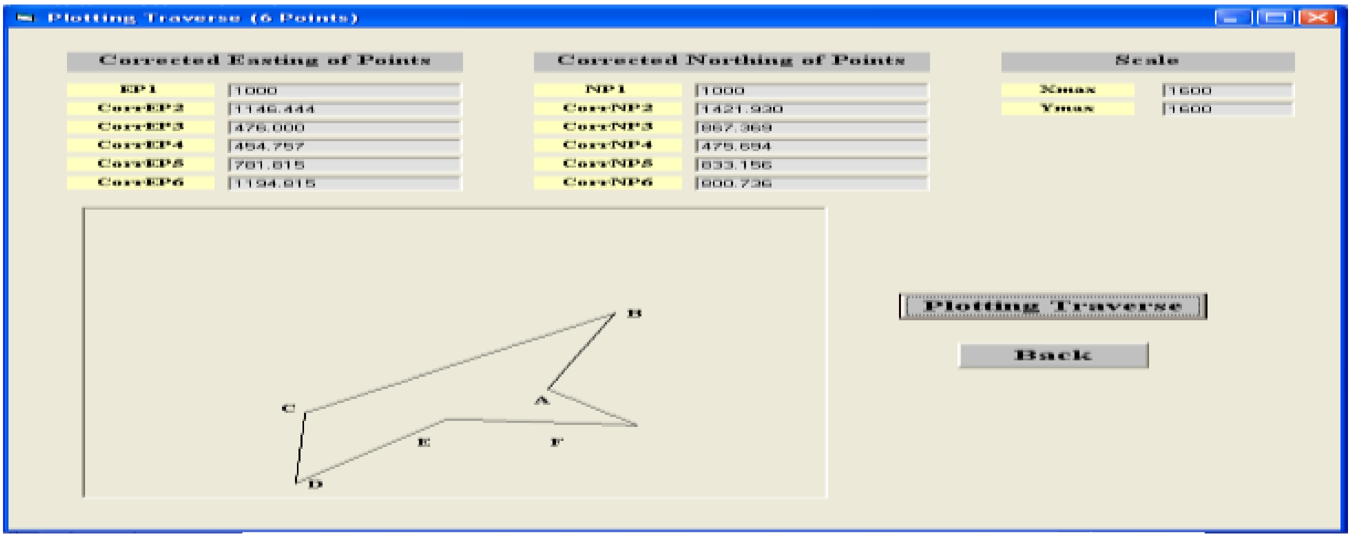


Figure (9/d): Plotting Traverse (6 points) Input and Plotting.

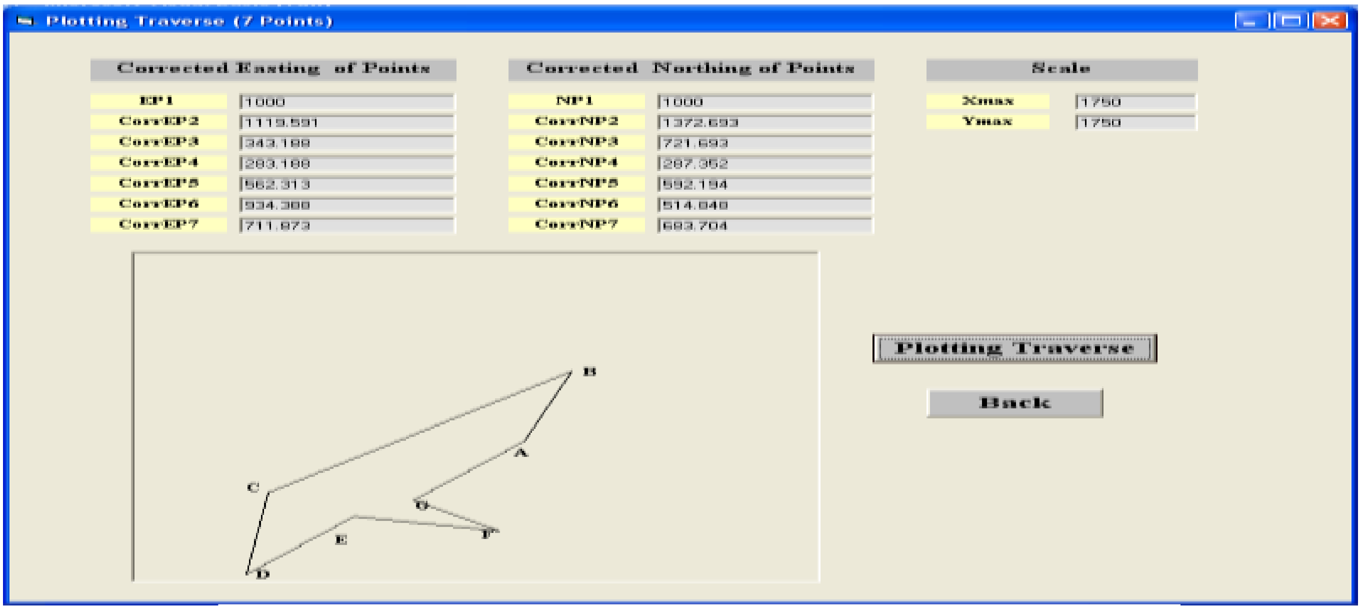


Figure (9/e): Plotting Traverse (7 points) Input and Plotting.

