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Teaching Methodology for Topography: Didactic Proposal for the Free Station Survey Method

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RESEARCH ARTICLE

Abstract
This article presents an innovative proposal for teaching Topography topics, as there are no qualified official publications on the subject of study referring to topographic positioning by the free station method, resulting in a shortage of didactic material on this topic in educational institutions in Brazil. Thus, the research work resulted from the didactics applied in the Topography discipline, of the UFPE's Cartographic Engineering degree program. It was proposed to the students to accomplish some practices of the free station method during the Topography discipline development. Thus, the students carried out a theoretical study on the topic. Subsequently, field work was developed with topographic equipment containing a program for surveying by free station method. Topographic vertices of the cadastral reference network of the "Joaquim Amazonas" campus of UFPE served as reference and adjustment points. A comparative analysis of the results calculated manually with the results obtained by the internal programs of the topographic equipment was carried out, using the official coordinates of the cadastral network as references. A program was developed in MATLAB for fixing the learning, whose results were also compared with the same official reference coordinates. This made it possible to generate a complete quantitative statistical analysis of the results.

Keywords: free station method; topography surveying; planimetry coordinates; electronic total station; topographical positioning; topographical network.

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INTRODUCTION

Before discussing about the free station method it is very important to highlight the article from Nap et al. (2021), where the authors hold a discussion about the impact of the modern topo-geodetic technologies on positionning techniques, including levelling with digital level equipment (Sălăgean et al., 2014; Sălăgean et al., 2016; Șuba et al., 2017), robotic total station (Dematteis et al., 2022) and terrestrial laser scanner (Shi et al, 2022) using advanced processing software and the techinical principles, as distance measurement using light waves, the triangulation, the measuring time and the optical interferometry.

About the education in geomatics it is important to relate a recent work developed by Jia et al. (2022) where the authors make a complete discussion about the current situation and the recent development leading them to conclude by the necessity for carry out annual investigation on the demand for talents in geomatics industry and guide vocational colleges to adjust and set priorities, strengthen international cooperation in geomatics, continue to increase investment in geomatics in terms of funds, teacher staff and teaching facilities, so as to aggregate all resources to geomatics, enhance the social identity of geomatics, broaden the rising space of geomatics students and expand the number of high-quality geomatics colleges and expand the trial of certificate system.

Nowadays, an important tecnique embedded in the context of geomatics education is the free station method which is applied in topographic surveys when it is necessary to obtain, with great accuracy, the planialtimetric position of a point in relation to other known position points of a network, conveniently materialized on the ground. The present study is included in the scope of an undergraduate discipline named Topography 1, focused on planimetry methods, therefore, only the X and Y planimetry coordinates were determined and subject to study. The free station topographic method is also known as the resection or backward intersection method. Its use is often applied in station point determinations for surveying topographic details when these features are located in places that make it impossible to direct sight from points of the main traverse of the survey. According to Erba et al. (2003) the Free Station method, which has been applied in several studies such as Teskey and Radovanovic (2001), Horemuž and Andersson (2011), Sun (2013), Shults and Roshchyn (2016), Horemuž, and Jansson (2017), Amin Alizadeh-Khameneh et al. (2018), Chukwuocha (2018), Shevchenko et al. (2020), Walker and Awange (2020), Zahradník (2021), Qin et al. (2022), Hussein et al. (2023), consists of using the topographic instrument properly anchored in a point of unknown topographic position from which the topographic coordinates are determined by means of the sights for two other points with known topographic coordinates. For the solution of geometric position, readings of azimuthal directions and distance measurements are performed. In the present work, several possible procedures are presented to determine the free station geometric position, as described in the thre ways that follows: the manual calculation, the calculation with the proper program embedded in the total station instrument and the calculation using the specific program developed by the students of the discipline Topography 1. This whole approach aimed to develop a different didactics from the traditional approach, in order to better integrate the undergraduate student in the learning of this subject belonging to the syllabus of the Topography 1 discipline. This didactic approach can be considered innovative due to the scarcity of published didactic texts on the focused subject for use in learning in undergraduate or even graduate teaching institutions in Brazil. The discipline Topography 1 focused in this work is part of the curriculum of the undergraduate course in Cartographic Engineering, containing 30 hours of theoretical classes and another 30 hours of practical classes. So, the main objective of the study is to describe the experience lived in the production of didactic knowledge, incorporating some innovation aspects associated to topography surveying based on the free station method for application in teaching of topography.

