SOME ISSUES REGARDING SPATIAL POSITIONING WITH GPS SYSTEMS USING SIMPLE AND DUAL FREQUENCY RECEIVER

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Abstarct

The current use of GNSS technology has diversified technological opportunities, due to the advent of new logistics represented by GPS receivers of various accuracy classes and the presence of a large infrastructure.

The establishment of the national GPS network, especially active points represented by permanent GPS stations (considered Class A), allowed the use of GNSS recordings made by them for various topo-geodetic applications.

To obtain relatively homogeneous results (using the same work algorithm), National Agency for Cadastre and Land Registration (ANCPI) has developed an application called TransDatRO to be used to transform coordinates of the national reference system.

The case study was conducted in the town of Abram, Bihor County, in 2013 and had the objective to support the network necessary for compiling topographic General Urban Plan (GUP).

Spatial positioning of topographic points (of interest) was achieved with GPS using 4 receivers with one frequency and a receiver with two frequencies, the data being used by GNSS GPS station Oradea.

The primary recorded data were processed in two versions, the first version using transformation parameters recommended by the National Agency for Cadastre and Land Registration (ANCPI) for Bihor County, the application TransDatRO, and the second option used local transformation parameters with Trimble Total Control (TTC), obtained from previous practical applications in the study location.

The results of the two processing methods showed that the differences obtained between the two sets of spatial coordinates of positioned topographic points, in principle, were determined by the accuracy of GPS positioning network, accuracy of the determination of surveying points and control points, common for the geodetic datum transformation we used.

Computer software used in GNSS data processing had a relatively small influence on the spatial positioning accuracy of the topographic points.

Key words: GPS receivers, spatial coordinates, city plan, coordinate transformation, GPS network, geodetic point, topographic point.

INTRODUCTION

To achieve various applications in the sector of terrestrial measurements currently there are used technologies for space-based positioning GNSS technology, various satellite systems (Hofmann-Wellenhof et al., 1997), conventional technologies (total stations) and combined technologies, which blend harmoniously, completely, comprehensively and unitary the technical possibilities of the first two technologies (Crainic, 2011).

In our country, the GPS is widely used, given the multitude of class geodetic receivers, surveyors. Also, the presence of specialized software provides a high degree of automation of the works (Tămâioagă, Tămâioagă D., 2007), to give the final digital product (Detrekői, 2009).

Spatial positioning of the various details of the GPS system is possible only if it satisfies a number of conditions related to advanced technologies at work, where it is framed and GNSS technology (Neuner et al., 2002). It is therefore necessary to ensure proper infrastructure, namely the existence of support points Class A-Figure 1, generally referred to as active points represented by GPS permanent stations, appropriate to satisfy the conditions imposed by the work algorithms (Crainic, 2011; Dragomir et al., 2005).

Permanent G.P.S. stations have been designed – at least one for each and in particular circumstances, even two, to ensure optimal distance (minimum 50 km) for Coating satellite information (Crainic, 2011).

Fig.1 GNSS Network points in Romania
(http://www.cngcft.ro/main/images/BDSG.jpg)

Aside Class points have been designed other points, B and C - Figure 1 also called passive points of known coordinates, which can stand with total stations or GPS receivers to achieve various topo-cadastral applications, required by various sectors.

The use of classical geodesic points determined from the national geodetic network can bring better work efficiency in space positioning with GPS, using L1 and L2 frequency receivers (Boş, Iacobescu, 2009; Boş, Iacobescu, 2007; Crainic, 2011; Sabău, 2010, Sabău, Crainic, 2006).

MATERIAL AND METHOD

The case study was conducted in the administrative territorial unit (ATU) Abram, in Bihor (Figure 2) in 2013 and its main objective was to increase the density of geodetic network for the assistance of general urban plan PUG - Contract 552 of 25 04 2013.

Fig.2 Location of the study site
(http://upload.wikimedia.org/wikipedia/commons/c/cd/Abram_BIHOR_COMUNE_copy.png)

Documentation, observation on track, stationary observation, the experiment, and simulation were used as research methods.

Logistics used was represented by:

-a receiver G.P.S. Fujitsu Siemens G.I.S. class;

-4 Receivers G.P.S. Trimble R3 class terrain (single frequency - L1);

-a receiver G.P.S. Trimble R4 Class geodesic (with two frequencies L1 and L2);

-software for data collection: MapSys PDA, Trimble Digital Fieldbook;

-data-processing software: Trimble Total Control, TransDatRO4.01;

-software for data reporting: MapSys.

Photo1. Orthophotomap with the case study

Other sources of used information were:

-data from the database of the Office of Cadastre and Real Estates Publicity (OCPI) Bihor, respectively the system that coordinates national geodetic reference point orthophotomap Abram and work area – Photo 1;

-G.N.S.S. recording permanent station Oradea;

-local transformation parameters (regional) determined from four geodetic points for an area adjacent to the location of study – Photo 2 (Crainic, 2011);

-technical normative.

