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An Investigation of Gross Error Angle in a Connecting Traverse with a $\pm 200^{gon}$ Difference

Hüseyin İnce[1a], Nuri Erdem[2], Fazlı Engin Tombuş[1b]

[1a,b]High School of Mapping and Land Survey, Hitit University, Çorum, Turkey,
[2]Engineering Faculty, Department of Geomatic Engineering, Osmaniye Korkut Ata University, Osmaniye, Turkey

Abstract

The Global Navigation Satellite System (GNSS) cannot always be used efficiently in city surveys because of the effect of obstructions such as high-rise building and high trees in the city discussed in. In this situation the measurements of angles and lengths have to be carried out with the conventional (classical) traversing methods. Since geodetic surveys can be tedious and time consuming, it is inevitable that systematic errors, unsystematic errors and gross errors occur despite the care that is taken. An angle measured in a traverse with an error margin can be used in the calculation of traverse.

If there is an error in the measurement of a traverse angle of $\pm 200^{gon}$ and this is then used in the manual traverse calculation, then the identification of this gross error is not possible in the calculation. In this case, the gross error is noticeable when the α_n control bearing is checked. However, the Brönnimann formula can be used in manual calculations to determine the point where gross error occurred. After a wide literature survey it was found that there is no such study with concerning special case of gross error is seen in the literature. In this study a simple formula which can replace the Brönnimann formula is presented for the case where the error is $\pm 200^{gon}$. A new formula is created to calculate easier and simpler than classical formula for this special case. A flow chart of the program for scientific calculators and computers are given together with numerical examples.

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[2]Corresponding Author Email: nurierdem@osmaniye.edu.tr

1. Introduction

The Global Navigation Satellite System (GNSS) cannot always be used efficiently in city surveys because of the effect of obstructions such as urban canyon[1] and high trees discussed in [1, 2]. In this situation the measurements of angles and lengths have to be carried out with the conventional (classical) traversing methods. Since geodetic surveys can be tedious and time consuming, it is inevitable that systematic errors, unsystematic errors and gross errors occur despite the care that is taken. In this study, a method is proposed for the special case of gross error that can occur in angle surveys. This is when the error is to $\pm 200^{gon}$ of the normal value of a traverse angle. After a wide literature survey it was found that there is no such study with concerning special case of gross error is seen in the literature [3-7].

A single calculation method has been developed by many researchers [8-13] to investigate the gross error angle and it is possible to use the formula developed by [14].

If there is an error in the measurement of a traverse angle of $\pm 200^{gon}$ and this is then used in the manual traverse calculation, then the identification of this gross error is not possible in the calculation. In this case, the gross error is noticeable when the α_n control bearing is checked (Fig. 1). However, the Brönnimann formula can be used in manual calculations to determine the point where gross error occurred. In this study a simple formula which can replace the Brönnimann formula (Brönnimann, Study On The Gross Error Angles Of Traverse Calculations (in German: Auffinfung eines groben Winkelfehlers in einem Polygonzug), submitted to the *Zfv., 1888*) is presented for the case where the error is $\pm 200^{gon}$. A new formula is created to calculate easier and simpler than classical formula for this special case.

[1] An urban canyon is community of very high buildings in a city

Currently the calculations of traverse coordinates, the search for gross angular error and gross error length are carried out by computer using CAD programs. If software used in traverse calculation has been coded without taking into consideration this special case give in this study, then the program application will fail this happens in Turkey with software such as Netcad [15]. This study will present the programming that is required to prevent the failure of certain programs when facing a gross error of $\pm 200^{gon}$. The flow chart of the program has been developed, which will even run on scientific calculators and computers.

This paper outlines the background to the study, then the evaluation of the gross error and gross error angle with the flow chart of the program are presented. Finally, sample numerical examples are given.

