Possibilities of modelling surface movements in GIS in the Košice Depression, Slovakia

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Abstract: It is necessary to understand the geo-tectonic recent movements and landslides and mining subsidence of the earth surface and the earth crust movements as a natural continuation of dynamic tectonic processes. Determined movements by means of using the geodetic terrestrial or satellite navigation technologies give information about displacements in concrete time information on the base of repeated geodetic measurements in the concrete time intervals. 3D deformation investigation of the point of the monitoring station stabled in Košice-city and the Košice Depression territory in East Slovakia is the main task of the presented paper. The obtained results are transformed into GIS (Geographical Information Systems) in a frame of the environmental protection.

Key words: 3D deformations, GPS, geo-tectonic movements, mine subsidence, landslides, GIS.

1. Introduction

The terrestrial and GPS (Global Positioning System) measurements are realised on points of the geodetic network (*GN*) localised in the Košice Depression, Slovakia (Figures 1 and 2). The aim of these measurements is to determine recent geo-tectonic movements, landslides and subsidence of the earth surfaces caused by underground mine activity in the urban agglomeration of Košice-city. The terrestrial and GPS measurements are periodically realised twice a year (spring and autumn). Altogether, 20 points of *GN* are measured by means of using the trigonometric and GPS kinematics method. The determined *GN* points are solved by double GPS vector technology always regarding two reference points, i.e. three GPS receivers are used for measurements. The main tectonic fault in the Košice Depression, according to which two expressive geological faults of the Earth ground blocks should move, is assumed in the north-south direction along the river Hornád. The secondary tectonic faults of smaller extent are in the direction perpendicular to the Hornád fault, i.e. in the east-west direction. These secondary tectonic faults are mutually parallel. The landslides are expected in the territory of Košická Nová Ves closed to Košice-city. The mining subsidence is occurred in the Košice-Bankov forest park, which is situated in the magnesite underground mine Košice-Bankov

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(Figures 1 and 2) (FRAJT & MIŠOVIC, 2001, SEDLÁK, 2000, SEDLÁK ET AL. 2001, 2004).

The GPS receivers ASHTECH: ProMARK X-CM and the total stations TOPCON: GTS 6A were used for satellite and terrestrial measurements. The non-linear rotary matrix method was applied to the adjustment. After transformation, the coordinates were consecutively adjusted by an adjustment with constraints (FRAJT & MIŠOVIC, 2001, SEDLÁK ET AL., 2001, 2004).

Figure 1. The Košice Depression GN (GPS measurements).

2. DEFORMATION ANALYSIS

The Košice Depression *GN* can be adjusted by two ways. If we consider datum parameters as absolutely accurate and we do not include them into an adjustment process, the adjustment with constraints is considered in this case. In fact, those datum parameters are also determined with a concrete accuracy that has an influence on an accuracy of adjustment parameters except for measurement accuracy. In this case a network can be adjusted by a free adjustment with consideration of datum parameters. Regarding the applied confinement adjustment in the Košice Depression *GN* a theoretic procedure of this adjustment is presented, which is the most convenient for our national geodetic (FRAJT & MIŠOVIC, 2001, SEDLÁK ET AL., 2001, 2004).

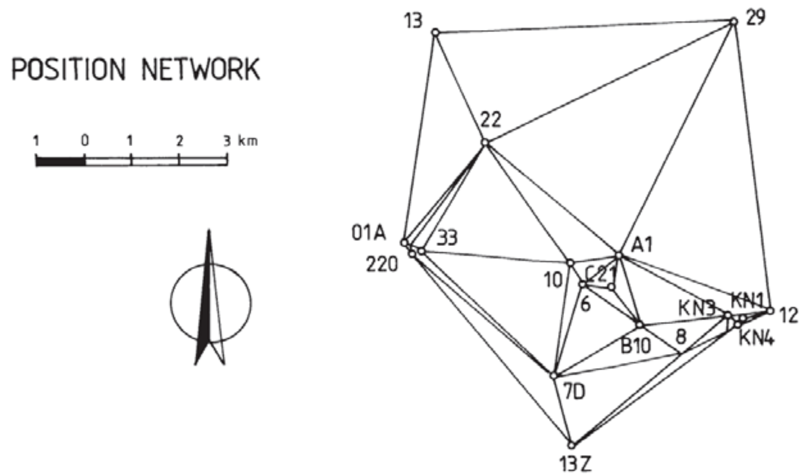

Figure 2. The Košice Depression GN (terrestrial measurements).