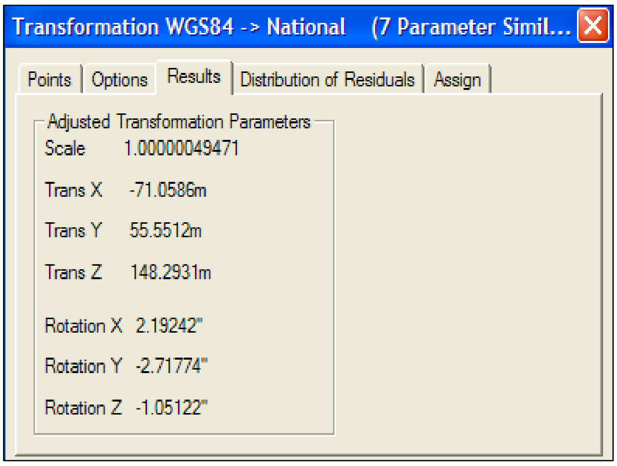

Photo 2. Parameters of regional transformation (Sîniob4)

For positioning the designed topographic points, the traditional static method (Adam et. Al. 2004; Neuner, 2000) and rapid static method (Adam et. al. 2004; Neuner, 2000: Păunescu et al., 2006; Rus, 2009) were used.

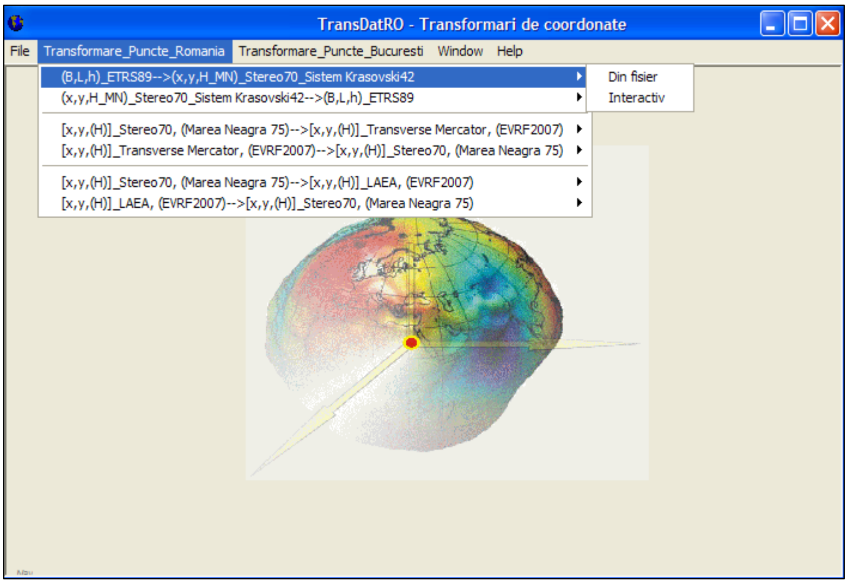

Photo.3 Interface of TransDatRO4.01 application

Two topographic points were placed for the receiver Trimble R4 for four hours in order to relate to GNSS station Oradea. The other points were stationary for a period of 30 minutes, with relatively little regard to the length of the GPS position vectors.

To have a control of the points positioned with GPS, for the topographic point Abram, the national reference coordinates were requested. It was identified in the field with a GPS receiver of Fujitsu Siemens GIS class.

The transformation of geocentric coordinate reference system in national reference system was performed in two ways, by using the transformation parameters ANCPI with TransDatRO4.01-foto.3 application, and by using local transformation parameters with Trimble Total Control (TTC)-Photo 4.

To use the application TransDatRO4.01, registration for GNSS satellite data from the nearest station in the work area was required (case study GNSS station Oradea) for joint observations with one or more GPS receivers.