2. Investigation of Gross Error and Gross Angle Error Angle on a Traverse

2.1. Investigation of the Gross Angle in Checking of the Control Bearing

Where, $\beta_0, \beta_1, ..., \beta_n$ are the measured angles and $\alpha_0, \alpha_1, ..., \alpha_n$ are the bearings. The angular misclosure error (f_β) in Figure1 is calculated as shown in equation (1).

$$f_\beta = \alpha_n - \alpha'_n \tag{1}$$

α'_n is calculated from equation (2).

$$\alpha'_n = \alpha_0 + [\beta] - k * 200^{gon} \tag{2}$$

The k value is determined to be a positive integer to calculate α_n approximately from $\alpha_0 + [\beta]$ in equation (2) and it is not a constant. The tolerable limit (F_β) of the angular misclosure determined by equation (1) is calculated according to the Regulations of Map Making used in Turkey**.** If $f_\beta < F_\beta$, d_β is computed the correction factor is as follows:

$$d_\beta = \frac{f_\beta}{n} \tag{3}$$

Thus, f_β is distributed over the angles using d_β as shown in equation (4).

$$(B1) = \alpha_0 + \beta_0 + d_\beta \pm 200^{gon}$$

$$(12) = (B1) + \beta_1 + d_\beta \pm 200^{gon}$$

$$(3C) = (23) + \beta_3 + d_\beta \pm 200^{gon} \tag{4}$$

Then, as shown in Figure 1 using the formula given in equation (4), all the bearings (azimuths) are calculated for all points starting from where the traverse is initially connected. The bearing from C to D is calculated with the first basic geodetic rule using the arctangent function (equation (5).

$$(CD) = \arctan\left(\frac{Y_D - Y_C}{X_D - X_C}\right) \tag{5}$$

(CD) is also controlled by the relationship in equation (6).

$$(CD) = (3C) + \beta_n + d_\beta \pm 200^{gon} \tag{6}$$

If one of the angles in this traverse route is mistakenly taken as $\pm 200^{gon}$, (CD) calculated using equation (6) will be $\pm 200^{gon}$ different than when calculated using equation (5). An angular error of $\pm 200^{gon}$ to an angle cannot be detected in normal traverse calculations.

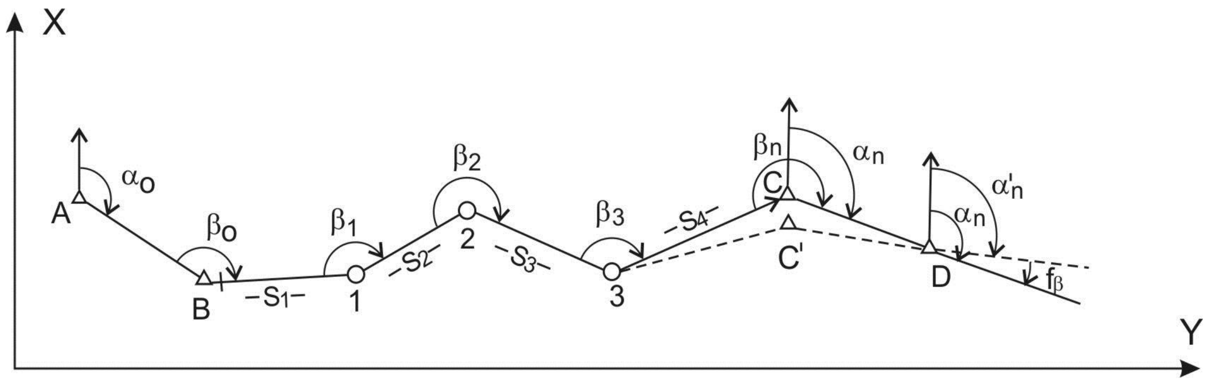


Figure 1. Locations of a connecting traverse route without a gross angular error (α_0: starting bearing, α_n: control bearing, β: traverse angles at the points).

2.2. Investigation of Gross Error Angle Using Single Calculation Method

The investigation of the gross angular error will be explained in two stages, theoretically and practically.

2.2.1. Theoretical Investigation of The Point Where a Gross Error Angle Measurement is made

Taking the situation shown in Figure 2 where the error is applied to the angle at station 1. Thus, $\beta_1' = \beta_1 - 200^{gon}$ this error will cause points 2 and C to be located at $2'$ and C' respectively. Drawing a line from C to C', two similar triangles are formed, namely $C'2'1$ and $C21$. M is the midpoint on the line and its position coincides with the position of point 1. From these similar triangles, the following relationships exist:

$$C'2' = 2''C \text{ , } 12' = 12 \text{ , } C'2' // 2C \text{ and } \beta_2 = \beta_2' \text{ then } C'1 = 1C$$