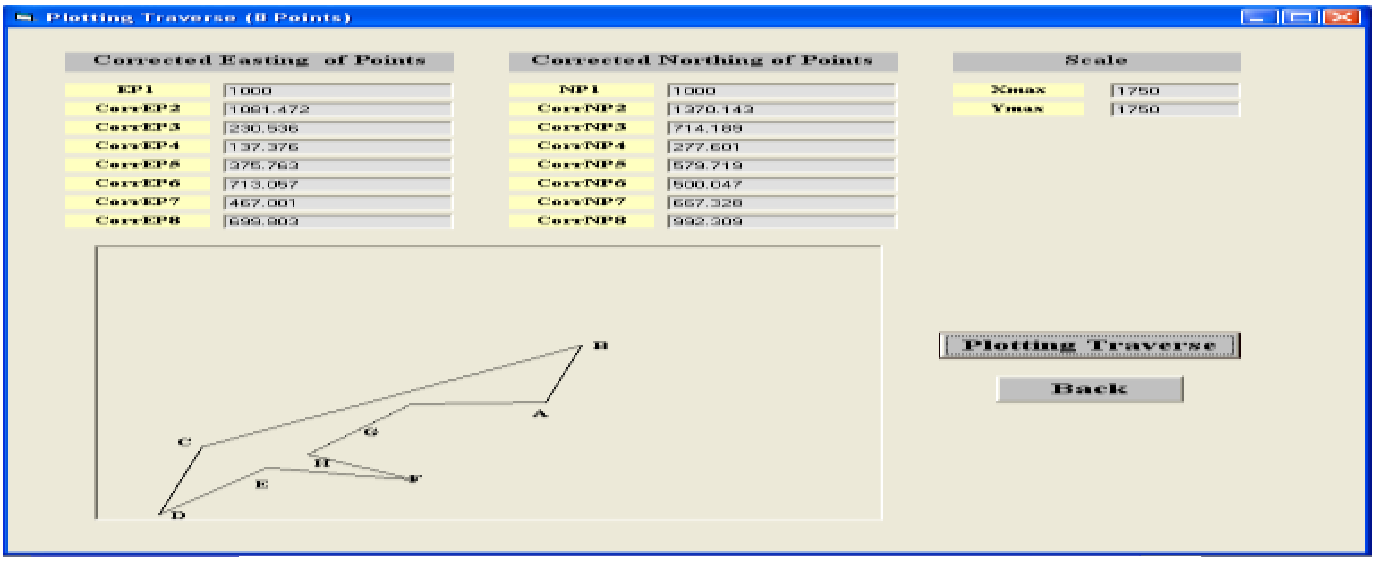


Figure (9/f): Plotting Traverse (8 points) Input and Plotting.

