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Calculation of Centering Elements by Methods Other Than the Classical Method

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ABSTRACT

In cartography, when it is necessary to measure the angle at the center of the minaret, on which no tools can be installed, a point marked on the minaret balcony is used as the off-center point. The calculation of the basic elements required to reduce the angle measurements made at this off-center point to the center point is called "Calculation of Centering Elements". In the local coordinate system created with the help of two points established on the land near the minaret in the classical method, the centering elements can be calculated after the coordinates of the center point and the off-center point are found. It is possible to calculate the centering elements with other methods besides the classical method. As a matter of fact, there is also a study in the past that provides convenience in calculation. In this study; taking into account the other study on this subject, another method that does not require coordinate calculation is explained. Numerical applications related to the subject have been made in such a way as to reset the effects of rounding errors. The results obtained with other methods and the classical method were examined. At the end of the study, the findings and opinions are stated.

1. INTRODUCTION

In cartography, when it is necessary to measure the angle at the center of the minaret, on which no tools can be installed, a point marked on the minaret balcony is used as the off-center point. The calculation of the basic elements required to reduce the angle measurements made at this off-center point to the center point is called "Calculation of Centering Elements". In order to reduce the measurements made at the off-center point to the center point, the so-called centering elements must be calculated. In order to make this calculation, two auxiliary points (A, B) are established on the ground near the minaret (Figure 1).

In the classical method, a local coordinate system is created with the help of these points, one of these points is accepted as the starting point, and the coordinates of the center point (Z) and the off-center point (D) are calculated. After these calculations, the centering elements (DZ=e, αZ) are calculated. Instead of this method, which requires a long calculation process, another method has been developed that provides convenience in the past (Allan et al. 1968; Kıran 1983). Today, it is possible to calculate the centering elements by another method.

In this study; Taking into account the other study on this subject, another method that does not require coordinate calculation is explained (Figure 2). Practices related to the subject were made, and the findings and opinions obtained as a result of the study were stated.

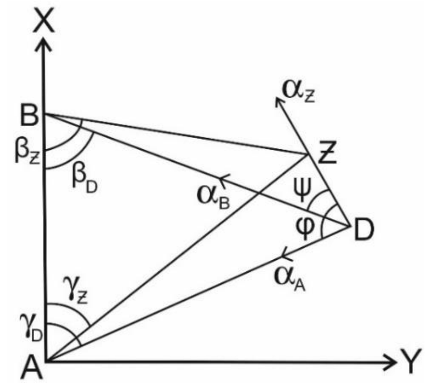

Figure 1. Centering elements according to the classical method

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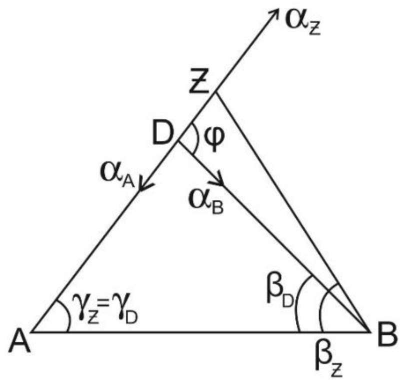

Figure 2. According to the first method centering elements

2. CALCULATION METHODS of CENTERING ELEMENTS OTHER THAN the CLASSICAL METHOD

2.1. First Method

The basis of this method is to mark the off-center point on the minaret balcony on the direction connecting the auxiliary point on the ground to the central point (Kıran 1983; Wolf and Ghilani 2008).

In Figure 2;

Z: The center point in the minaret realm,

D: The off-center point marked on the minaret balcony,

A and B: Auxiliary points marked on the land near the minaret,

DZ=e, αz : Indicates the centering elements.

Angles γZ =γD, βZ, βD and edge AB are measured from points A and B in the field.

In addition, horizontal distances AD and BD can be measured with an electronic tachometer.

From Figure 2, angle φ and sides AZ, BZ and DZ in triangle AZB are obtained from the following relations.

$$\varphi=\gamma_Z + \beta_D \tag{1}$$

$$AZ=\frac{AB*sin\beta Z,}{\sin(\gamma_{Z+\beta_Z})} \tag{2}$$

$$BZ=\frac{AB*sin\delta Z,}{\sin(\gamma_{Z+\beta_Z})} \tag{3}$$

$$DZ=AZ-AD \tag{4}$$

Since the direction measurements are made from the D point to the surrounding triangulation points, A and B points, the unknown αz is obtained from the following relations (Kıran 1983).

$$\alpha_z= \alpha_A +200 \tag{5}$$

$$\alpha_z = \alpha_B -\varphi \tag{6}$$

To make this method even easier, the following application can be made. With the electronic tachometer instruments produced today, it is possible to orientate from one point to another with a certain directional angle (URL_1). By making use of this feature of the instrument, if the direction angle of αA =200.0000 is viewed as the direction angle to point A while observing point A from the off-center point D, then the direction angle of the Z center point becomes αz=0.0000. Relation (6) is used as a control.