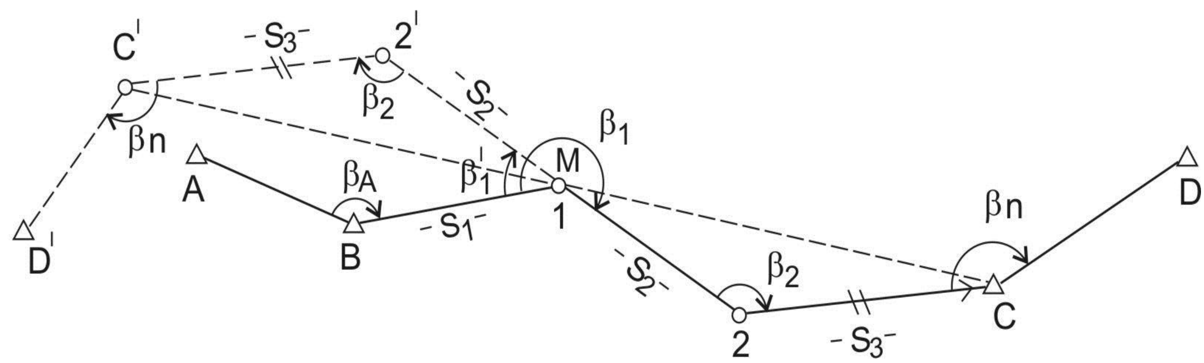


Figure 2- The effect of the error on the location of the following points when the angle on the connecting traverse route is taken as $\beta_1' = \beta_1 - 200^{gon}$ at point 1.

Taking the situation shown in Figure 3 where the error is applied to the angle at station 3. Thus, $\beta_3' = \beta_3 + 200^{gon}$ this error will cause points 4 and C to be located at $4'$ and C' respectively. Drawing a line from C to C', two similar triangles are formed, namely $34'C'$ and $34C$ triangles. M is the midpoint on the line and its position coincides with the position of point 3. From these similar triangles, the following relationships exist:

$C'4' = 4C$, $34' = 34$, $C'4' // 4C$ and $\varepsilon = \varepsilon' = 400 - \beta_4$ then $C'3 = 3C$

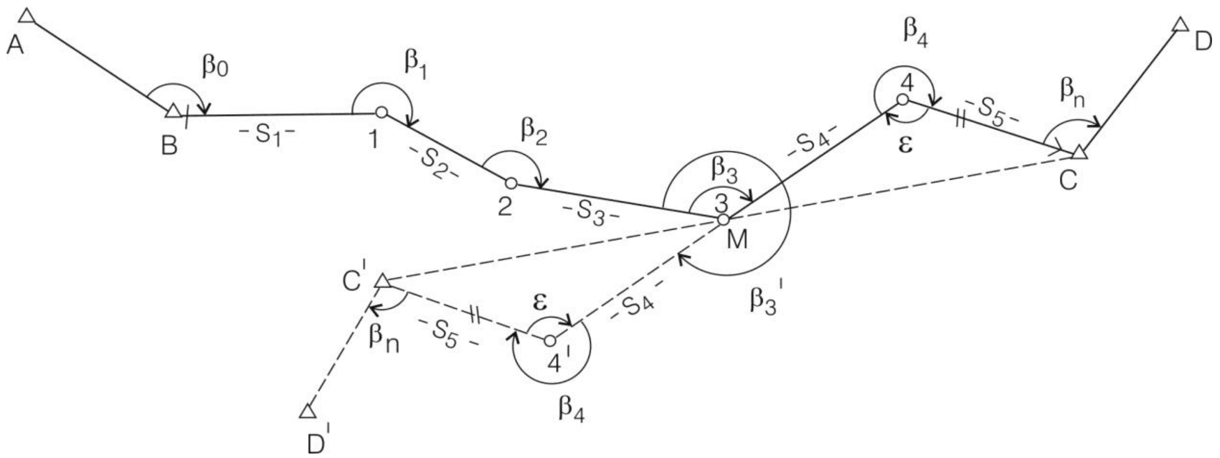


Figure 3- The effect of the error on the location of the following points when the angle on the connecting traverse route is taken as $\beta_3' = \beta_3 + 200^{gon}$ at point 3.