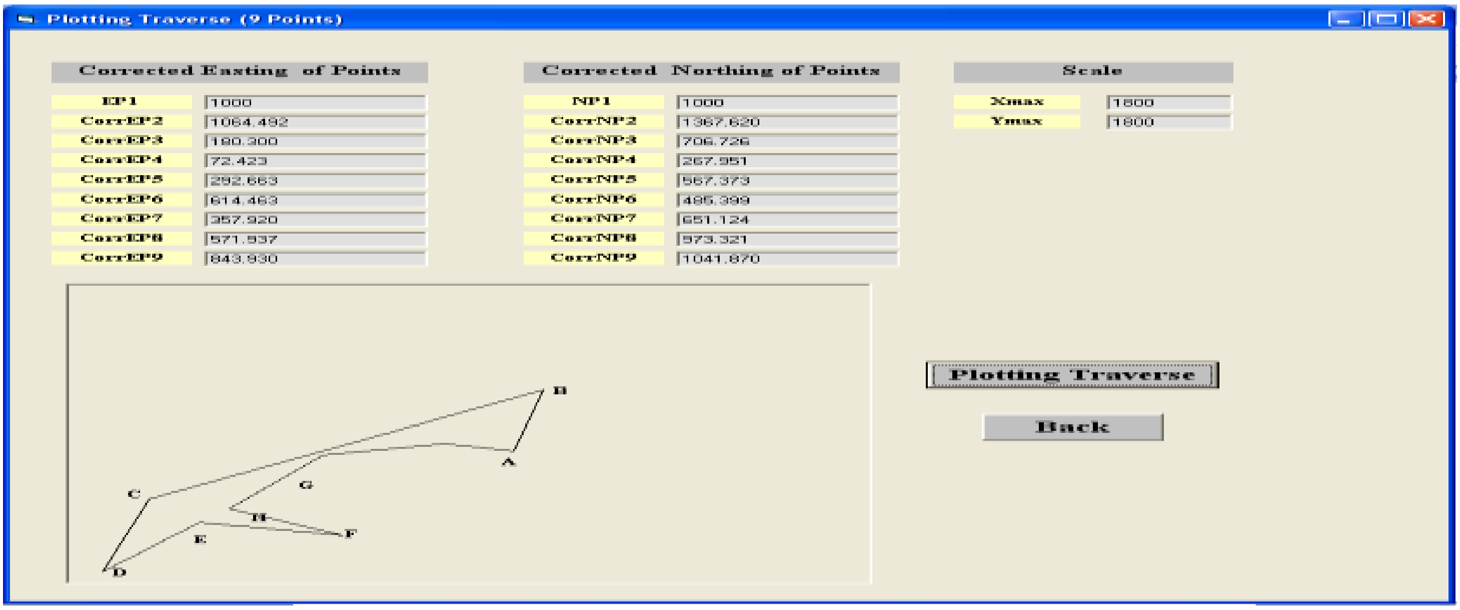


Figure (9/g): Plotting Traverse (9 points) Input and Plotting.

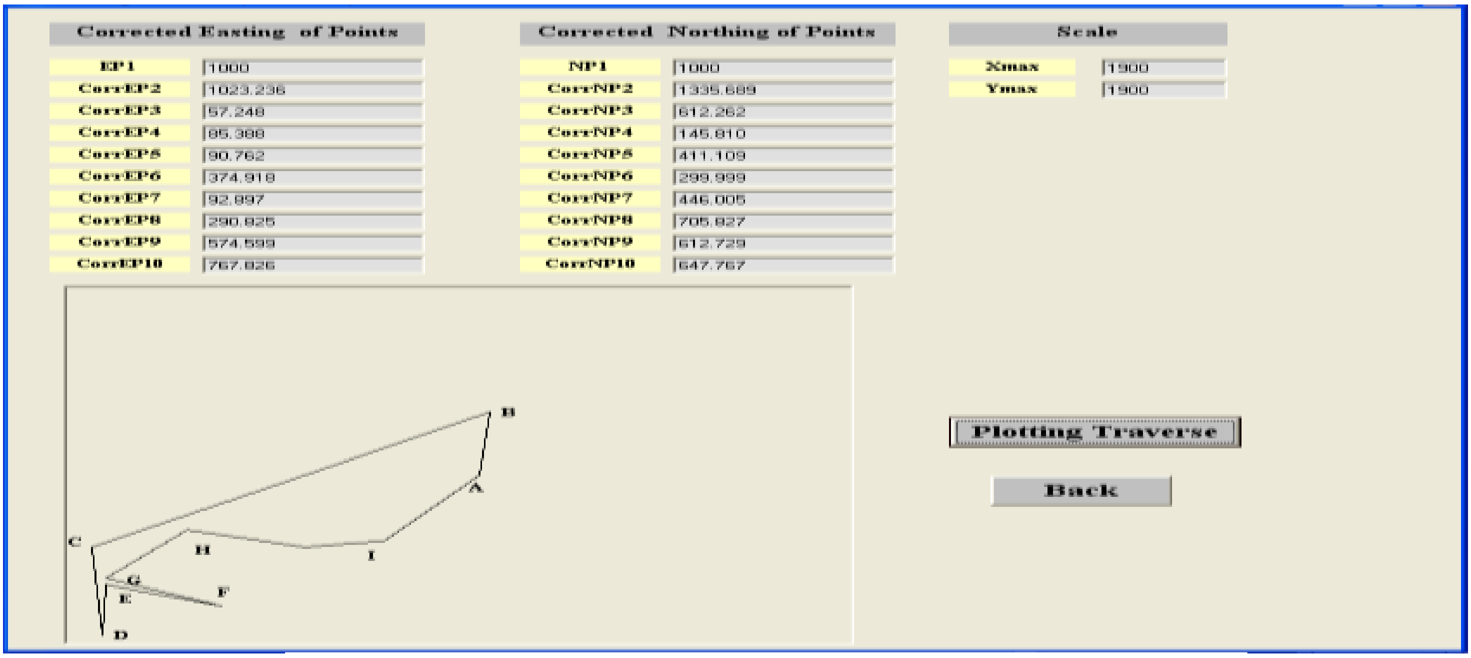


Figure (9/h): Plotting Traverse (10 points) Input and Plotting.