CALCULATION OF FREE STATION POSITION

In the application of the free station method, initially the coordinates of the station point are unknown. The ideal place to set the topographic instrument mainly depends on the visibility between the points with already known coordinates (reference points), as well as the new points whose positions must be determined. Station coordinates are obtained by reading azimuth directions and distances with sights to reference points. The calculations are usually performed in the internal program built into the topographic instrument. Once the point related to free station has its coordinates calculated, it is now assigned as an occupied point, making it possible, from there, to collect the detail points related to features of interest to the survey project. The coordinates of these detail points are now adjusted in relation to the coordinates of the reference points, that is, the data become homogeneous and obeying the neighborhood principle (ABNT, 1994, and ABNT, 2021), which can be seen in Figure 1.

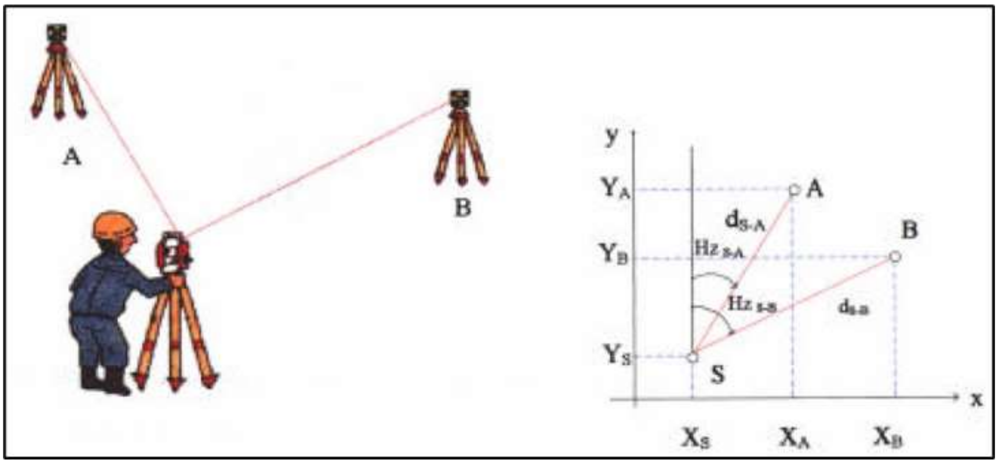

Figure 1. Illustrative diagram of positioning determination by the free station method. Source: Veiga (2000).

To increase the quality of the measurement, the point of the free station must be determined, preferably, taking at least three known points as a reference, with the point occupied in the free station being inside the triangle formed by the reference points. However, in this work, a quantitative test was carried out using two ways, the trigonometric method, and the axis rotation method, which allow in its mathematical model the use of only two reference points. It is recommended that the point occupied by the topographic instrument, that is, the point of the free station, should preferably be between 30° and 120° in relation to the reference points. Thus, measurements of azimuth direction and distance are carried out with a view to these points. The trigonometric method and the axes rotation method are better explained below along with their singularities and respective mathematical models.

In this work, three types of calculations were used to determine the position of the free station, namely: the manual calculation, the calculation using MATLAB (program for elaboration of computational algorithms) and calculation by the internal program built into the total station instrument.