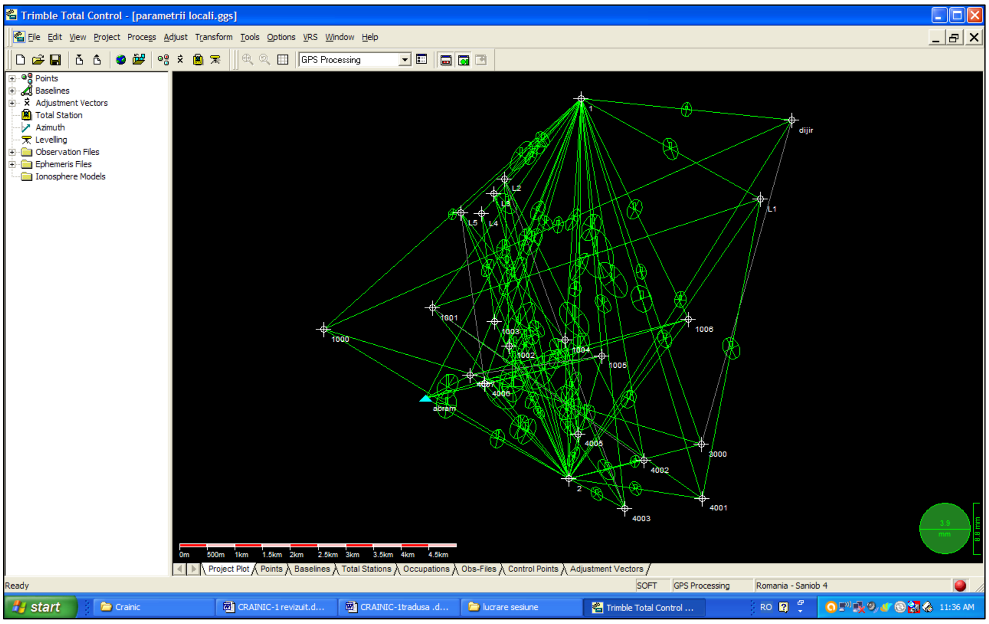

Photo 4. Program interface Trimble Total Control (TTC)

The usage of local transformation parameters implies the existence of common points of transformation (which have known coordinates in the national reference) which were positioned with GPS receivers (and included in the positioning network), or actual knowledge of the local transformation parameters and hence the respective datum from other applications, research and / or previous studies.

RESULTS AND DISCUSSION

GNSS data recorded with Trimble receivers were processed in two different procedures: with Trimble Total Control (TTC) and the application TransDatRO in order to analyse the differences between the two types of procedures (on the coordinate values and accuracy).

In the first variant, GNSS data were processed primarily with Trimble Total Control (TTC). The national reference system transformation was performed by using the application TransDatRO.

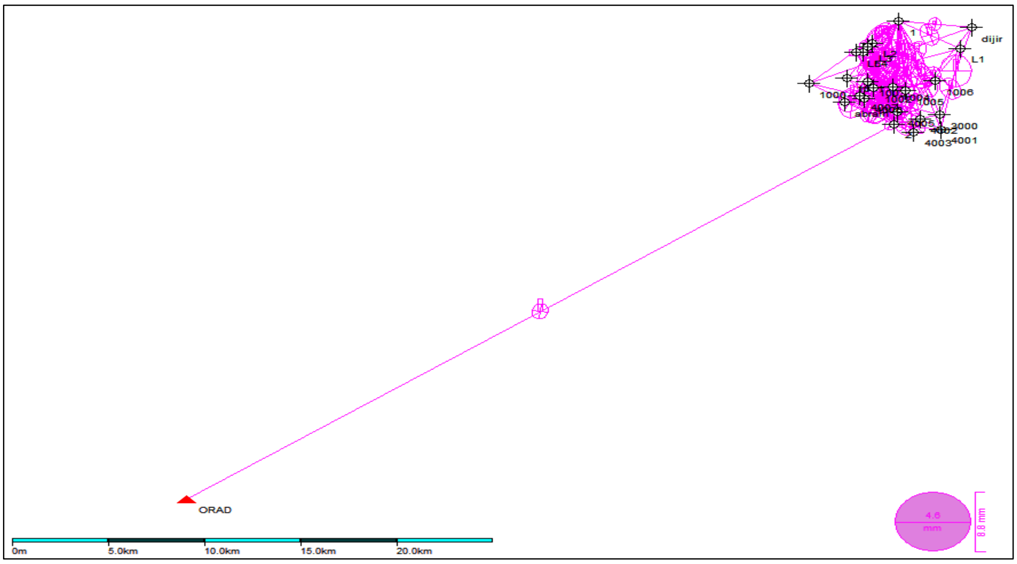

Fig.3 Outline of the overall position vectors in processing option 1 with Trimble Total Control (TTC)