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.

<u>Case1: number of Stations = (3)</u>

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).

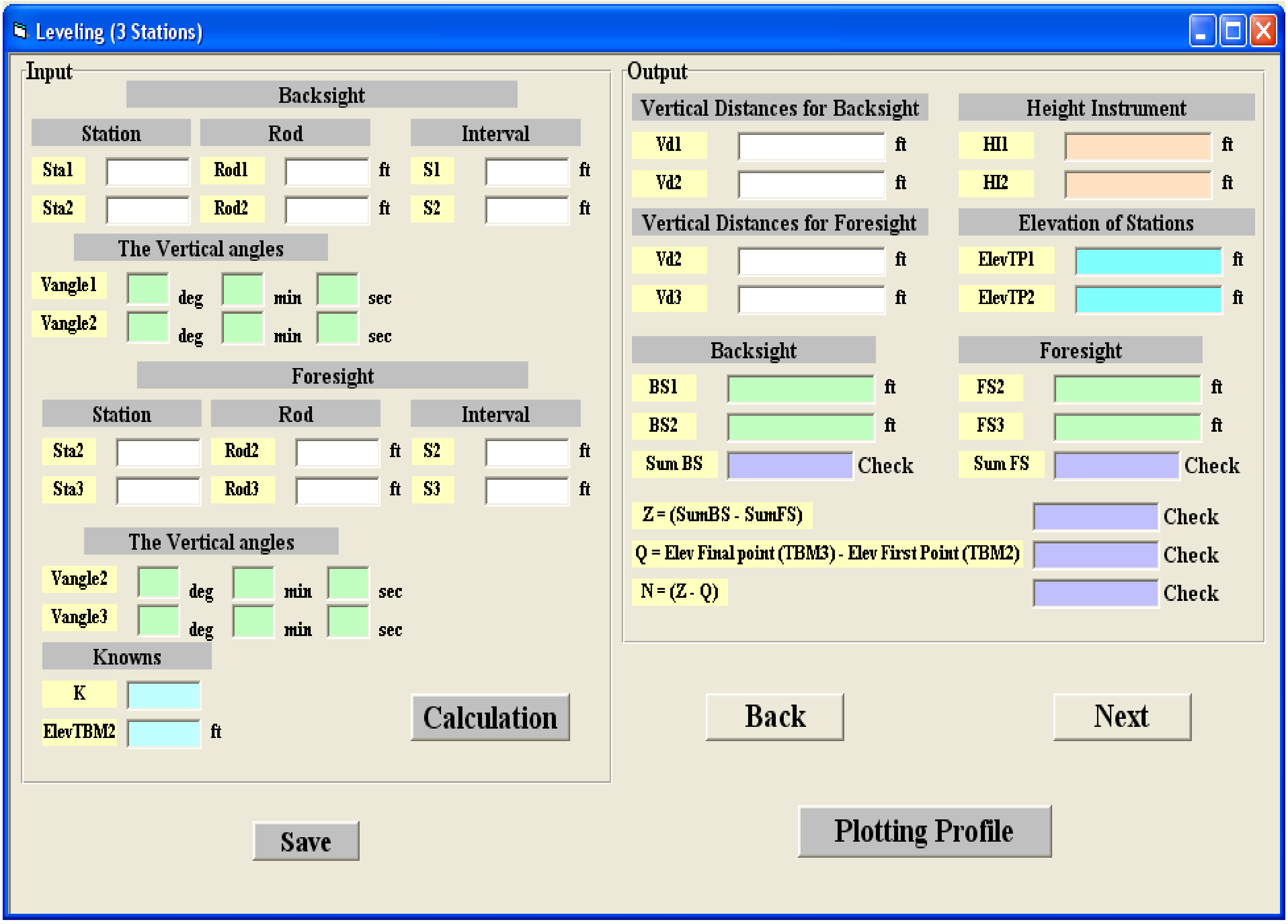


Figure (10/a): Leveling (3 Stations).

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.