Trigonometric method

In this method, initially the positional coordinates of the station point where the topographic instrument is to be set are not known. This position will be defined as a function of the visibility between the points with known coordinates (reference points), as well as the new points whose coordinates must be determined. Subsequently, the station coordinates are determined through measurements of azimuth directions and distances. Figure 2 shows the position of the points with known coordinates (M1 and M2), the point where the coordinates must be calculated (E), the distance between the free station point and the M1 point (dEM1), the distance between the free station point and the M2 point (dEM2), the angle between the EM1 and EM2 alignments (α), the angle between the EM1M2 and M1E alignments (β).

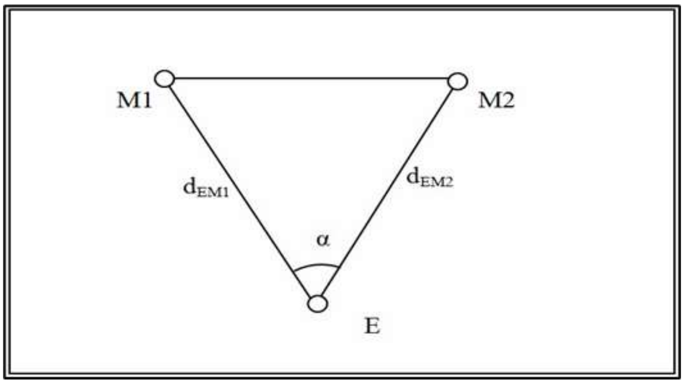

Figure 2. Trigonometric method for determining the topographic position of the free station.

The coordinates are calculated using the distances and angle obtained in the field. Initially, the distance between points M1 and M2 is calculated using their respective coordinates, according to equation (1).

$$d'_{M1M2} = \sqrt{(X_{M1} - X_{M2})^2 + (Y_{M1} - Y_{M2})^2} \quad (1)$$

The distance between the points M1 and M2 is also calculated using the law of cosines method through equation (2).

$$d''_{M1M2} = \sqrt{d_{EM1}^2 + d_{EM2}^2 - 2.d_{EM1}.d_{EM2}.\cos\alpha} \quad (2)$$

The relationship between the distances allows the determination of the scale factor (F) given by equation (3), to reduce errors, since the distance between points M1 and M2 can be calculated in two ways proposed by equation (1) and equation (2).

$$F = d'_{M1M2}/d''_{M1M2} \quad (3)$$

The angle (β) between the alignments M1M2 and M1E is calculated by the law of sines method, according to equation (4).

$$\beta = \arcsin(d_{EM2}.\sin\alpha / d''_{M1M2}) \quad (4)$$

With these data, the azimuth of the M1E alignment can be calculated, according to equation (5) and, subsequently, the coordinates of station E with the application of equations (6) and (7).

$$Az_{M1E} = Az_{M1M2} + \beta \quad (5)$$

$$X_E = X_{M1} + Fd_{M1E}.\sin Az_{M1E} \quad (6)$$

$$Y_E = Y_{M1} + Fd_{M1E}.\cos Az_{M1E} \quad (7)$$

Axes rotation method

Determining the coordinates of the free station point through the rotation of coordinate axes consists of assigning the origin of the axes to one of the points with known coordinates and the free station to the extension of the Y axis after the rotation, designated as Y' (Figure 3).

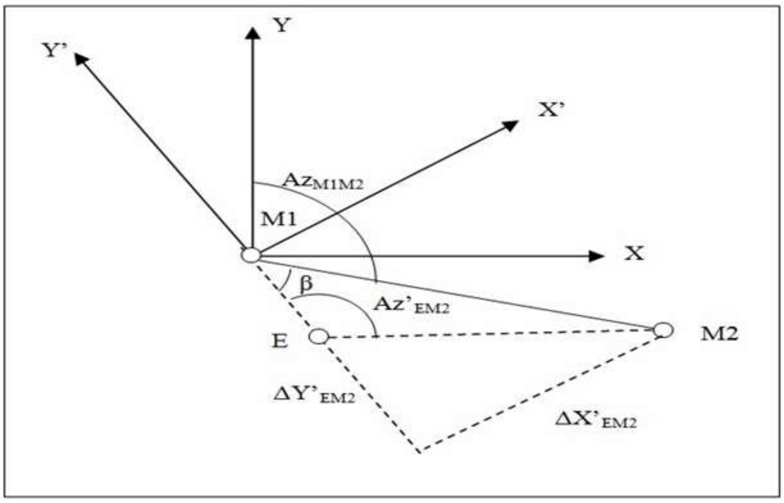

Figure 3. Axes rotation method for determining the topographic position of the free station.