After obtaining the αz and DZ centering elements, the rules specified in the reduction of off-centre observations to the center are applied to reduce the angles measured at the D point to the Z point. (Atasoy 2014; Aydın 1974; İnce et al. 2021; Uren and Price 1986; Özbenli and Tüdeş 1989; Şerbetçi and Atasoy 2000).

2.2. Second Method

The basis of this method is calculating the centering elements from the triangles formed by tangent and cosine relations without making coordinate calculations. By making observations from the auxiliary point A to the points B, Z, D, the angles γZ, γD and the edge AB are measured. βZ, βD angles are measured by observing from auxiliary point B to points Z, D, A. The sides of AZ, AD, BZ, BD are obtained from the following equations by applying the sine relation in triangles ABZ and ABD (Figure 3).

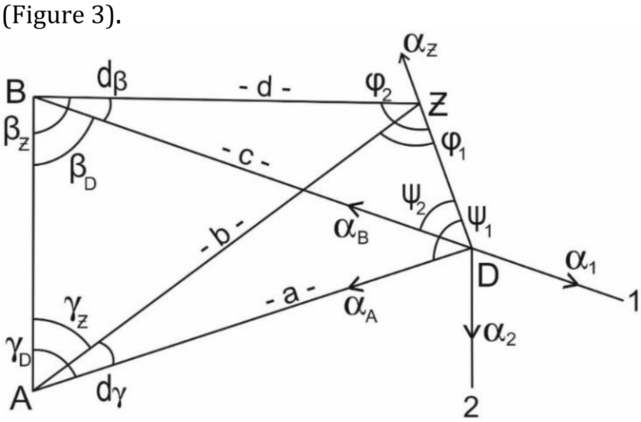

Figure 3. Observations from the auxiliary point A and B to the points B, Z, D

$$AZ=\frac{AB*sin\beta Z,}{\sin(\gamma_{Z+\beta_Z})} \tag{7}$$

$$BZ=\frac{AB*sin\gamma_Z,}{\sin(\gamma_{Z+\beta_Z})} \tag{8}$$

$$AD=\frac{AB*sin\beta D,}{\sin(\beta_D+\gamma_D)} \tag{9}$$

$$BD=\frac{AB*sin\delta D,}{\sin(\beta_D+\gamma_D)} \tag{10}$$

In Figure 3, a=AD, b=AZ, c=BZ, d=BD, $d\gamma=\gamma_D -\gamma_Z$, $d\beta= \beta_Z - \beta_D$ are abbreviated. In triangles AZD and BZD, the cosine relation for DZ is written.

$$DZ=\sqrt{(a^2 + b^2 - 2 * a * b * cosd\gamma)} \tag{11}$$

$$DZ=\sqrt{(c^2 + d - 2 * c * d * cosd\beta)} \tag{12}$$

In Figure 3, the following relation is written for $\frac{\varphi_1+\psi_1}{2}$ in triangle AZD

$\frac{\varphi_1+\psi_1}{2}=\frac{200-d\gamma}{2}$ (13)

and the tangent relation for $\frac{\varphi_1-\psi_1}{2}$ is written.

$\frac{\varphi_1-\psi_1}{2}=arc\tan((a-b)*\tan(\frac{\varphi_1+\psi_1}{2})/(a+b)$ (14)

Considering equations (13) and (14), φ_1 and ψ_1 are obtained from the following relations.

$\varphi_1=\frac{\varphi_1+\psi_1}{2}+\frac{\varphi_1-\psi_1}{2}$ (15)

$\psi_1=\frac{\varphi_1+\psi_1}{2}-\frac{\varphi_1-\psi_1}{2}$ (16)

Similarly, in Figure 3, the following equations are written for $\frac{\varphi_2+\psi_2}{2}$ and $\frac{\varphi_2-\psi_2}{2}$ in triangle BZD.

$\frac{\varphi_2+\psi_2}{2}=\frac{200-d\beta}{2}$ (17)

$\frac{\varphi_2-\psi_2}{2}=arc\tan((c-d)*\tan(\frac{\varphi_2+\psi_2}{2})/(c+d)$ (18)

Considering the equations (17) and (18), φ_2 and ψ_2 are obtained from the following relations.