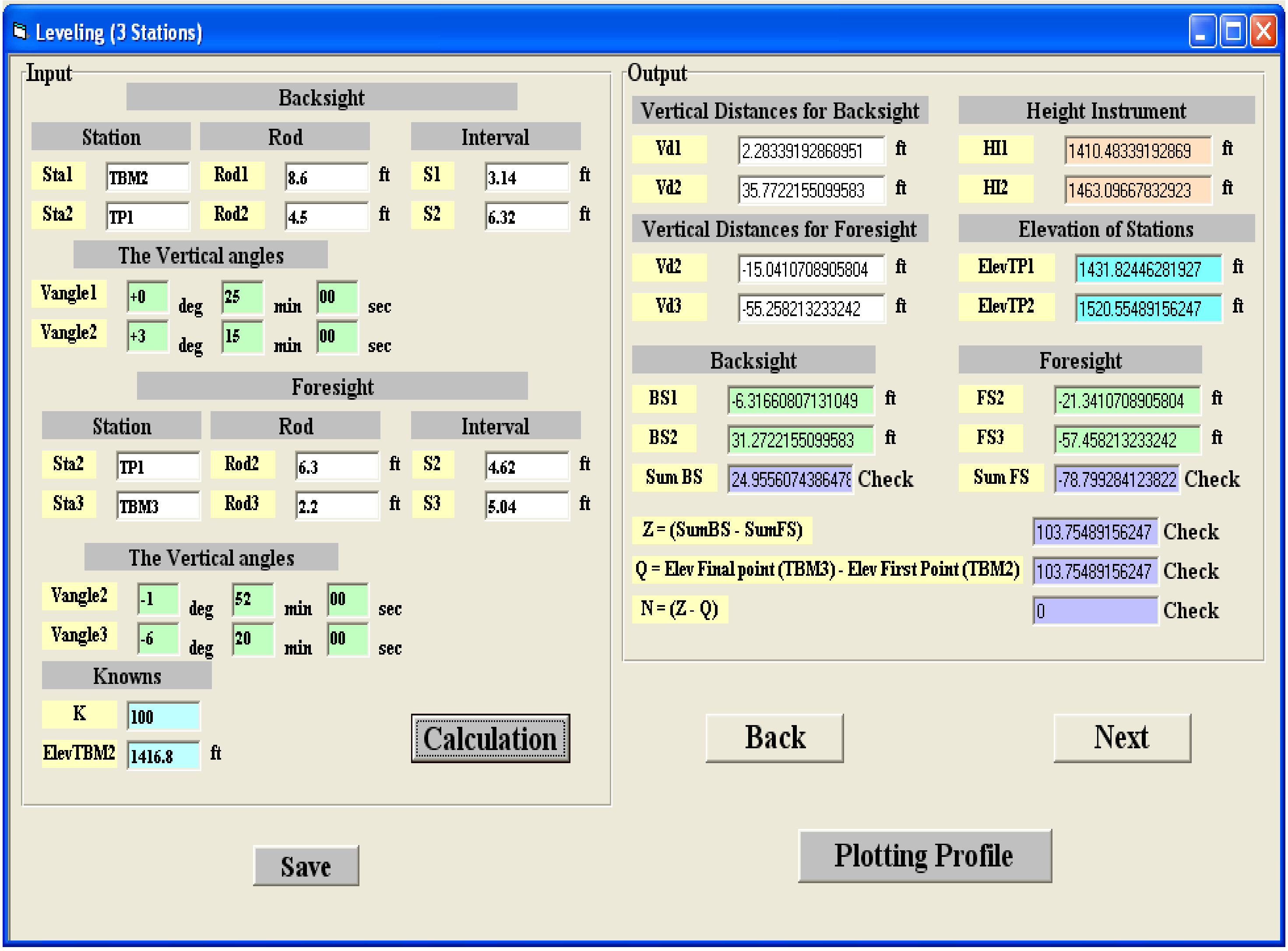


Figure (10/b): Leveling (3 Stations) Input and Computation [4].

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).