Initially, the distance and azimuth between points M1 and M2 are calculated using the formulations presented in (1) and (5), respectively. Considering the point M1 as the origin of the system after the rotation, the coordinates of the point M2 in this new system can be calculated by obtaining its projections in X and Y (equations 8 and 9).

$$\Delta X'_{EM2} = d_{EM2}.\sin(Az'_{EM2} \pm 180°) \quad (8)$$

$$\Delta Y'_{EM2} = d_{EM2}.\cos(Az'_{EM2} \pm 180°) \pm d_{EM1} \quad (9)$$

The calculation of the distance from the alignment M1 M2 (d''') in the new system is done using equation (10), presented below:

$$d'''_{M1M2} = \sqrt{(X'_{M1} - X'_{M2})^2 + (Y'_{M1} - Y'_{M2})^2} \quad (10)$$

The angle (β) between the alignments M1M2 and M1E is calculated by the law of sines method, according to equation (11).

$$\beta = \arctan(\Delta X'_{M1M2} / \Delta Y'_{M1M2}) \quad (11)$$

With the relationship between the two distances obtained for the points M1 and M2, by equations (1) and (10), the scale factor F is determined, according to equation (12).

$$F = d'_{M1M2} / d'''_{M1M2} \quad (12)$$

The azimuth of the M1E alignment in the original axis system is calculated from the azimuths of the M1 and M2 alignment in the two systems. Subsequently, the coordinates of the free station are calculated using the same formulas already presented in the trigonometric method.

Internal free station program built into topographic instrument

In modern total stations, the term free station corresponds, in most cases, to the name of an internal program in the equipment. In the program interface, the user is required to provide the scale factor and the standard deviations of the newly determined coordinates (verification of the accuracy of the free station point).

The internal program then requests a name for the new determined point (free station point on which the topographic instrument must be centered and leveled) with the option of store the new coordinates in the internal memory. So, according to the variants of the method for determining that point, already discussed above, the transformation of coordinates is performed, which are calculated for the point where the instrument is set. Once the point is stored in the internal memory and it is assigned as an occupied point, it is possible to collect the detail points, these latter being adjusted in relation to the fixed reference points, that is, with homogeneous data and obeying the topographic neighborhood principle (ABNT, 1994, ABNT, 2021).

To increase the quality of the measurement, the free station point must be determined taking at least three fixed known points as reference, the new point being within the area of the triangle formed by the reference points, to resolve the tensions between the points, thus making the results homogeneous.

MATERIALS AND METHODS

Available resources

In the development of the research work, the following resources were used:

1 Total Station model Trimble 3305 DR (Figure 4) with the characteristics: angular accuracy ± 1.5 micro-grads (5''); distance measurement accuracy ± (3mm + 2ppm); minimum operating distance 1.50 m; maximum operating distance 100 m without reflection prism and from 500 to 7500 m with single prism and three prisms, respectively; measuring time 3 s up to 30 m + 1s/10 m; operating temperature -20°C to +50°C. (Trimble, 2004).

Figure 4. Electronic total station Trimble 3300 DR. Source: Trimble (2004)

Field accessories composed of 2 common Wild Model Reflection Prisms, 2 Leveling Bases with optical plummet, 1 wooden tripod, 1 clipboard with field notebook.