The M coordinate of midpoint of CC' line is obtained from following equations.

$$Y_M = \frac{Y_{C'} + Y_C}{2} \quad , \quad X_M = \frac{X_{C'} + X_C}{2} \qquad (7)$$

To find the angle that is given in any value, the single calculation method developed by various researchers [5, 8-11, 14] is expressed as follows:

$$Y_P = Y_M - 0.5*(X_{C'} - X_C)/\tan(f_\beta/2) \quad , \quad X_P = X_M + 0.5*(Y_{C'} - Y_C)/\tan(f_\beta/2) \tag{8}$$

2.2.2. Practical Investigation of The Point Where a Gross Error Angle Measurement is made (Manual Calculation)

According to Figure 3, when the direction of calculation is taken from B to C, and after the (CD) value calculated for control purposes using equation (6) is determined to be $\pm 200^{gon}$ different from that calculated using equation (5), corrections made on angles using equation (3) are deleted. In the traverse calculation table, all bearings between the first and last connection points are calculated from following relationship.

$$(B1)' = \alpha_0 + \beta_0 \pm 200^{gon}$$

$$(12)' = (B1)' + \beta_1 \pm 200^{gon}$$

$$\vdots \qquad (9)$$

$$(3C)' = (23)' + \beta_3 \pm 200^{gon}$$

$$(CD)' = (3C)' + \beta_n \pm 200^{gon}$$

Using the calculated bearing and length values, the ΔY and ΔX values are calculated, as follows:

$$\begin{array}{ll} \Delta Y_1 = S_1 (B_1)', & \Delta X_1 = S_1 \cos(B1)' \\ \Delta Y_1 = S_2 (12)', & \Delta X_2 = S_1 \cos(12)' \\ \vdots & \vdots \\ \Delta Y_4 = S_4 (3C)', & \Delta X_4 = S_4 \cos(3C)' \end{array} \tag{10}$$

Then the traverses and point of the C' coordinates are calculated as follows:

$$\begin{aligned} & Y_1 = Y_B + \Delta Y_1 \quad , X_1 = X_B + \Delta X_1 \\ & Y_2 = Y_1 + \Delta Y_2 \quad , X_2 = X_1 + \Delta X_2 \\ & \quad \vdots \qquad\qquad\qquad \vdots \\ & Y_{C'} = Y_3 + \Delta Y_4 \quad , X_{C'} = X_3 + \Delta X_4 \end{aligned} \tag{11}$$

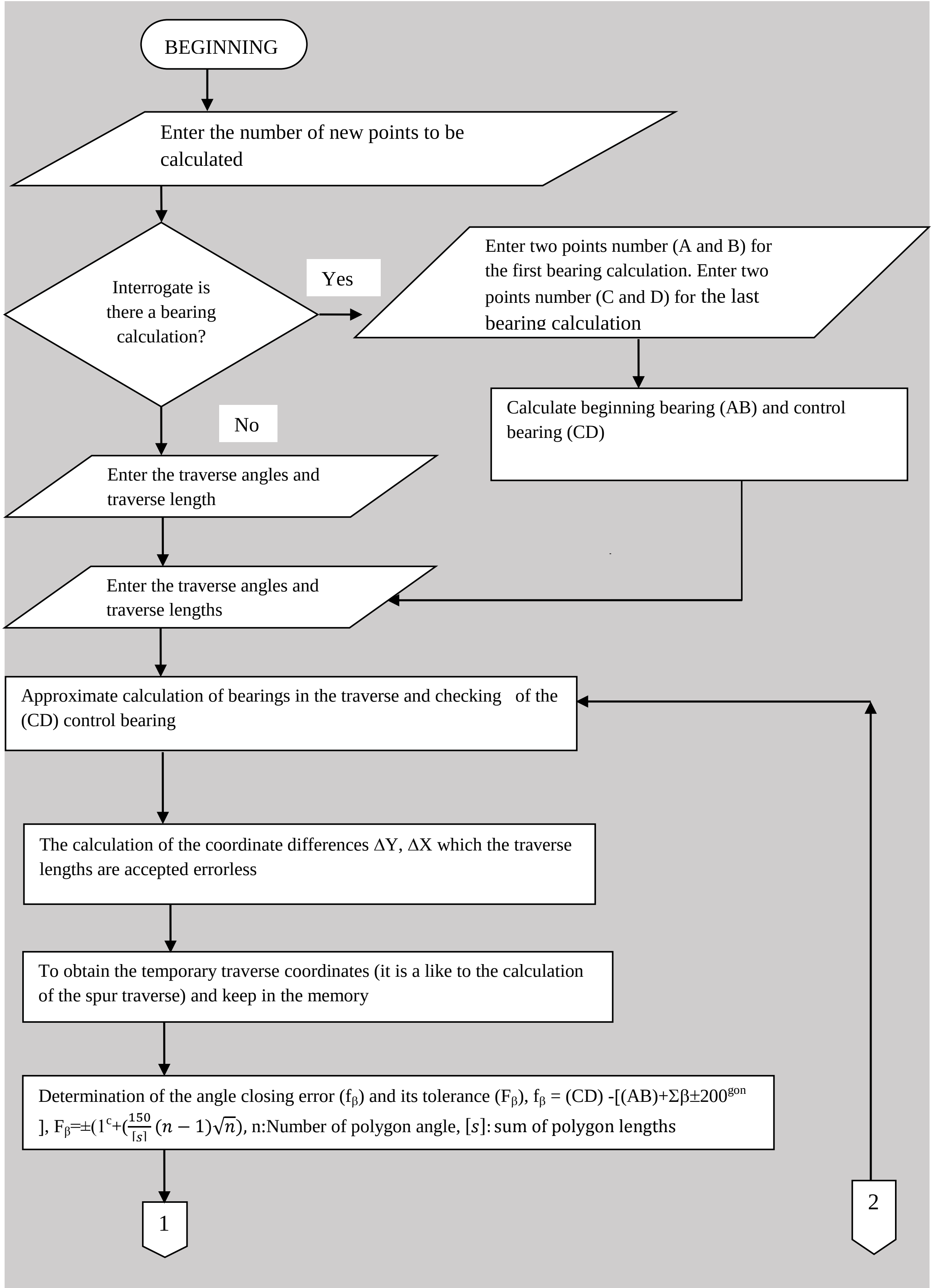
In the evaluation of the point at which the gross error angle is measured using the developed single calculation method (Figure 2 and Figure 3), equation (7) is used. The point coordinate value in the traverse calculation table, which is, nearly equal the values obtained from equation (7) is considered to be the point where the coarse error angle was measured.

