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GPS ACTIVITY AT THE DEPARTMENT OF GEODESY IN TECHNICAL UNIVERSITY BUDAPEST

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Abstract

GPS activity in Department of Geodesy has been done since 1987. For lack of receiver(s) we have joined to other Institutes and Companies in our works. Our activity is directed to three main lines: to take part in observation in different campaigns in Hungary; establishing and monitoring our test-network in Sóskút in geodynamical point of view; investigation about the determination of geoid height with GPS techniques. Significant results of our observations in the tectonic area would be expected after 6 – 8 years because of the nature of the phenomenon.

Keywords: Satellite geodesy, Global Positioning System, network adjustment.

Introduction

The possibilities of the Global Positioning System are going to change geodesy and surveying, although we certainly do not yet know the final result of the present collision between classical and modern concepts. One of the most significant and unique features of space-based positioning systems, such as NAVSTAR/GPS is that the positioning signals are available to users at any position world-wide at any time. In the last twenty-five years geodetic and navigation positioning accuracy has increased by over two orders of magnitude. These improvements are attributable to the development of systems based on the so-called extraterrestrial instrumentation techniques. An extraterrestrial positioning system is a system for establishing positions of points on or near the surface of the earth which utilizes electromagnetic radiation either emitted or reflected from an object in orbit about the earth or at some greater distances. One of these systems is the NAVSTAR/GPS (Navigation System using Time And Ranging/Global Positioning System), based on 21 satellites arrayed in 6 orbital planes [1]. Appropriate receivers track the codes or the phase of carriers (or both) and in most cases also extract the broadcast message. Different techniques are available for range measurement using this special construction of the electromagnetic wave broadcasting from the satellites. If the ranges to four satellites are combined with the orbit description, the receiver can determine its three-dimensional geocentric coordinates. For precise geodetic work, carrier of code-frequency phase is measured and recorded for future processing.

From the geodesist's point of view the GPS has three main attractions: high accuracy, low cost and unified coordinate system. Therefore GPS will likely be used not only by positioning professionals, such as surveyors, but also by large segments of the general public for new position-related tasks which were not previously feasible [2].

At the application of the GPS technique in the establishment of a high precision geodetic or geodynamic network we are facing the problem of the reference systems. GPS uses WGS–84 reference system which is a global one and has no exact connection with the local traditional coordinate systems defined by the local physical parameters. To find this connection empirically, it is necessary to establish such a GPS network which is ptoperly dense, and the coordinates of the points of this network are known in the traditional local geodetical system. For each country which intends to use GPS technique the first step is to establish a GPS Reference Network. This kind of basic network can be applied in different tasks.

This National GPS Network (NGPSN) was established in Hungary in 1991 [3]. It is the reference network not only for joining to the EUREF system but also for the Hungarian Geodynamic GPS Network (HGGN). The aim of the HGGN is to have high-precision base for geodynamical investigation, for example in the regional crustal deformation measurements [4].

The NGPSN consists of 24 points and 5 of these are the Hungarian points in EAREF network. Fifteen Trimble 4000 SST receivers were working in this campaign which lasted 8 days. Organizer of this work both in measurements and in computation is the Institution of Geodesy, Cartography and Remote Sensing supported by Institut für Angewandte Geodesie, Frankfurt and from different Hungarian geodetic institutions, one of these is Department of Geodesy. Processing of the measurements is going to use the Bernese software. Results of the computation will be available only at the end of 1992.

Study of Slow Crustal Movements

Introduction

In 1984, Department of Geodesy of TU Budapest built up a network for movement analysis consisting of 6 points in Sóskút with the leadership of Dr. LÁSZLÓ MISKOLCZI [5]. The points were situated on both sides ofa geologically known fault section. The distances in the network are 160 – 670 m. To determine the tectonic movements, in this 6-point network, angle, height and distance measurements were carried out from time to time.

The crustal movements in general direction could not be observed at the same time with the traditional measuring instruments. Because of the possibilities provided by the measuring instruments, we could determine the horizontal and vertical components of the movement separately, with the accuracy of 10 mm and 2 mm, respectively.

In today's geodetical practice, the NAVSTAR/GPS allows the three-dimensional positioning — with 0.1 – 1 ppm relative error — fast and economically. Determining the horizontal and vertical components and connecting these two measurements with the new measuring technology, the former inevitable separation can be avoided using precise measurements provided by GPS technology.