The least mean square method is chosen as an estimate principle, and the inverse solution is chosen as a mathematical principle (Gauss-Markov model), which is a standard procedure in an adjustment of the Košice Depression *GN*. After adjustment the position and form of *GN* are changed but the datum point positions are not changed (datum points are considered as absolutely accurate).

Analysis of deformations is realized through the following basic phases:

- Measurement of the *GN* points in the first - base period and determination co-ordinate estimates.
- Measurement of the *GN* points in the further period and determination co-ordinate estimates.
- Determination of the position differences and their testing.

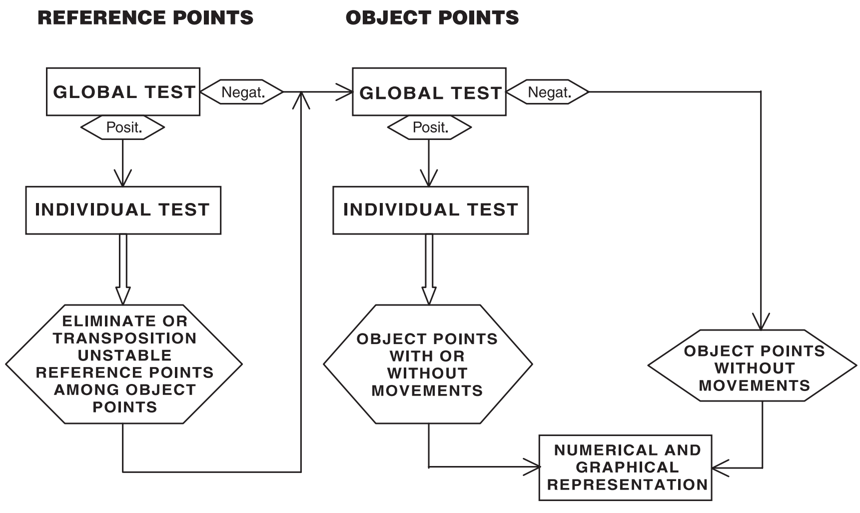

Figure 3. Test decision procedure.

The test decision procedure for appreciating the stability of points is demonstrated in Figure 3. At first, the global test for reference points is made. If the test is positive, unstable points are transposed to the object points. The test of object points is similar. The stable and unstable points are determined by an individual test (SEDLÁK, 2000).

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2.1 Graphical representation and analysis of accuracy

The condition of observed points is transparently and completely displayed in individual periods by graphical representation in the following epochs:

- The isolines and vectors of movements (2D) in the period of two years since 1997 to 1999.
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- The isolines and vectors of movements (2D) in the period of the years since 1997 to 2001 (Figure 4). It is evident, the biggest movement occurred in the Košice-Bankov and Košická Nová Ves territory. It was verified by the deformation tests.

The numerical values (*WGS-84*) of the horizontal and vertical movements of terrestrial and GPS measurements are shown in Table 1. The points: KN2, KN3, 33, 112, 220, which changed their position according to the used test-statistics, are colour marked.

The confidence ellipses, which cover non-random vectors parameter, were determined