1 HP 10S Scientific Calculator: to assist with manual calculations.

1 MacBook Pro 13'': composed of Core i3 2.3GHz processor, 4GB DDR 3 1333Mhz memory, 320GB Serial ATA disc, 5400 rpm, 8x SuperDrive (DVD±R DL/DVD±RW/CD-RW), MagSafe charger 60W, wall and cord AC adapter.
Computer Programs used in calculations and for programming of algorithms and equations:
1 MATLAB® Student Version Software: for application development and free station calculation program.
1 Microsoft Office Excel 2007: spreadsheet program for tabulating field data and helping with manual calculation.

Description of methodology

The Trimble 3305 DR Total Station was installed, centered, and leveled at the EPS04 point materialized in a forced centering concrete pillar on the "Joaquim Amazonas" Campus of UFPE, previously considered as a point with unknown planimetry coordinates. Next, sights were carried out for the EPS07 and M015 topographic landmark, where the previously leveled reflection prisms were placed using the leveling bases. These topographic vertices make up the cadastral reference network of the University Campus "Joaquim Amazonas" at UFPE, which is discussed in more detail in Vila Flor (2006) and Mendonça et al (2010).

Table 1. Data collected in the field for further calculation.

Free Total Station for further calculation (MATLAB)						Free Total Station for further calculation (MATLAB)					
Coordinates	**Base**	**Back**	**Vant**	**Angle**	**Dist. (m)**	**Coordinates**	**Base**	**Back**	**Vant**	**Angle**	**Dist.(m)**
1	EPS04	EPS07		0°0'0"	117.972	**16**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'45"	105.347				M015	197°12'41"	105.348
2	EPS04	EPS07		0°0'0"	117.974	**17**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'30"	105.347				M015	197°12'36"	105.347
3	EPS04	EPS07		0°0'0"	117.972	**18**	EPS04	EPS07		0°0'0"	117.972
			M015	197°12'41"	105.347				M015	197°12'43"	105.347
4	EPS04	EPS07		0°0'0"	117.972	**19**	EPS04	EPS07		0°0'0"	117.972
			M015	197°12'48"	105.347				M015	197°12'41"	105.348
5	EPS04	EPS07		0°0'0"	117.973	**20**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'17"	105.348				M015	197°12'30"	105.348
6	EPS04	EPS07		0°0'0"	117.972	**21**	EPS04	EPS07		0°0'0"	117.972
			M015	197°12'35"	105.345				M015	197°12'40"	105.347
7	EPS04	EPS07		0°0'0"	117.972	**22**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'41"	105.348				M015	197°12'41"	105.347
8	EPS04	EPS07		0°0'0"	117.973	**23**	EPS04	EPS07		0°0'0"	117.972
			M015	197°12'48"	105.347				M015	197°12'31"	105.348
9	EPS04	EPS07		0°0'0"	117.973	**24**	EPS04	EPS07		0°0'0"	117.972
			M015	197°12'45"	105.347				M015	197°12'33"	105.347
10	EPS04	EPS07		0°0'1"	117.972	**25**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'40"	105.348				M015	197°12'30"	105.347
11	EPS04	EPS07		0°0'0"	117.973	**26**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'37"	105.348				M015	197°12'36"	105.347
12	EPS04	EPS07		0°0'0"	117.972	**27**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'51"	105.347				M015	197°12'41"	105.347
13	EPS04	EPS07		0°0'0"	117.973	**28**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'32"	105.348				M015	197°12'42"	105.346
14	EPS04	EPS07		0°0'0"	117.973	**29**	EPS04	EPS07		0°0'0"	117.972
			M015	197°12'34"	105.348				M015	197°12'45"	105.348
15	EPS04	EPS07		0°0'1"	117.972	**30**	EPS04	EPS07		0°0'0"	117.973
			M015	197°12'25"	105.347				M015	197°12'37"	105.348

In the manual process, a field notebook was created to record the directions read and the measured horizontal plane distances, according to Table 1. It is noted that 30 series of angular direction readings and distances backwards were carried out for the EPS07 topographic vertex and the forward to vertex M015, in order to obtain statistically redundant and reliable results.

