THE METHODOLOGICAL APPLICATION OF DGNSS-DATA FOR MAKING SPELEO-DENDROLOGICAL SKETCHES

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***Abstract* - The speleo-dendrological sketch shows the distances and bearings of trees and shrubs in the neighbourhood of a cave entrance. The determination of a tree position is measured with a DGNSS-receiver or with another GNSS-receiver, and with a tape and a magnetic bussole. The required absolute accuracy is 5 meters; the relative accuracy is 2 meters. In respect of the preliminary accuracy and reliability parameters we can consider, that the traditional offset method and the centre of gravity method satisfy the requirements, too. I recommend the use of the traditional offset method, because it is much faster and economical as the centre of gravity method. The results does not influence the distinction between the bearing and magnetic azimuth (because of the short distances), and the some centimetres identification accuracy of the centre of a trunk (using estimation method on the field). The test measurements, which were making on a wooden area in Székesfehérvár showed that by the traditional offset method the absolute accuracy was 1.4 meters, and the relative accuracy 1.1 meters. Considering the received results we may declare, that the traditional offset method (so not the directly method) is suitable for the measurements.**

I. INTRODUCTION

On the today's development level of technology we are able to determine adequate accurate position for punctiform geographical objects, like trees or shrubs, using single point positioning or the service of the GNSS-infrastructure. In my investigation I deal with the use of single point positioning and EGNOS-corrections in the viewpoint of tree positioning. It must be mention, that there are a lot of other solutions for the real-time, code-correction based positioning f.e. the service of the Hungarian active GNSS-network, WAAS-corrections etc. I complemented the measured data with traditional taping and bussole measurements to make speleo-dendrological sketches in the Velence Hills.

II. THE OPTIMAL SOLUTION OF TREE-POSITIONING USING DGNSS-TECHNOLOGY

The required accuracy of a tree positioning for a speleo-dendrological sketch depends on the scale of the output maps. The trees will be put on a topographical map, which has a scale 1 part in 10 000, and on a real sketch, which has no restricted scale, but shows the features on their right location compared to each other. The measurement accuracy of a point on a map is 0.1 mm [1], which means 1 meter on the field in a scale 1 part in 10 000. The absolute accuracy is defined in the coordinate system of the Hungarian Datum 1972; the relative accuracy means the trees mutual position compared to each other. The absolute accuracy affects the visualisation of trees on a topographical map, the relative accuracy the making of the sketches. For the absolute accuracy and reliability claim of positioning trees and shrubs, which are growing in the neighbourhood of a cave entrance, we can consider 5 meters on the field, which means 0.5 mm on the map. This is fifth more, than the smallest map measurement accuracy. It is not necessary to know the absolute location of a tree in one meter accuracy on the field, and 0.1 mm accuracy on the map. This five meters (or can we say 0.5 mm) accuracy does not cause interpretation problems or information distortion. We can consider adequate a measurement, if the relative accuracy and reliability does not exceed the limit of two meters on the field, and 0.2 mm on the map.

I investigated the accuracy and reliability of two different measurement methods, using the rules of the error-theory:

1. Traditional offset measurement: manual offset parameters determination with a tape and a magnetic bussole; the coordinate was calculated by the receiver after data input on the field,
2. Centre of gravity method: the location of a tree was calculated on the field by the receiver as a centre of gravity, based on three measured coordinates.

By the traditional offset method the input data were the measured coordinates of the offset point, the measured distance and azimuth and their root mean square errors. For the generalization of the method (like by the centre of gravity method) I used the accuracy parameters (Table I.) and test measurements of a former investigation of DGNSS-technology [2].

TABLE I.
THE ACCURACY AND RELIABILITY PARAMETERS OF THE SPP-MEASUREMENTS AND EGNOS-DGNSS MEASUREMENTS

	SPP	EGNOS
	Estimated root mean square error in meters	
y	±1.3	±0.9
x	±2.6	±1.8
M	±4.2	±3.0

2D	±2.0	±1.4
	Estimated horizontal accuracy in meters	
2D	4.0	2.8
	Estimated vertical accuracy in meters	
1D	5.9	5.1

The calculation equations of a trunk are the same, as by the traditional polar point calculation (O – offset, T – trunk).

$$y_T = y_O + t_{OT} \cdot sin\delta_{OT} \qquad (1)$$
$$x_T = x_O + t_{OT} \cdot cos\delta_{OT}$$

For the determination of reliability we must partial derivate the (1) equation with respect to the different variables, and than using the law of the error theory we derive the (2) equations.