$\varphi_2=\frac{\varphi_2+\psi_2}{2}+\frac{\varphi_2-\psi_2}{2}$ (19)

$\psi_2=\frac{\varphi_2+\psi_2}{2}-\frac{\varphi_2-\psi_2}{2}$ (20)

Considering the direction angles α_A and α_B in Figure 3, α_Z is obtained from the following equations.

$\alpha_Z=\alpha_A+\varphi_1$ (21)

$\alpha_Z=\alpha_B+\varphi_2$ (22)

As can be seen, the centering elements were calculated with the above-mentioned relations without creating a local coordinate system.

3. NUMERICAL APPLICATIONS

Here, one numerical application was made for the first method and two numerical applications were made for the second method and classical method.

In the calculations made with the classical method and the second method, the fraction of the integer is taken up to the eighth digit after the comma in order to eliminate the effect of the rounding error on the results (Yüncü and Aslan 2002; Dilaver 2010).

3.1. Numerical Application 1

In accordance with Figure 2, calculate the centering elements with the first method, taking into account the measurements made at points A, B and D given in Table 1.

Table 1. Measurements made at points A, B and D

Station Point	Point of View	Horizontal Angle	Horizontal Distance	Station Point	Point of View	Horizontal Angle	Horizontal Distance
A	Z	0.0000		D	1	0.0000	
	D	0.0000	52.535		2	127.3356	
	B	83.3236	50.138		...		
B	A	0.0000	50.137		B	242.6565	
	D	60.2750	62.526		A	299.3580	
	Z	61.3632					

Solution:

$\gamma=\gamma_Z=\gamma_D=83.3236$, $\beta_D=60.2750$, $\beta_Z=61.3632$, AB=50.138 m, $\alpha_A=299.3580$, $\alpha_B=242.6565$

$\varphi=\gamma+\beta_D=143.5986$, $\psi=200-(\gamma+\beta_Z)=55^g.3132$

$AZ=\frac{AB*\sin\beta Z,}{\sin\psi}=53.935$ m e=AZ-AD=1.40 m

$\alpha_z=\alpha_A+200-400=99.3580$, $\alpha_z=\alpha_B-\varphi=99.3579$,

Average value $\alpha_z=99.3580$

3.2. Numerical Application 2

Calculate the centering elements with the classical method and the second method, taking into account the measurements made at points A, B and D given in Table 2, in accordance with Figure 1 and Figure 3.

Table 2. Measurements made at points A, B and D

Station Point	Point of View	Horizontal Angle	Horizontal Distance	Station Point	Point of View	Horizontal Angle	Horizontal Distance
A	B	0.0000	94.376	D	1	0.0000	
	Z	71.8280			2	127.3356	
	D	75.4420			...		
B	Z	0.0000			A	161.3819	
	D	1.1820			B	244.7059	
	A	42.4140	94.376				

Obtaining and simply balancing the elements to be used in the calculations:

$\gamma_Z=71^g.8280$, $\gamma_D=75^g.4420$, $\beta_D=41^g.2320$, $\beta_Z=42^g.4140$, AB=94.376 m, $\alpha_A=161^g.3819$, $\alpha_B=244^g.7059$,

$\omega=244.7059-161.3819=83^g.3240$

$\omega+\gamma_D+\beta_D=199.9980$,

$(83.3240+7^{cc})+(75.4420+6^{cc})+(41.2320+6^{cc})=200.0000$,

$\gamma_{D'}=75.4426$, $\beta_D'=41.2326$

3.2.1. Solution with the Classical Method

$(AD)=\gamma_{D'}$, $(AZ)=\gamma_Z$, $(BD)=200-\beta_D'=158.7674$ $(BZ)=200-\beta_Z=157.5860$