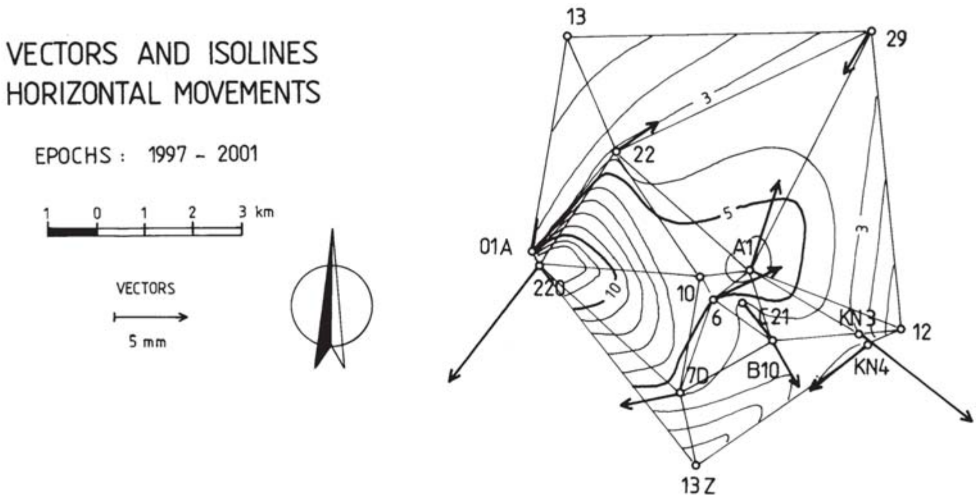

Figure 4: Isolines and deformation vectors, 1997 – 2001 epoch.

for each of the object points. The spectral analysis cofactor matrix of the co-ordinate estimate determines the structural parameters of the confidence ellipses.

Table 1. The deformation (2D & 1D) vector values and the vector bearings.

Object points	1997 - 1999			1999 - 2001			1997 - 2001		
	δ_P [m]	σ_{dp} [^{g}]	δ_Z [m]	δ_P [m]	σ_{dp} [^{g}]	δ_Z [m]	δ_P [m]	σ_{dp} [^{g}]	δ_Z [m]
KN2	0.006	80.6235	-0.0012	0.004	73.6583	-0.0013	0.010	77.6983	-0.0031
KN3	0.006	34.2141	-0.0009	0.006	29.5069	0.0004	0.012	31.8001	-0.0012
KN4	0.003	168.9086	-0.0016	0.003	159.5458	-0.0008	0.006	164.4653	-0.0023
KN5	0.002	27.4548	-0.0004	0.001	29.1307	0	0.00	28.1065	0
A1	0.003	315.0060	-0.0005	0.003	330.0773	-0.0003	0.006	322.7850	-0.0010
B10	0.002	65.2953	-0.0006	0.002	71.7866	-0.0004	0.004	68.7907	-0.0012
C21	0.001	81.4231	-0.0006	0.002	52.2829	0.0002	0.003	64.2709	0
6	0.003	351.6824	-0.0003	0.003	370.1831	-0.0003	0.006	361.2637	-0.0014
29	0.001	144.8129	-0.0002	0.004	139.8180	0.0003	0.005	141.2165	0
22	0.001	337.3384	0.0003	0.002	351.4133	-0.0005	0.003	345.6190	0
10	0.003	142.4283	-0.0002	0.003	134.8389	-0.0004	0.006	138.5027	-0.0009
7D	0.002	176.9814	-0.0007	0.002	180.8509	0.0002	0.004	179.0511	0.0008
33	0.008	134.2371	0.0011	0.007	130.4754	0.0010	0.015	132.5342	0.0024
112	0.006	123.0186	-0.0061	0.005	130.4708	-0.0017	0.011	126.6067	-0.0077
220	0.006	158.3338	0.0020	0.007	132.4913	0.0013	0.013	144.1060	0.0031
01A	0.002	324.2060	-0.0007	0.002	312.0153	-0.0004	0.004	316.9566	-0.0009
01B	0.001	102.3104	-0.0007	0.001	97.6472	-0.0005	0.002	100.3674	-0.0008

δ_P – positional deformation vector, δ_Z – vertical deformation vector σ_{dp} – bearing of confidence ellipses.

2.2 GIS applications

GIS of interested area is based on the next decision points:

- Basic and easy data presentation;
- Basic database administration;
- Wide information availability.

The best viable solution is to execute GIS project as the Free Open Source application available on Internet. The general facility feature is free code and data source viability through the HTTP and FTP protocol located on the project web pages. Inter among others features range simple control, data and information accessibility, centralized system configuration, modular stuff and any OS platform (depends on PHP, MySQL and ArcIMS port) (Frajt & Misovic, 2001, Sedlák et al., 2001, 2004).