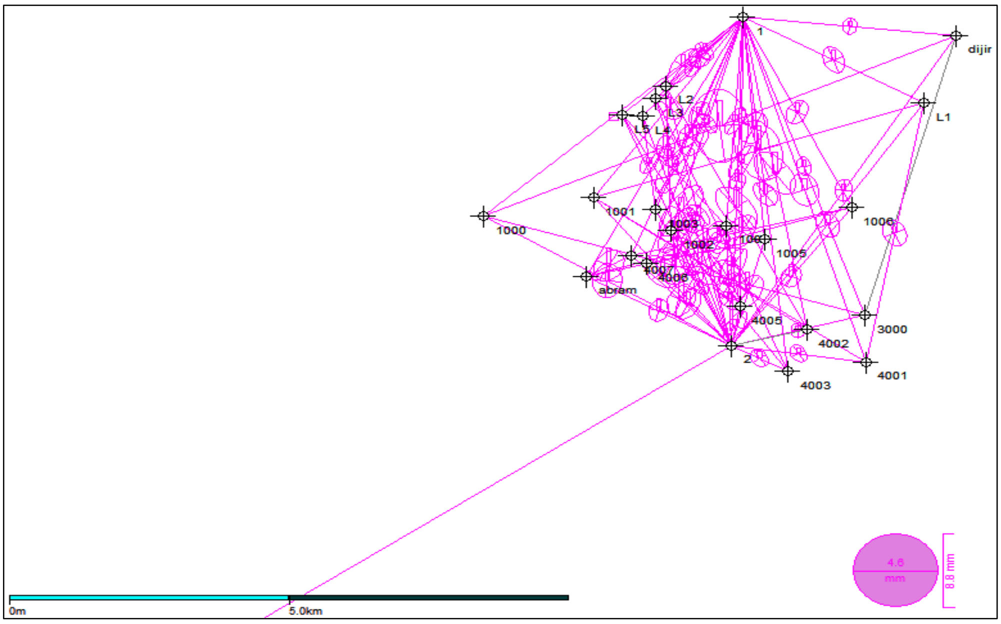

Figure 4. Network of vectors primarily processed with Trimble Total Control (TTC) system geocentric reference

During the analysis of the network, the GPS vectors determined using processing option 1 fig. 3, it was found that the vector GNSS station Oradea and that section 2 had a length of 40 km.

From the analysis of data from fig. 4, it was concluded that, after the primary processing of GNSS data, it was obtained a deviation of 4.6 mm and 8.8 mm for quotas.

Table 1

Adjusted Points in WGS84 (Cart. Coordinates and Std.Dev.)

Nr pct	X(m)	s_x(mm)	Y(m)	s_y(mm)	Z(m)	S_z(mm)
0	*1*	*2*	*3*	*4*	*5*	*6*
1	4001595.173	65.1	1650573.182	33.1	4668985.313	66.4
1000	4006208.076	67.5	1647605.321	35.8	4666024.528	68.5
1001	4005156.660	72.6	1649274.096	44.1	4666337.235	69.4
1002	4005059.623	66.6	1650756.460	35.2	4665903.759	68.9
1003	4004877.640	67.7	1650372.124	35.2	4666191.657	69.1
1004	4004590.421	72.0	1651641.273	34.4	4666006.836	67.9
1005	4004509.246	87.0	1652340.966	36.7	4665826.826	77.8
1006	4003449.074	69.7	1653566.186	37.9	4666310.593	72.3
2	4006235.958	64.0	1652492.954	32.2	4664319.213	65.6
3000	4004844.116	66.9	1654479.730	35.7	4664781.802	67.7
4001	4005499.682	68.8	1654802.096	39.2	4664141.171	67.8
4002	4005456.664	87.4	1653620.054	56.1	4664561.411	77.8
4003	4006192.606	66.5	1653588.503	36.0	4663981.978	70.1
4005	4005623.842	73.4	1652380.385	34.8	4664859.263	68.6
4006	4005696.841	83.4	1650560.929	36.5	4665431.461	73.2
4007	4005695.377	72.5	1650265.703	38.9	4665535.554	74.4
L1	4001497.883	71.6	1654087.471	40.7	4667841.423	68.4
L2	4003090.057	69.1	1649745.984	36.9	4667956.476	69.9
L3	4003345.661	66.8	1649652.055	37.4	4667772.294	71.0
4	4003672.923	67.3	1649552.472	34.4	4667511.344	68.6
5	4003808.141	81.3	1649215.003	35.9	4667514.712	70.0
ORAD	4037693.733	0.0	1626553.31	0.0	4646395.432	0.0
Abram	4006307.167	71.1	1649677.535	37.1	4665231.268	72.1
Dijir	4000313.625	67.6	1654171.261	36.4	4668807.698	69.0

Table 1 and Fig. 5 show the coordinates rigorously-compensated in the offset geocentric reference system and their associated precision elements. OX axis standard deviations for determining the coordinates vary between 64.0 and 87.4 mm, the axis OY between 32.2 and 44.1 mm and axis OZ between 65.6 and 77.8 mm.

It appears that the OX and OZ standard deviations for determining the coordinates of the geocentric system are relatively higher than those on OY. Geographical coordinates offset (corresponding precision indicators) related to calculated topographic points are shown in Table no. 2.

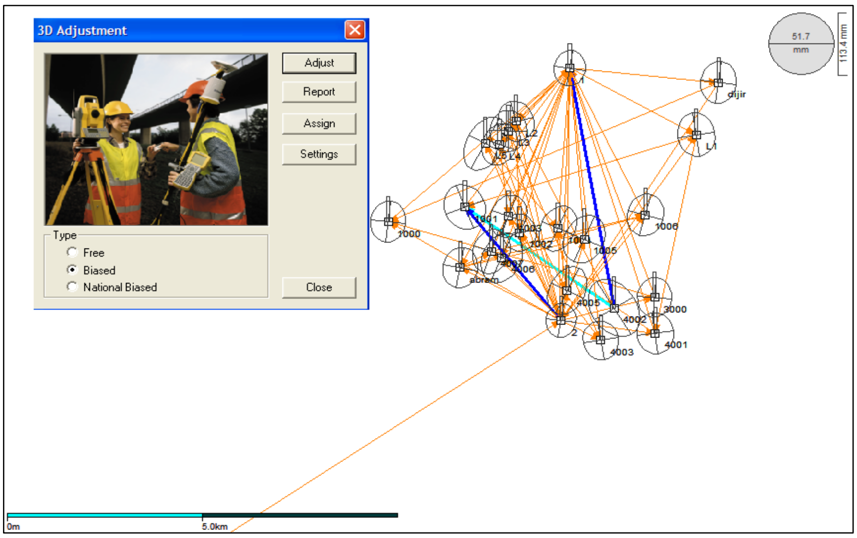

Photo 5. Network GPS vectors strictly compensated geocentric reference system with Trimble Total Control (TTC)

Table 2

Adjusted Points in WGS84 (Geogr. Coordinates and Std.Dev.)