The coordinates obtained by the free station process were then manually calculated, by the internal program available in the total station equipment and by means of a program developed in MATLAB® Student Version. Figure 5 presents the flowchart of the general methodology.

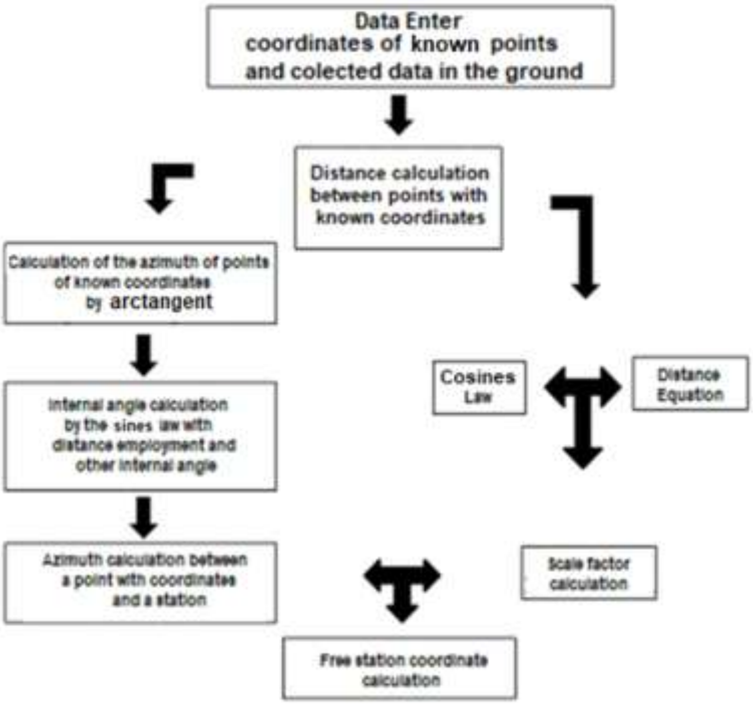

Figure 5. Routine flowchart in MATLAB.

RESULTS AND DISCUSSIONS

About 30 repetitions of the free station method were performed to determine the planimetry coordinates of the EPS04 topographic vertex. The step-by-step procedure of how the free station results were obtained is detailed as follows description below.

Initially, data from known coordinates were introduced, which in this case corresponded to the positions of points EPS07 and M015 in the local topographical system of the "Joaquim Amazonas" campus (Mendonça et al., 2010). Then, the data collected in the field were added. These data correspond to the distances from the free station to each point of known coordinate (dE1 and dE2) and to the angle formed between these two alignments (E), making the angular conversion from degrees, minutes and seconds format to decimal degrees format for use in MATLAB, which can be seen in Figure 6.

```
%DADOS DE CAMPO----------------------------------
%COORDENADA DO PONTO EPS07
x1=149718.3980;
y1=249854.3097;

%COORDENADA DO PONTO M015
x2=149909.6231;
y2=249964.7190;

%ANGULO ENTRE OS PONTOS 1 E 2 (FORMATO GG MM SS)
E=[197 12 53];

%DISTANCIAS DA ESTAÇÃO PARA OS PONTOS 1 E 2
dE1=118.033;
dE2=105.399;

%TRANSFORMAÇÃO ANGULO
ANGE=E(1,1)+E(1,2)/60+E(1,3)/3600;

%-----------------------------------------------
```

Figure 6. Data entry screen in the program developed in MATLAB.

In the second step, the calculation of the distance between the two known coordinate points was performed by two methods, namely: the triangle hypotenuse method (D12C) and the law of cosines method (D12M), being possible to determine the scale factor (Fe).