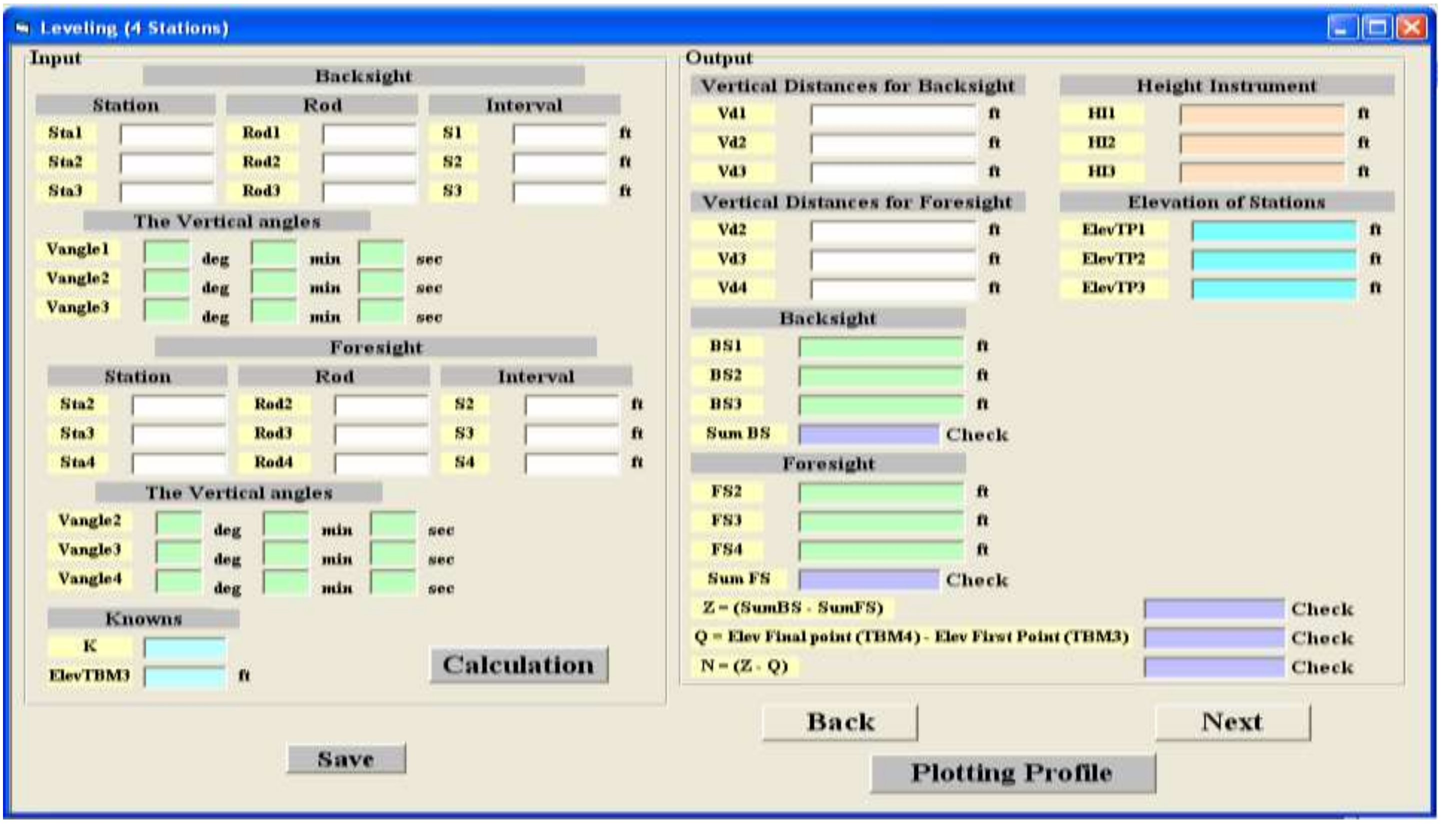
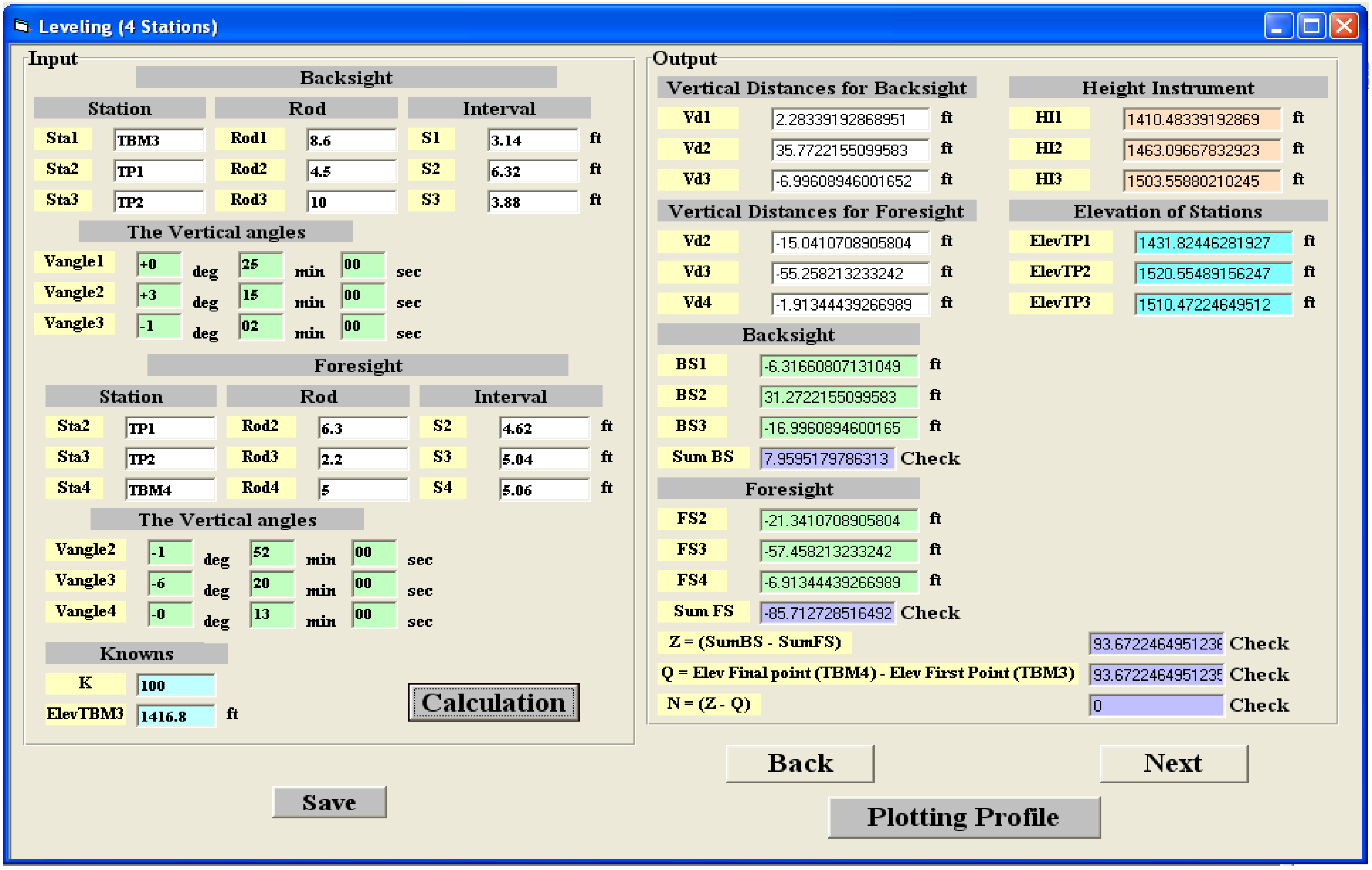