$$\mu_{y_T} = \sqrt{(+1)^2 \cdot \mu_{y_K}{}^2 + (sin\delta_{OT})^2 \cdot \mu_t{}^2 + (t_{OT} \cdot cos\delta_{OT})^2 \cdot (\frac{\mu_\delta}{\rho''})^2} \qquad (2)$$
$$\mu_{x_T} = \sqrt{(+1)^2 \cdot \mu_{x_K}{}^2 + (cos\delta_{OT})^2 \cdot \mu_t{}^2 + (-t_{OT} \cdot sin\delta_{OT})^2 \cdot (\frac{\mu_\delta}{\rho''})^2}$$

Let assume, that the magnetic azimuth is 154-10-20, and its reliability is ± 2°, the distance is 5.00 meters, and its reliability is ±5 centimeters. Using the data of the Table I. and the (2) equations we are able to calculate the reliability and accuracy of the coordinates, based on the traditional offset method (Table II.).

TABLE II.
ACCURACY AND RELIABILITY PARAMETERS BASED ON THE TRADITIONAL OFFSET METHOD

	SPP	EGNOS
$\mu_{yT} = \mu_{yO}$ (m)	±1.3	±0.9
$\mu_{xT} = \mu_{xO}$ (m)	±2.6	±1.8
μ_{2D} (m)	±2.0	±1.4
Accuracy (m)	4.0	2.8

The accuracy and reliability of the coordinates of a trunk and the offset point are the same in the easter and northern direction. The accuracy parameters using SPP are only on an optimal case the same, as can we read in the Table II. On a normal case they will be much larger, so for the tree positioning the use of the EGNOS-code corrections are recommendable. In this case the accuracy will be 2.8 meters on a 90% confidence level [2], and the reliability parameter in the horizontal plane will be ±1.4 meters. The usage of the extreme situations (δ_{OT}=0° or δ_{OT}=90°) does not influence the reliability.

By the centre of gravity method the input data were the coordinates and the root mean square errors of the three points. The coordinate of the trunk was calculated as the arithmetical mean of the measured points.

$$y_T = \frac{y_1 + y_2 + y_3}{3} \qquad (3)$$
$$x_T = \frac{x_1 + x_2 + x_3}{3}$$

For the determination of reliability we must partial derivate the (3) equation with respect to the different variables, and than using the law of the error theory we derive the (4) equations.

$$\mu_{y_T} = \sqrt{3 \cdot (\frac{1}{3})^2 \cdot \mu_{y_i}{}^2} \qquad (4)$$
$$\mu_{x_T} = \sqrt{3 \cdot (\frac{1}{3})^2 \cdot \mu_{x_i}{}^2}$$

Using the data of the Table I. and the (4) equations we are able to calculate the reliability and accuracy of the coordinates, based on the centre of gravity method (Table III.). The angle and distance, and their root mean square error are the same, as by the traditional offset method.

TABLE III.
ACCURACY AND RELIABILITY PARAMETERS BY THE CENTRE OF GRAVITY METHOD

	SPP	EGNOS
μ_{yi} (m)	±1.3	±0.9
μ_{xi} (m)	±2.6	±1.8
μ_{yT} (m)	±0.8	±0.3
μ_{xT} (m)	±1.5	±1.0
μ_{2D} (m)	±1.2	±0.7
Accuracy (m)	4.0	2.8

The reliability of the coordinates of a trunk is better, as by the traditional offset method. Also by the centre of gravity method we recommend the use of the EGNOS-code corrections. In this case the accuracy will be 2.8 meters on a 90% confidence level [2], and the reliability parameter in the horizontal plane will be ±0.7 meters. In respect of the preliminary accuracy and reliability parameters (5 meters in absolute accuracy and 2 meters in relative accuracy) we can consider, that both methods satisfy the requirements. I recommend the use of the traditional offset method, because it is much faster and economical as the centre of gravity method.

The results does not influence the distinction between bearing and magnetic azimuth (because of the short distances), and the some centimetres identification accuracy of the centre of a trunk. For the identification of the centre of a trunk we can choose the estimation method, the diameter-method (r=0.5×d), and the perimeter-method (r=K/2Π). Among these methods are not any distinctions in accuracy or in reliability; on the field we shall use the estimation-method, because of his simplicity and velocity. It is not necessary to deal with the identification of the centre of a trunk, when we can measure directly on the side of a trunk. We need trunk centre identification only by the traditional offset method.