Point	Latitude	σ mm	Longitude	σ mm	Height	Elevation	σ mm
0	1	2	3	4	5	6	7
1	47° 21' 28.93886"	29.9	22° 24' 54.39425"	25.2	224.197	183.492	90.6
1000	47° 19' 09.32326"	34.2	22° 21' 19.99591"	27.9	171.416	130.611	92.6
1001	47° 19' 24.21485"	37.8	22° 22' 52.53472"	33.0	172.702	131.896	97.5
1002	47° 19' 03.39438"	31.8	22° 23' 59.56004"	27.5	175.987	135.149	93.0
1003	47° 19' 17.20504"	35.6	22° 23' 45.94163"	29.1	174.296	133.474	92.1
1004	47° 19' 07.95430"	37.7	22° 24' 47.02618"	29.8	186.336	145.495	93.1
1005	47° 18' 59.43762"	40.1	22° 25' 19.29846"	32.9	184.027	143.172	110.8
1006	47° 19' 22.25418"	34.9	22° 26' 32.48854"	29.0	192.294	151.452	97.3
2	47° 17' 46.96884"	28.5	22° 24' 54.63829"	24.1	197.602	156.670	89.7
3000	47° 18' 09.70190"	33.3	22° 26' 47.33041"	27.4	179.189	138.268	92.0
4001	47° 17' 38.28718"	34.8	22° 26' 49.59753"	29.4	202.776	161.818	93.7
4002	47° 17' 59.19834"	48.0	22° 25' 58.37821"	41.0	178.630	137.703	113.4
4003	47° 17' 30.57342"	33.0	22° 25' 43.62476"	28.3	206.022	165.063	93.5
4005	47° 18' 13.31472"	40.0	22° 25' 00.79546"	31.0	181.638	140.735	93.5
4006	47° 18' 40.77651"	41.9	22° 23' 39.39258"	33.0	177.726	136.867	104.0
4007	47° 18' 45.77074"	36.7	22° 23' 26.42326"	30.0	177.070	136.218	100.3
L1	47° 20' 34.04319"	36.9	22° 27' 30.92432"	30.2	230.664	189.884	95.9
L2	47° 20' 40.96416"	33.4	22° 23' 50.80901"	28.9	190.169	149.429	95.3
L3	47° 20' 32.14775"	34.6	22° 23' 42.03254"	29.9	190.600	149.853	93.9
L4	47° 20' 20.12036"	35.0	22° 23' 31.70751"	28.2	178.033	137.276	91.7
L5	47° 20' 20.27807"	44.3	22° 23' 14.39082"	34.8	178.124	137.370	98.1
ORAD	47° 03' 33.17756"	0.0	21° 56' 29.95756"	0.0	195.956	154.549	0.0
Abram	47° 18' 30.95793"	34.3	22° 22' 49.43890"	28.0	185.081	144.220	98.3
Dijir	47° 21' 20.54231"	35.2	22° 27' 56.17072"	28.5	221.552	180.815	92.7

To obtain the final coordinates from the national reference system, it is necessary to transform geographical coordinates offset to rigorous reference system WGS84-Table 2, using the TrasDatRO.

Therefore, by using the transformation parameters ANCPI specific for Bihor county, the final coordinates (national reference system) were obtained, Table 3, which should be used for topo-cadastral applications in the current work area.

Table 3

Coordinates in the national reference system

Point	X(m)	Y(m)	Z(m)
0	***1***	***2***	***3***
1	654171.938	304881.515	143.913
1000	650011.412	300239.393	184.553
1001	650406.078	302197.240	131.751
1002	649716.828	303582.871	133.089
1003	650152.596	303311.100	136.284
1004	649824.772	304583.930	134.582
1005	649539.583	305252.740	146.585
1006	650193.891	306812.159	144.284
2	647319.499	304661.648	157.648
3000	647944.056	307051.061	139.352
4001	646972.710	307067.217	162.905
4002	647653.095	306012.571	139.038
4003	646779.665	305673.884	166.171
4005	648128.549	304817.636	141.836
4006	649032.611	303136.397	137.985
4007	649195.859	302869.288	137.459
L1	652370.345	308110.297	190.982
L2	652734.894	303498.741	150.557
L3	652468.898	303305.686	150.875
L4	652104.666	303076.670	138.448
L5	652121.625	302713.428	138.495
ORAD	622250.022	267841.534	155.701
ABRAM	648764.319	302077.545	144.213
DIJIR	653788.709	308686.179	181.927

Option 2 processing GNSS data was processed with Trimble Total Control Primary, The national reference system transformation was performed by using regional transformation parameters (Saniob 4), which were determined during some previous studies in the area surrounding the location of this case study (Crainic, 2011).