Figure (11/a): Leveling (4 Stations).



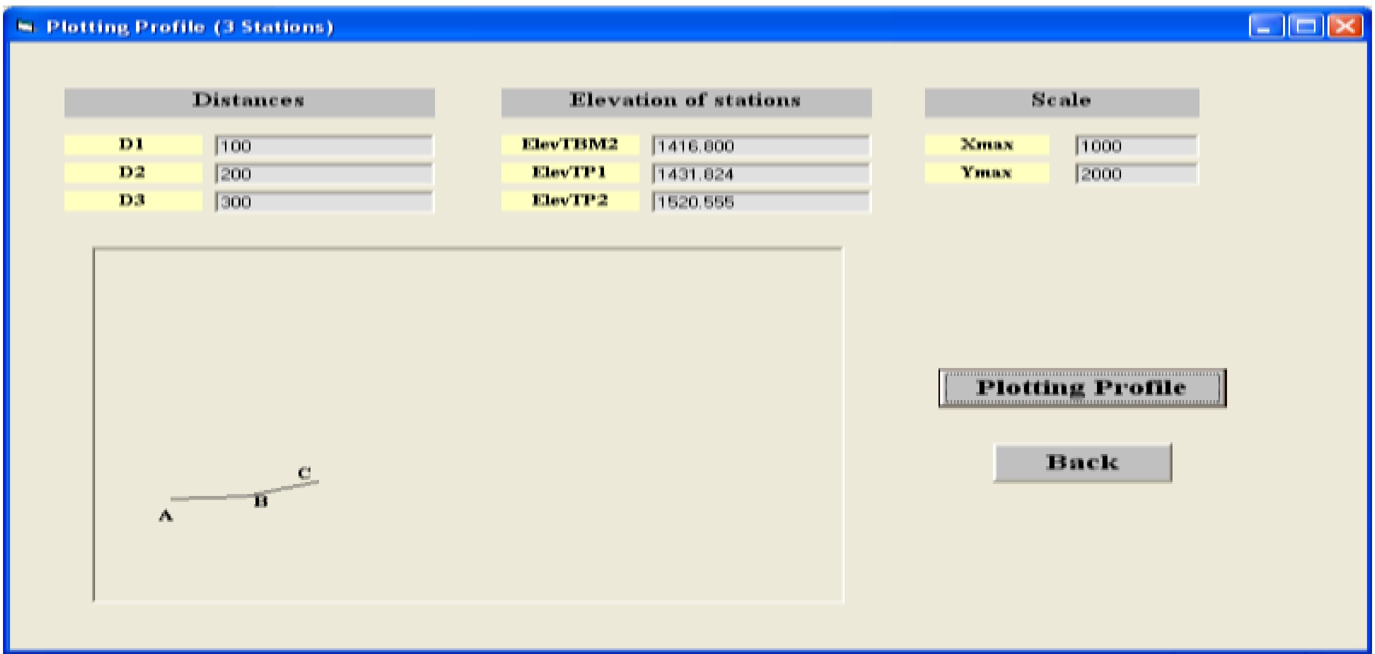
Plotting Pro

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.