The azimuth of these two points was also calculated through the arctangent trigonometric function (AZ12), carrying out the study of its sign to define its trigonometric quadrant.
These calculation steps are presented in the algorithm programming lines shown in Figure 7.

```
%CALCULO DA DISTANCIA E DO AZIMUTE ENTRE OS PTS COORDENADOS (D12C,AZ12C)
D12C=sqrt((x2-x1)^2+(y2-y1)^2);
AZ12=atan((y2-y1)/(x2-x1))

if AZ12<0
    if (y2-y1)<0
        AZ12C=abs(AZ12)+(pi/2);
    else
        AZ12C=abs(AZ12)+(3/2)*pi;
    end
else
    if (y2-y1)<0
        AZ12C=(3/2)*pi-abs(AZ12);
    else
        AZ12C=(1/2)*pi-abs(AZ12);
    end
end

%CALCULO DA DISTANCIA ENTRE OS PTS COORD PELA LEI DOS COSSENOS (D12M)
d12m=((dE1)^2)+((dE2)^2)-(2*dE1*dE2*cosd(ANGE));
D12M=sqrt(d12m);
```

Figure 7. Calculation of distance and azimuth between points of known coordinates.

In the next step, one of the coordinate points (1) was chosen and its internal angle (AINT1) was calculated for the subsequent calculation of the azimuth between a known coordinate point and the free station (AZ1E). This procedure can be seen in the programming codes shown in Figure 8.

```
%CALCULO DO ANG INTERNO 1 PELA LEI DOS SENOS
AINT1=asin(dE2*sind(ANGE)/D12M);

%CALCULO DO AZIMUTE ENTRE UM PTO COORD E A ESTAÇÃO
AZ1E=AZ12C+AINT1;

%CALCULO DO FATOR DE ESCALA (Fe)
Fe=(D12C/D12M);

%CALCULO DA COORD DA ESTAÇÃO
XE=x1+Fe*dE1*sin(AZ1E)
YE=y1+Fe*dE1*cos(AZ1E)
```

Figure 8. Determination of the internal angle and the azimuth between a point of known coordinate and the station point.

Finally, with the known coordinate of the chosen point (1), the scale factor, its distance to the free station and the azimuth, it is possible to determine the desired coordinates, which can be seen in Figure 9.

```
Coordenadas_Ponto_1 =

                149718.398
               249854.3097

Fe =

         0.999487747489122

dE1 =

                   118.033

AZ1E =

         0.905508310302169

Coordenadas_Estacao_Livre =

          149811.211599477
          249927.132466419
```

Figure 9. Results obtained through MATLAB.

Thus, Table 2 was generated, containing the 30 observations of topographical coordinates obtained from the test performed (X(m), Y(m)), the official topographical coordinates referenced to the local topographic plane of vertex EPS04 (X(m), Y(m)), the differences between the official coordinates of the EPS04 vertex and those obtained from the test performed (ΔX(m), ΔY(m)).

The official coordinates of the vertex EPS04, originate from the curvilinear geodetic coordinates referred to the SIRGAS 2000 datum of the RECF station (φ = 8 03'03.46970" S, λ = 34 57'05.45910" W), corresponding to the coordinates in the local topographic system of the "Joaquim Amazonas" campus (X0 = 150000,000 m, Y0 = 250000,000m) and the average altitude of the local topographic plane (Hptl = 4,217 m) obtained based on the average altitudes EPS1, EPS2,..., EPS7 , as described in Mendonça et al (2010).

Table 2. Coordinates obtained using the computer program developed in MATLAB and the differences relative to official reference coordinates for comparative analysis.

Unknown position in the Total Station (Free Station)