I made test measurements on a wooded area near the building of the Alba Regia Technical Faculty in the Pirosalma Street. The aim of the test was to determine the absolute and relative accuracy of the traditional offset method compare with the measurements directly near a trunk. For the determination of the absolute accuracy I used the parameters, which were indicated by the receiver. For the determination of the relative accuracy I compared the distances between the trees, calculated from coordinates, and measured with a tape. For the positioning I used a Hemisphere Crescent receiver mounted on a TDS Recon rugged handheld computer, controlled with the SurvCE software.

In the Table IV. can we see the results of the measurements. By the method directly near the trunks the foliage caused a considerable cut-off effect, and only by three trees can the receiver found EGNOS-code corrections. By the traditional offset method the offset point was on an optimal location for GNSS-measurements (the EGNOS-code corrections were observable). I determinate manual the offset parameters using a tape and a magnetic bussole; and the coordinates were calculated as a polar point by the receiver after the data input.

TABLE IV.
THE RESULTS OF THE TEST MEASUREMENTS USIN THE HEMISPHERE-RECEIVER

	Directly method
Averaged absolute accuracy (m)	6.3
Averaged relative accuracy (m)	2.2
	Traditional offset method
Averaged absolute accuracy (m)	1.4
Averaged relative accuracy (m)	1.1

The coordinates absolute accuracy by the directly method is not enough for the visualisation on a topographical map, because it is larger (6.3 m) as the preliminary declared 5 meters. The relative accuracy was good (2.2 m). These parameters are meaning 0.6 mm accuracy on the topographical map, and 0.2 mm accuracy on a sketch. By the traditional offset method the absolute accuracy was 1.4 meters, and the relative accuracy was 1.1 meters. This is meaning 0.1 mm accuracy on the topographical map, and 0.1 mm accuracy on a sketch. Considering the received results we may declare that the traditional offset method is suitable for the measurements.

III. THE RULES OF MAKING A SPELEO-DENDROLOGICAL SKETCH

The speleo-dendrological sketch shows the distances and bearings of trees and shrubs in the neighbourhood of a cave entrance. A cave entrance is a part of a landscape, and in every occasion a natural conservation area. To know, what kind of trees are growing there is basic information. The determination of a tree position is measured with a DGNSS-receiver or with another GNSS-receiver, and with a tape and a magnetic bussole. The under mentioned elements are visible on the upper part of the sketch: name of the cave, cadastral number, datum of the measurement, and the scale (Fig.1). On the right side of the sketch are the following elements: wind rose for the magnetic azimuth, list of symbols, date of the mapping, name of the surveyor and cartographer. On the left side at the bottom of the sketch are the tree species on a latin language identified with a number. The lay-out is in the centre of the sketch. The symbol list contains the following different symbols: deciduous tree, coniferous tree, not indigenous tree, shrub, not indigenous shrub, cave entrance and the bearing of the cave entrance. Deciduous tree symbol identified the indigenous deciduous trees, and those deciduous trees, which were installed with the aim of profit, but are not indigenous in Hungary. Coniferous tree symbol identified the indigenous coniferous trees, and those coniferous trees, which were installed with the aim of profit or ornament, but are not indigenous in Hungary.

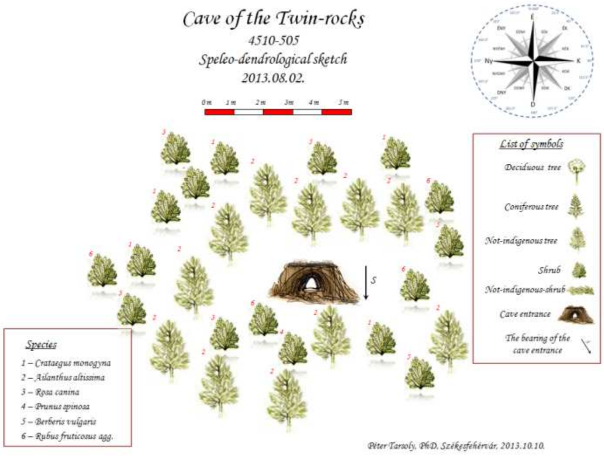

Figure 1. Trees and shrubs around the entrance of the Cave of the Twin-rocks

Not indigenous tree and shrub symbol identified those trees and shrubs which are growing mainly in horticultural areas, but are disposed to spread to the forest, like an invasive species. The additional refinement of trees means the separation to species; the application of more symbols would not enhance the informative value of the lay-out. I handled with speleo-dendrological sketches, when I measured the trees and shrubs by the caves of the Pakozd Rocking Stone Natural Conservation Area[3].

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