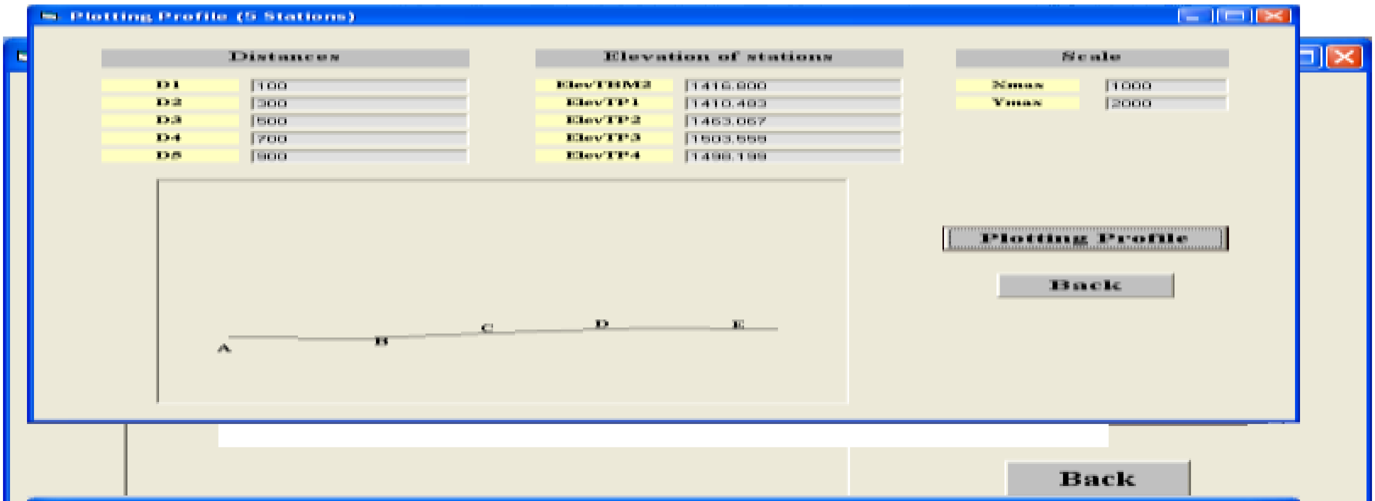


Figure (12/c): Plotting Leveling (5 Stations) Input and Plotting.

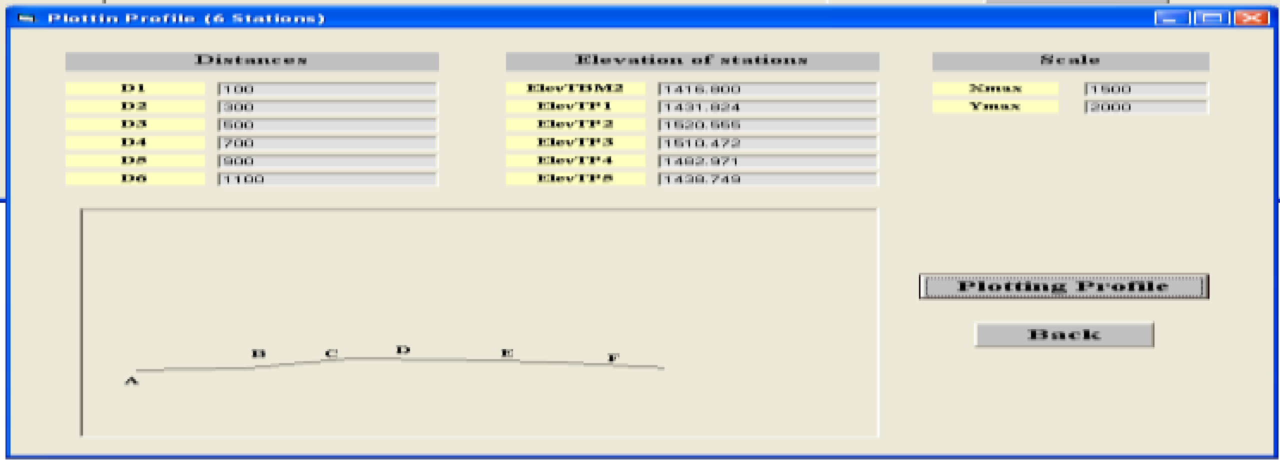


Figure (12/d): Plotting Leveling (6 Stations) Input and Plotting.

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
4. The developed program **(MSM)** needs less time as compared to the manual method in order to solve the problem.

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