Therefore, implementing the geodetic control point the benchmark Abram (Fig. 5, and Photo no.6) after clearing rigorous national reference system, final coordinates (offset rigorous) Stereo System 1970 and the system of quotas MN 1975 were obtained.

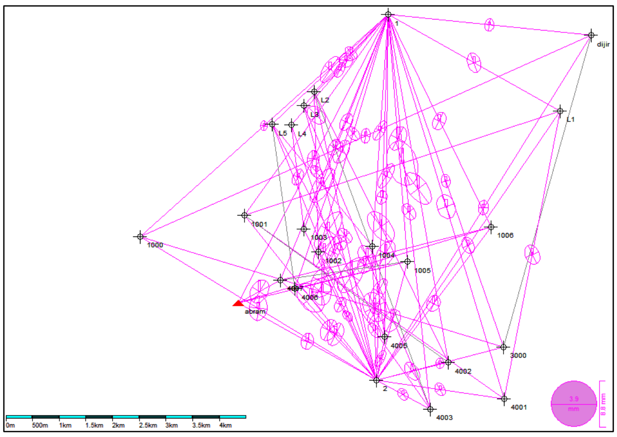

Fig.5 Network of GPS vectors primarily processed with TTC in the geocentric reference system program

Processed GPS base network computing variant 2 (primary processing and rigorous compensation) are shown in Fig. no.5 and Photo. no.6.

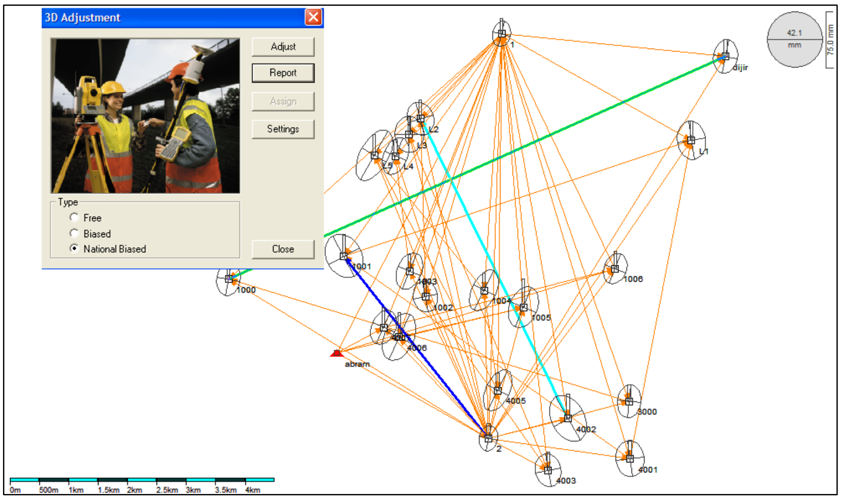

Photo 6. Network of vectors compensated rigorously in the national reference system

Final coordinates in the national reference system (2D 1D) are shown in Table 4.

Table 4

Final coordinates and adjusted Points in National System (Plane Coord. and Std.Dev.)

Point	X(m)	s_X(mm)	Y(m)	s_Y(mm)	H(m)	E(m)	s_Z(mm)
1	654171.893	19.4	304881.469	14.2	197.260	185.241	41.2
1000	650011.397	24.9	300239.367	18.0	144.563	132.359	44.9
1001	650406.137	32.9	302197.211	28.8	145.854	133.688	58.3
1002	649716.824	23.5	303582.850	19.1	149.062	136.895	47.5
1003	650152.603	27.8	303311.066	20.8	147.376	135.217	45.1
1004	649824.776	30.8	304583.910	22.0	159.388	147.237	47.3
1005	649539.652	31.1	305252.765	23.3	157.057	144.907	75.0
1006	650193.896	23.0	306812.122	18.2	165.301	153.193	47.8
2	647319.532	19.4	304661.648	14.3	170.595	158.360	41.2
3000	647944.096	25.0	307051.035	18.4	152.181	140.005	45.2
4001	646972.784	27.5	307067.213	21.7	175.770	163.560	48.8
4002	647653.082	35.1	306012.556	28.6	151.966	139.764	65.3
4003	646779.7122	24.7	305673.874	19.8	179.066	166.826	48.2
4005	648128.5767	31.2	304817.628	22.0	154.679	142.476	46.6
4006	649032.6206	35.6	303136.388	25.9	150.800	138.603	66.3
4007	649195.8049	25.9	302869.205	20.0	150.154	137.959	53.3
L1	652370.3265	28.9	308110.260	21.8	203.655	191.632	51.5
L2	652734.8506	25.1	303498.703	20.6	163.268	151.188	51.1
L3	652468.8378	27.1	303305.577	22.0	163.661	151.571	49.1
L4	652104.6748	28.1	303076.608	20.3	151.125	139.021	44.7
L5	652121.5954	38.1	302713.397	28.0	151.222	139.114	56.1