	Observed Coordinates		**Official Coordinates**		**Differences**	
Observation	X (m)	Y (m)	X (m)	Y (m)	ΔX (m)	ΔY (m)
1	149,811.212	249,927.137 c	149,811.211	249,927.136 c	0.001	-0.001
2	149,811.212	249,927.133 c	149,811.211	249,927.136 c	-0.001	0.003
3	149,811.212	249,927.136 c	149,811.211	249,927.136 c	-0.001	-0.000
4	149,811.212	249,927.135 c	149,811.211	249,927.136 c	0.001	0.001
5	149,811.212	249,927.136 c	149,811.211	249,927.136	-0.001	-0.000
6	149,811.212	249,927.134 c	149,811.211	249,927.136 c	-0.001	0.002
7	149,811.212	249,927.135 c	149,811.211	249,927.136 c	-0.001	0.001
8	149,811.212	249,927.134 c	149,811.211	249,927.136	-0.001	0.002
9	149,811.212	249,927.135 c	149,811.211	249,927.136 c	-0.001	-0.001
10	149,811.212	249,927.135 c	149,811.211	249,927.136 c	-0.001	0.001
11	149,811.211	249,927.136	149,811.211	249,927.136 c	0.000	0.000
12	149,811.213	249,927.133 c	149,811.211	249,927.136 c	-0.002	-0.003
13	149,811.212	249,927.134 c	149,811.211	249,927.136 c	-0.001	0.002
14	149,811.213	249,927.133 c	149,811.211	249,927.136 c	-0.002	0.003
15	149,811.211	249,927.135 c	149,811.211	249,927.136	0.000	0.001
16	149,811.213	249,927.133 c	149,811.211	249,927.136 c	-0.002	0.003
17	149,811.213	249,927.134 c	149,811.211	249,927.136 c	-0.002	0.002
18	149,811.212	249,927.135 c	149,811.211	249,927.136 c	-0.001	0.001
19	149,811.212	249,927.134 c	149,811.211	249,927.136 c	-0.001	-0.002
20	149,811.211	249,927.135 c	149,811.211	249,927.136	0.000	0.001
21	149,811.212	249,927.135 c	149,811.211	249,927.136	-0.001	0.001
22	149,811.212	249,927.134	149,811.211	249,927.136	-0.001	0.002
23	149,811.213	249,927.133 c	149,811.211	249,927.136	-0.002	0.003
24	149,811.211	249,927.136 c	149,811.211	249,927.136	0.000	0.000
25	149,811.211	249,927.136 c	149,811.211	249,927.136	0.000	0.000
26	149,811.211	249,927.136 c	149,811.211	249,927.136	0.000	0.000
27	149,811.213	249,927.132	149,811.211	249,927.136	-0.002	0.004
28	149,811.210	249,927.138 c	149,811.211	249,927.136	0.001	-0.002
29	149,811.213	249,927.132 c	149,811.211	249,927.136	-0.002	0.004
30	149,811.212	249,927.136 c	149,811.211	249,927.136	-0.001	-0.000

The comparative results obtained for the coordinates of the EPS04 vertex generated by the free station process in relation to its official topographic coordinates pointed to discrepancies that did not exceed 0.004 m (4 mm). In addition, the error averages were calculated for both coordinates (ΔX(m), ΔY(m)), which corresponded respectively to -0.001 m (-1 mm) and 0.001 m (1 mm).

CONCLUSIONS

Several interviews were conducted with students at the end of the course and most of the participants considered the methodology very innovative and quite useful in learning, as they had to study hard and apply a lot of effort to understand well all the formulations, in addition to developing the algorithm for programming. However, as it is a new applied didactic, there are still not enough data so far to faithfully verify the improvement of the evaluation scores. This suggests the initiative of future research for the possible consolidation of the methodology used.

So, it is concluded that the teaching methodology adopted in the research was very well accepted by the students of the class to which it was applied, as they interacted in such a way that the concept of the subject addressed became clearer, confirmed by the answers to the interviews themselves. This resulted mainly due to the integration and completeness of the research steps involving calculations performed manually, development of programming algorithm that stimulates logical reasoning, practical handling, and operation of the topographic equipment with the support of the theoretical knowledge acquired. Thus, it can be inferred that the whole set of used procedures provides students with a better preparation for future professional activities aggregating maturity for the job market performance.

Finally, it is recommended that this methodology be tested for other disciplines within the undergraduate programs in cartographic engineering.

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Conflicts of Interest

There is no conflict of interest.

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