3. The Flow Chart of the Program

Recently the calculation of the traverse has been performed with CAD software. However, this software appeared on the market, the calculation of traverse and the researching of gross error angle and gross error length was achieved by programs written by researchers [16, 17] in Turkey in Basic or FORTRAN.

The investigation of gross error angle was carried out in two ways in this study. The first way was to use the classical formula (8) to calculate the coordinate of the point with a measured gross error angle of any value (8). The second way was to find the coordinate of the point with measured angle with a $\pm 200^{gon}$ after the incorrect formula (7) was used. In addition another study [18-20] concerning the investigation of the gross error length was taken into the consideration.

The flow chart for the program was originally created for scientific calculators and it is given below (Fig. 4).


BEGINNING
Enter the number of new points to be calculated
Interrogate is there a bearing calculation?
Yes
Enter two points number (A and B) for the first bearing calculation. Enter two points number (C and D) for the last bearing calculation
Calculate beginning bearing (AB) and control bearing (CD)
No
Enter the traverse angles and traverse length
Enter the traverse angles and traverse lengths
Approximate calculation of bearings in the traverse and checking of the (CD) control bearing
The calculation of the coordinate differences ΔY, ΔX which the traverse lengths are accepted errorless
To obtain the temporary traverse coordinates (it is a like to the calculation of the spur traverse) and keep in the memory
Determination of the angle closing error (f_β) and its tolerance (F_β), f_β = (CD) -[(AB)+Σβ±200^{gon}], $F_\beta=\pm(1^c+(\frac{150}{[s]}(n-1)\sqrt{n})$, n:Number of polygon angle, [s]: sum of polygon lengths
1
2