Abram	648764.3210	0.0	302077.534	0.0	158.180	145.960	0.0
Dijir	653788.7008	25.6	308686.220	18.5	194.532	182.559	45.1

The analysis of Table 4 shows that the standard deviation for the determination of OX coordinate varies in the range 19.4-38.1 mm and axis OY in the range 14.2-28.8 mm. For altitude, the standard deviation varies between 41.2 and 66.3 mm.

It is found that the OY recorded the lowest standard deviations followed by OX and quotas were characterized by the highest positioning standard deviations.

In Table no. 5 presents the values of the geometric error ellipse (corresponding topographic coordinates from the GPS network points) which were obtained by processing raw data with Trimble Total Control (TTC).

Table 5

Adjusted Points Error Ellipses

Point	Semimajor Axis	Semiminor Axis	Angle	95% confidence radius
1	19.7mm	13.8mm	13.3°	42.3mm
1000	25.0mm	17.8mm	10.0°	53.9mm
1001	34.6mm	26.8mm	-28.7°	76.2mm
1002	23.7mm	18.9mm	-10.1°	52.7mm
1003	29.1mm	18.9mm	22.7°	61.4mm
1004	33.1mm	18.3mm	26.1°	68.2mm
1005	32.4mm	21.5mm	22.0°	68.7mm
1006	23.8mm	17.1mm	21.6°	51.4mm
2	19.7mm	13.9mm	13.1°	42.4mm
3000	25.1mm	18.3mm	6.5°	54.4mm
4001	27.6mm	21.6mm	-8.4°	61.0mm
4002	37.7mm	25.1mm	-29.4°	80.1mm
4003	24.9mm	19.6mm	-10.7°	55.2mm
4005	33.6mm	18.1mm	26.3°	69.0mm
4006	37.8mm	22.6mm	24.8°	78.8mm
4007	27.1mm	18.3mm	23.4°	57.7mm
L1	29.1mm	21.6mm	-9.1°	63.4mm
L2	25.5mm	20.1mm	-16.5°	56.5mm
L3	27.1mm	22.0mm	0.8°	60.7mm
L4	29.6mm	18.1mm	23.2°	61.8mm
L5	42.1mm	21.5mm	29.7°	86.0mm
abram	0.0mm	0.0mm	90.0°	0.0mm
dijir	25.8mm	18.2mm	10.0°	55.5mm

It appears that the large semi-axis of the ellipse plan error is between 19.7 and 42.1 mm and smaller semi-axis between 13.8 and 26.8 mm Table no.5.

Following the inspection of Table no. 6, one can analyze the difference between topographic coordinates from the two variants of calculation, the local transformation parameters (regional). Calculations based on commonalities and county parameters recommended by ANCPI.

The differences between coordinates on OX axis were ranging between 0.004 and 0.074 m, in absolute value, and on OY axis between 0000 m and 0109 m, also in absolute value.

For altitudes, coordinate differences were larger because the variations during conversion, the ellipsoid (N) could not be determined with high precision in the process (even at national level).

Table 6

The difference between the coordinates of infill processed by two working versions

Nr. pct.	d_X(m)	d_Y(m)	d_Z(m)	Nr. pct.	d_X(m)	d_Y(m)	d_Z(m)
0	*1*	*2*	*3*	*0*	*1*	*2*	*3*
1	-0.040	-0.046	41.328	4003	0.047	-0.010	0.655
1000	-0.015	-0.026	-52.194	4005	0.028	-0.008	0.639
1001	0.059	-0.029	1.937	4006	0.010	-0.009	0.618
1002	-0.004	-0.021	3.805	4007	-0.054	-0.083	0.500
1003	0.007	-0.034	-1.067	L1	-0.019	-0.037	0.650
1004	0.004	-0.020	12.655	L2	-0.043	-0.038	0.631
1005	0.069	0.025	-1.678	L3	-0.060	-0.109	0.696
1006	0.005	-0.037	8.909	L4	0.009	-0.063	0.573
2	0.033	0.000	0.712	L5	-0.030	-0.031	0.619
3000	0.040	-0.026	0.653	ABRAM	0.002	-0.011	1.747
4001	0.074	-0.004	0.655	DIJIR	-0.008	0.041	0.632
4002	-0.013	-0.015	0.726	-	-	-	-

Due to topo-cadastral applications using plane coordinates (2D space) final coordinates obtained by the two processing options can be used without restraint, given the relatively small recorded differences.

CONCLUSIONS

By enabling various topographic details GNSS technology shows that the GPS system is the main current and future approach for efficient topo-cadastral applications. Although the National Geodetic Network GPS related infrastructure was shaped with the completion of the National Network of Permanent GPS Stations (RN-SGP) considered active points, and was supplemented by points B and C considered passive points, additional points can be used for geodesic triangulation performed already for more than four decades ago.