$AD=\frac{94.376*sin\beta_D'}{\sin(\gamma_D'+\beta_D')}=58.95139246$ m

$BD=\frac{94.376*sin\gamma_D'}{\sin(\gamma_D'+\beta_D')}=90.5288754$ m

$AZ=\frac{AB*sin\beta Z,}{\sin(\gamma_{Z+\beta_Z})}=59.8180741$ m

$BZ=\frac{AB*sin\gamma_{Z'}}{\sin(\gamma_{Z+\beta_Z})}=87.4645758$ m

$Y_D=Y_A+AD*\sin(AD)=54.61951034$ m,

$X_D=X_A+AD*\cos(AD)=22.18052666$m

$Y_Z=Y_A+AZ*\sin(AZ)=54.05600204$ m,

$X_Z=X_A+AZ*\cos(AZ)=25.61543739$ m

$\Delta Y_{DZ}=-0.5635083$, $\Delta X_{DZ}=3.43491073$,

$(DZ)=389.64825$,

$DZ=\sqrt{(\Delta Y_{DZ}^2+\Delta X_{DZ}^2)}=3.480826529$

$\varphi=(DZ)-(DA)=114.20565$,

$\psi=(DZ)-(DB)=30.88085$

$\alpha_Z=\alpha_A+\varphi=275.58755$, $\alpha_Z=_{AB}+\psi=275.58675$

Average value $\alpha_Z=275.58715$

3.2.2. Solution with the Second Method

$\beta_Z+\gamma_Z=114.2420$, $\beta_D+\gamma_D=116.6740$, $d\gamma=\gamma_{D'}-\gamma_Z=3.6146$, $d\beta=\beta_Z-\beta_{D'}=1.1814$

$b=AZ=\frac{AB*sin\beta Z,}{\sin(\gamma_{Z+\beta_Z})}=59.8180741$m,

$c=BZ=\frac{AB*sin\gamma_{Z'}}{\sin(\gamma_{Z+\beta_Z})}=87.46465758$m

$a=AD=\frac{AB*sin\beta D'}{\sin(\beta_{D'}+\gamma_{D'})}=58.95139246$ mm,

$d=BD=\frac{AB*sin\delta D,}{\sin(\beta_D+\gamma_D)}=90.5288754$ m

$DZ=\sqrt{(a^2+b^2-2*a*b*cosd\gamma)}=3.480826518$ m

$DZ=\sqrt{(c^2+d-2*c*d*cosd\beta)}=3.48082654$ m

$\frac{\varphi_1+\psi_1}{2}=\frac{200-d\gamma}{2}=98.1927$,

$\frac{\varphi_1-\psi_1}{2}=arc\tan((a-b)*\tan(\frac{\varphi_1+\psi_1}{2})/(a+b)=$ -16.01295492

$\varphi_1=98.1930+(-16.03904)=82.17974$,

$\psi_1=98.1930-(-16.03904)=114.20565$

$\frac{\varphi_2+\psi_2}{2}=\frac{200-d\beta}{2}=99.4093$,

$\frac{\varphi_2-\psi_2}{2}=arc\tan((c-d)*\tan(\frac{\varphi_2+\psi_2}{2})/(c+d)=$ 68.52844

$\varphi_2=99.4090+(-68.50445)=30.88085$, $\psi_2=99.4090-(-68.50445)==167.9377$

$\alpha_Z=\alpha_A+\psi_1=275.58755$

$\alpha_Z=\alpha_B+\varphi_2=275.58675$

Average value $\alpha_Z=275.58715$

3.2.3. Numerical Application 3

In accordance with Figure 1 and Figure 3, calculate the centering elements with the classical method and the second method, taking into account the measurements made at points A, B and D given in Table 3.

Table 3. Measurements made at points A, B and D

Station Point	Point of View	Horizontal Angle	Horizontal Distance	Station Point	Point of View	Horizontal Angle	Horizontal Distance
A	B	0.0000	56.328	D	1	0.0000	
	Z	58.7462			2	138.3164	
	D	60.2465			...		
B	Z	0.0000			A	157.1788	
	D	1.3314			B	231.5709	
	A	66.6934	56.328				

Obtaining and simply balancing the elements to be used in the calculations:

$\gamma_Z=58^g.7462$, $\gamma_D=60^g.2465$, $\beta_D=65^g.3620$, $\beta_Z=66^g.6934$, AB=56.328m, $\alpha_A=157^g.1788$, $\alpha_B=231^g.5709$,

$\omega=213.5709-157.1788=74^g.3921$

$\omega+\gamma_D+\beta_D=200.0006$,

$(74.3921-2^{cc})+(60.2465-2^{cc})+(65.3620-2^{cc})=200.0000$,

$\gamma_{D'}=60.2463$, $\beta_D'=65.3618$

3.3. Solution with the Classical Method

$(AD)=\gamma_{D'}$, $(AZ)=\gamma_Z$, $(BD)=200-\beta_D'=134.6382$, $(BZ)=200-\beta_Z=133.3066$