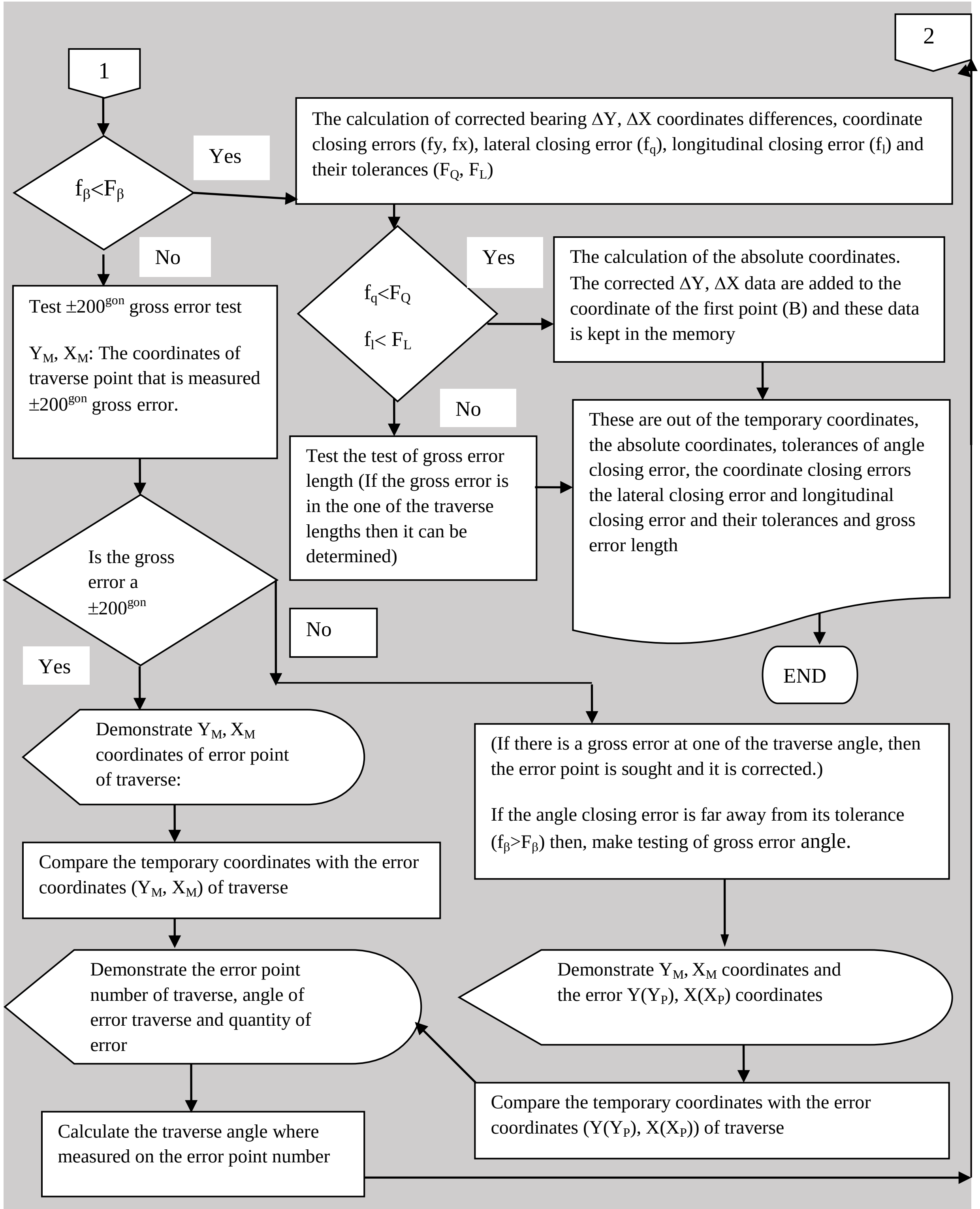


Figure 4- Flow chart of the program

4. An Application

For a numerical application, the traverse route without a gross error in which the lateral and longitudinal closing errors are smaller than their tolerances was taken into the consideration. The data of traverse route is given in Table 1. Assuming that the angle at point 2 in Figure 5 is measured as 115.2756^{gon} by mistake;

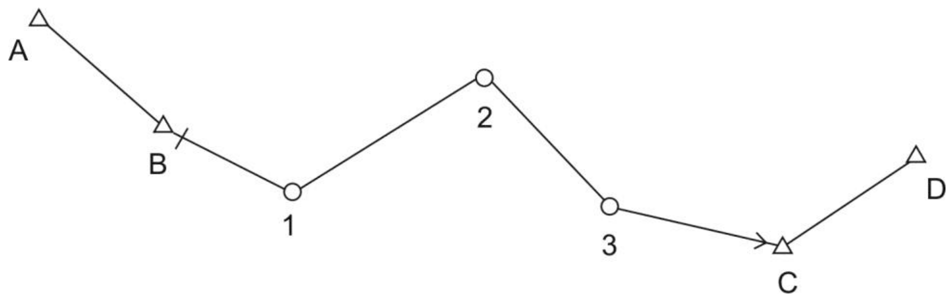


Figure 5- A traverse route placed without gross error

Table 1. The data of the traverse net without gross error angle

Point Number	Y	X	Traverse Angles (gon)	Lengths (meter)	Bearings (gon)
A	2701.38	4945.10	β_0=175.4253	B1=150.27	α_0=(AB)=185.9613
B	2750.62	4725.43	β_1=101.3347	12=180.56	α_n =(CD)=84.1350
C	3140.10	4382.63	β_2=315.2756	23= 195.42	
D	3383.10	4444.47	β_3=185.4877	3C=160.90	
			βn=120.6385		