The use of the classical geodetic network points to obtain the coordinate transformation parameters for certain areas, zones, regions can provide a better accuracy for points positioned GNSS technology, GPS. The analysis of the precision and accuracy of the positioning of the various landmarks may experience slightly different processing options, namely the use of sets of transformation parameters for the work area determined under relatively different conditions.

Coordinate differences were due in principle to the level of accuracy with which the parameters were determined by transformation (both the local and county-ANCPI) to spatial positioning accuracy points (geocentric reference system) and to algorithms (principles) employed in the two types of processing data recorded utilizing GNSS technology. Repositioning old points, network support, GPS GNSS technology have shown that differences in plane (2D space) coordinates of these points obtained by classical methods and those obtained using modern methods of positioning are relatively low.

REFERENCES

1. Ádám J., Bányai L., Borza T., Busics G., Kenyeres A., Krauter A., Takács B., 2004, Müholdas helymeghatározás, Editura Müegyetemi, Ungaria;
2. Boş N., Iacobescu O., 2009, *Cadastru şi cartea funciară*, Editura C.H. Beck, Bucureşti, 401 pag.;
3. Boş N., Iacobescu O., 2007, *Topografie modernă*, Editura C.H. Beck, Bucureşti, 542 pag.;
4. Crainic G.C., 2011, Cercetări privind modernizarea lucrărilor topo-geodezice din sectorul forestier, Ministerul Educației, Cercetării, Tineretului şi Sportului, Universitatea Transilvania din Braşov, Facultatea de Silvicultură şi Exploatări Forestiere, Departamentul de Exploatări Forestiere, Amenajarea pădurilor, Măsurători terestre -Teză de doctorat, Braşov;
5. Crainic G. C., Damian V. L., 2011, *Issues Related to the Use of The Points in Geodetic Triangulation of State in Positionig With Static Relative GNSS Method*, Analele Universității din Oradea, Fascicula: Protecția Mediului, Vol. 17(16), ISSN-1224-6255, pag. 450-459;
6. Crainic G. C., Damian V. L., Spîlca M., 2011, *Posibilities of Realisation of the Minor Control Network with GNSS Tehnology in the Occupyed Areas with Forest Vegetation in Mountain Areas*, Research Journal of Agricultural Science, University of Agricultural Science and Veterinar Medicine of the Banat Timişoara, Vol. 43 No. 3, ISSN – 2066-1843, pag. 283-291;
7. Dragomir P. I., Rus T., Dumitru P.D., 2005, *Modernizarea rețelei naționale de stații GPS permanente a României*, Revista de Geodezie Cartografie şi Cadastru, vol. 14, numerele 1, 2, Bucureşti, pag. 84-94;
8. Detrekői A., 2009, *Geodézia és Kartográfia*, 2009/05, Budapest, pag. 3-7;
9. Hofmann-Wellenhof B., Lichtenegger H., Collins J., 1997, *Global Positioning System, Theory and Practice*, Springer Wien New York, Austria, 389 pag.;
10. Neuner J., 2000, Sisteme de poziționare globală, Editura Matrix Rom, Bucureşti;
11. Neuner J., Săvulescu C., Moldoveanu C., *Studiu privind posibilitatea de determinare a coordonatelor în proiecția stereografică 1970 utilizând tehnologia GPS*, Revista de Geodezie Cartografie şi Cadastru, 2002, Vol. 11, numerele 1, 2, Bucureşti, 130-143 pag.;
12. Păunescu C., Mocanu V., Dimitriu S.G., 2006, Sistemul global de poziționare G.P.S., Editura Universității din Bucureşti;
13. Rus T., 2009, Tehnologii geodezice spațiale-Note de curs, Facultatea de Geodezie, Universitatea tehnică de Construcții Bucureşti;
14. Sabău N.C., 2010, Măsurători Terestre, Editura Universității din Oradea;
15. Sabău N.C., Crainic Gh.C., 2006, Teledetecție şi cadastru forestier, Editura Universității din Oradea;
16. Sabău N.C., Crainic Gh.C., 2006, Aplicații ale teledetecției în cadastru, Editura Universității din Oradea;
17. Tămâioagă GH., Tămâioagă D., 2007, Automatizarea lucrărilor de cadastru, Editura Matrix Rom, Bucureşti;
18. **Contract nr.552 din25.04.2013;
19. http://www.cngcft.ro/main/images/BDSG.jpg;
20. http://www.uab.ro/reviste_recunoscute/revcad/revcad_2005/02.dragomir_p.rus_t.dumitru_p.pdf;
21. http://upload.wikimedia.org/wikipedia/commons/c/cd/Abram_BIHOR_COMUNE_copy.png;
22. http://www.satellitecitymaps.com/europe-map/romania-map/jude%C5%A3ul-bihor-map/abram-map.