Network based application MySQL is in a present time the most preferred database system on Internet. It is because, that MySQL company is a member of Open Source (based on GPL license), the price of this product is less than the prices of others commercial databases (i.e. Oracle, MS SQL Server, etc.), it has high-speed responses, uses fast data storing (in a binary file up to 1 TB - in 1 single file, supports unlimited quantity of s data files) etc. This database is relational database with relational structure and supports SQL language. At the present time

MySQL 4.0 is released and supports transaction data processing, full text searching and procedure executing. PHP, which stands for “PHP: Hypertext Pre-processor” is a widely used Open Source general purpose scripting language that is especially suited for Web development and can be embedded into HTML. Its syntax draws upon C, Java, and Perl, and is easy to learn. The main goal of the language is to allow web developers to write dynamically generated web pages quickly, but you can do much more with PHP.

Database part of GIS for the mine subsidence Košice-Bankov application runs on MySQL database, because it is free distributed for non-commercial projects (Figure 5). PHP supports native connections to many databases, for example MySQL, MSSQL, Oracle, Sybase, AdabasD, PostgreSql, mSQL, Solid, Informix. PHP supports also older database systems: DBM, dBase, FilePro ...PHP can communicate with databases with ODBC interface and this feature represents PHP to work with desktop applications supporting ODBC interface. PHP cans attend to another Internet services, because includes dynamics libraries of some Internet protocols (i.e. HTTP, FTP, POP3, SMTP, LDAP, SNMP, NNTP, etc.).

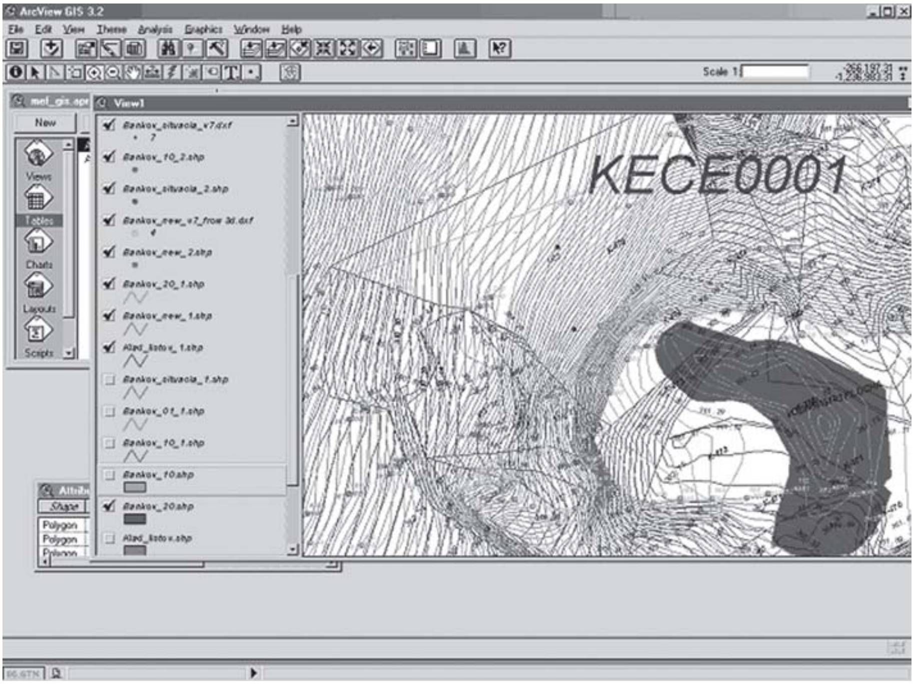

Figure 5. The mine subsidence: Košice-Bankov (GIS-MySQL).

3. Conclusions

The results of measurements by GPS technology confirm a typical event of using this satellite measurement in *GN* with a spread application in geodesy. The applied kinematics method of GPS measurements shows on a high accuracy of satellite measurements, which is also acceptable for some other geodetic measurements, for example: deformation surveying the earth surface and engineering structures. The chosen confinement adjustment by means of using the Gauss-Markov model is demonstrated as the most suitable mathematical model in an adjustment of *GN* in the Košice Depression locality.

The presupposed possible recent geo-tectonic movements in the direction of north south along the Hornád River are not confirmed. Also the points of GN in Košická Nová Ves, where landslides are expected, as well as the points of GN in the Košice-Bankov magnesite mine, where subsidence induced by underground activity are occurred, have fixed at the present. MySQL database is very convenient for many applications into GIS where land surveying, mine surveying and other geodetic data are occurred.

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