Manual Calculation;

Table 2. Calculation of the coordinates of the traverse without a gross error angle

Point Num.	Traverse Angles (^{gon})	Bearing (^{gon})	Length (m)	Y (m) ΔY (m)	X (m) ΔX (m)
A		$\alpha_{0=}$185.9613			
B	175.4253^{+23cc}			2750.62	14725.43
		161.3889	150.27	$85.65^{-3\ cm}$	$-123.47^{-2\ cm}$
1	101.3347^{+24}			2836.24	14601.94
		62.7260	180.56	150.49^{-3}	99.78^{-2}
2	315.2756^{+24}			2986.70	14701.70
		178.0040	195.42	66.18^{-4}	-183.87^{-2}
3	185.4877^{+24}			3052.84	14517.81
		163.4941	160.90	87.29^{-3}	-135.16^{-2}
C	120.6385^{+24}			3140.10	14382.63
D	$\alpha_{0+\sum\beta=}$ 1084.1231 -1000.0000 α_n'=84.1231^{gon}	α_n= 84.1350 -α_n'=-84.1231 f_β=0.0119^{gon} F_β= ±0.0295^{gon}		ΔY=389.48 - [ΔY]=-389.61 fy = -0.13 m f_q=0.15m F_Q= ±0.17 m	ΔX=-342.80 -[ΔX]=-(-342.72) fx = -0.08 m f_l=0.04m F_L= ±0.23 m

Table 3. Calculation of the coordinates of the traverse with a gross error angle of $\pm 200^{gon}$ value

Point Num.	Angle (^{gon})	Bearing (^{gon})	Length (m)	Y (m) ΔY (m)	X (m) ΔX (m)
A		$\alpha_{0=}$185.9613			
B	175.4253			2750.62	14725.43
		161.3866	150.27	85.66	-123.47
1	101.3347			2836.28	14601.96
		62.7213	180.56	150.48	99.79

2	115.2756			**2986.76**	**14701.75**
		377.9969	195.42	-66.20	183.86
3	185.4877			2920.56	14885.61
		363.4866	160.90	-87.31	135.15
C	120.6385			3140.10	14382.63
D	$\alpha_{0+\sum\beta}$=884.1231 800.0000	α_n= 84.1350 α_n'= $\underline{(284.1231)}$ f_β=200.0119^{gon}		Y_C'=(2833.25)	X_C'=(15020.76)

The coordinate of the midpoint, M , were computed with equation (7) as follows.

$$Y_M = (2833.25 + 3140.10) / 2 = 2986.67\, m.$$
$$X_M = (150202.76 + 143.63) / 2 = 14701.70\, m.$$

These Y_M and X_M values are similar to the coordinate values for point 2, indicating that the gross angular error occurred at point 2.

5. Results and Discussion

a) The investigation of gross error angle can be done in two ways:

- In the first way, the classical formula (8) can be used to calculate the coordinate of an angle with any value.
- As a second way, the formula (7) was developed to calculate the coordinate of a point with an angle with an error of $\pm 200^{gon}$ from the normal value.

b) The formulas in equation (7) are easier to use and simpler than classical formula given in equation (8) for this special case.

c) If software used to calculate the traverse has been coded without taking into consideration this special case, then the program application fails. This means that a special program must be created to cope with this error situation.

d) A study of gross error angle and gross error length on the traverse have been investigated used the software developed in this study. This software can even be used with scientific calculators such as Casio calculators.

e) To use the formula (7) in manual calculations, the following points should be noted:

- The use of $\pm 200^{gon}$ different value of an angle on calculation of the traverse coordinate appears when checking the control bearing.
- The corrections on the traverse angles have to be cancelled to find the gross error point and the coordinates of the points must be calculated using temporary bearings.
- The gross error point has to be determined by comparing the calculated value obtained by formula (7) with the coordinates calculated on the traverse calculation table.

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