$AD=\frac{56.328*sin\beta_D'}{\sin(\gamma_D'+\beta_D')}=52.37442008m$

$BD=\frac{56.328*sin\gamma_D'}{\sin(\gamma_D'+\beta_D')}=49.66197913$ m

$AZ=\frac{AB*sin\beta Z,}{\sin(\gamma_{Z+\beta_Z})}=52.96624644m$

$BZ=\frac{AB*sin\gamma_Z,}{\sin(\gamma_{Z+\beta_Z})}=48.750235$ m

$Y_D=Y_A+AD*\sin(AD)=42.49058137m$,

$X_D=X_A+AD*\cos(AD)=30.62075071m$

$Y_Z=Y_A+AZ*\sin(AZ)=42.22917398m$,

$X_Z=X_A+AZ*\cos(AZ)=31.97061349$ m

$\Delta Y_{DZ}=-0.26140739$, $\Delta X_{DZ}=1.34986278$, $(DZ)=387.8223$,

$DZ=\sqrt{(\Delta Y_{DZ}^2+\Delta X_{DZ}^2)}=1.374941216$

$\varphi=(DZ)-(DA)=127.5760$, $\psi=(DZ)-(DB)=53.1841$

$\alpha_Z=\alpha_A+\varphi=284.7548$,

$\alpha_Z=\alpha_{AB}+\psi=284.7550$

Mean value $\alpha_Z=284.7549$

3.3.1. Solution with the Second Method

$a=AD=\frac{56.328*sin\beta_D'}{\sin(\gamma_D'+\beta_D')}=52.37442008m$

$d=BD=\frac{56.328*sin\gamma_D'}{\sin(\gamma_D'+\beta_D')}=49.66197913$ m

$b=AZ=\frac{AB*sin\beta Z,}{\sin(\gamma_{Z+\beta_Z})}=52.96624644m$

$c=BZ=\frac{AB*sin\gamma_Z,}{\sin(\gamma_{Z+\beta_Z})}=48.750235$ m

$d\gamma=\gamma_{D'}-\gamma_Z=1.5001$, $d\beta=\beta_Z-\beta_D'=1.3316$

$DZ=\sqrt{(a^2+b^2-2*a*b*cosd\gamma)}=1.374941228$ m

$DZ=\sqrt{(c^2+d-2*c*d*cosd\beta)}=1.374941188$ m

$\frac{\varphi_1+\psi_1}{2}=\frac{200-d\gamma}{2}=99.24995$,

$\frac{\varphi_1-\psi_1}{2}=arc\tan((a-b)*\tan(\frac{\varphi_1+\psi_1}{2})/(a+b)=-28.32604$

$\varphi_1=98.1930+(-16.03904)=70.9239$,

$\psi_1=98.1930-(-16.03904)=127.5760$

$\frac{\varphi_2+\psi_2}{2}=\frac{200-d\beta}{2}=99.3342$,

$\frac{\varphi_2-\psi_2}{2}=arc\tan((c-d)*\tan(\frac{\varphi_2+\psi_2}{2})/(c+d)=-46.150109$

$\varphi_2=99.4090+(-68.50445)=53.18409$, $\psi_2=99.4090-(-68.50445)==145.484309$

$\alpha_Z=\alpha_A+\psi_1=284.7548$ $\alpha_Z=\alpha_B+\varphi_2=284.7550$

Mean value $\alpha Z=284.7549$

4. EXAMINATION OF NUMERICAL APPLICATION RESULTS

When the results of the centering elements obtained in the above 3.2 and 3.3 numerical applications (Table 4) are examined; It was observed that there was no difference between the elements calculated with the classical method and the second method.

Table 4. Summary of the results of 3.2 and 3.3 numerical applications according to both method

Numerical Application Number	Method Used	Calculation Results of Numerical Applications				
		DZ	$\alpha_Z=\alpha_A+\varphi$	$\alpha_Z=\alpha_B+\psi$	$\alpha_Z=\alpha_A+\psi_1$	$\alpha_Z=\alpha_B+\varphi_2$
2.2	Classic	3.480826	275.58755	275.58675		
	Classic	3.480826			275.58755	275.58675
2.3	Classic	1.374941	284.7548	284.7549		
	Second	1.374941			284.7548	284.7549

5. RESULTS

In the calculation of the centering elements, it is recommended to apply the first method in order to be established from the calculation load. With the electronic tachometer produced today, it is possible to look from one point to another with a certain directional angle. Taking advantage of this feature of the instrument, it is recommended to look at the off-center point, the auxiliary point that enables this point to be marked on the minaret balcony, with a directional angle of $200^g.0000$ for ease of calculation in the first method. In this case, the α_Z centering element is $0^g.0000$. Numerical applications of centering elements with the classical method and the second method; It was seen that there was no difference between the calculation results and the results were equal to each other. The advantage of the second method is that it does not require coordinate calculation and it can be said that it is equivalent to the classical method in terms of processing load.

Author contributions

The contributions of Yazar1, Yazar2, Yazar3 and Yazar4 to this article is equal.

Conflicts of interest

The authors declare no conflicts of interest.

Statement of Research and Publication Ethics

The authors declare that this study complies with Research and Publication Ethics

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