This was the reason why micronet GPS measurements were carried out in Hungary at the TUB of Sóskút, between April 2 – 5, 1990. We carried out the measurements with two L1 frequency 8 channel GEOTRACER 100 receivers [6].

The Preprocessing of the GPS Measurements

The observations were processed by the TRIMVEC-PLUS program of the Trimble Navigation Company [7]. The software consists of several consecutive subroutines which make possible the transfer of measurement data, the determination of the components of the vectors, and calculation of the elements of the variance-covariance matrix. The software gives an opportunity to the user to choose between the manual baseline or the multibaseline processing.

In our case, the batch baseline processing was most expedient because we carried out simultaneous static observations at each given point pair. Both processings give three kinds of phase-observable differences:

- triple difference (TD),
- double difference (DD) with floating solution,
- double difference (DD) with fixpoint solution.

In all three solutions an output file is created. These files contain the station coordinates, the base components and variance-covariance matrices.

Thus, there are enough data to determine the quality of the measurements and to decide weth^r the manual processing increases the accuracy, or not.

The program does not contain modelling of the ionosphere. To correct tropospherical errors, it employs the modified Hopfield model. The selection from three solutions is the function of the distance between the two points.

In the case when the distance does not exceed 15 – 20 km, the literature suggests using the fix solution. We choose this solution because the distances between the points do not reach even 1 km.

The float solution must be chosen if the distance is between 20 – 50 km, and we prefer the triple difference solution if the distance exceeds 50 km.

It is possible to have the results of all three solutions printed on one page (Results for All Solutions). This file contains the float and fix solution, the differences of the dx, dy and dz values, the accepted and not accepted epochs, the quality of the measurement and suggestion for the best solution.

The Adjustment of GPS Measurements

The adjustment itself follows the logic of the network determination. Basically, a GPS network can be determined in two ways:

a) in the first case we determine the position of the network points using two receivers, and the network is constructed from these so-called baselines (baseline approach),
b) in the second case the accuracy of the network is intended to increase, if we use more than two receivers at the same time, and we complete the network from these baselines (so-called multibase approach).

During the observations, we could use only two receivers, therefore only one solution could come into question.

The functional model of adjustment with the least squares method is given by (1), while the connected stochastic model is given by (2)

$$\mathbb{L} + \mathbb{v} = \mathbb{A}\mathbb{X}\,, \tag{1}$$

$$\mathbb{M}_{LL} = \sigma_0^2\,, \mathbb{Q}_{LL} \tag{2}$$

where $\mathbb{L}(n)$ — vector of observations
$\mathbb{v}(n)$ — vector of residuals

$\mathbb{A}(n, u)$ — configuration matrix
$\mathbb{X}(u)$ — vector of unknowns
$\mathbb{M}_{LL}(n, n)$ — covariance matrix for observations
σ_0^2 — variance factor
$\mathbb{Q}_{LL}(n, n)$ — cofactor matrix for observations

In our case, the stochastic model merits special attention, because our measurements are correlated, so the weight matrix $\mathbb{P}$ was choosen as $\mathbb{P}=\mathbb{M}^{-1}$. The $\mathbb{M}^{-1}$ matrix is one of the output results of the preprocessing.

The observation equations connect the measurements and the parameters to be determined, which can be written as:

$$\Delta\mathbb{X}_{ij} = \mathbb{X}_j - \mathbb{X}_i .$$

Taken to its components:

$$\Delta\mathbb{X}_{ij} = \begin{bmatrix} \mathbb{X}_{ij} \\ \mathbb{Y}_{ij} \\ \mathbb{Z}_{ij} \end{bmatrix} = \begin{bmatrix} \mathbb{X}_j - \mathbb{X}_i \\ \mathbb{Y}_j - \mathbb{Y}_i \\ \mathbb{Z}_j - \mathbb{Z}_i \end{bmatrix} .$$

For the unknowns to be determined, we took $\mathbb{X}_0$ preliminary value. The changes of the unknown parameters can be calculated with the following formula:

$$\mathbb{X} = -\mathbb{N}^{+}\mathbb{n} ,$$

where $\mathbb{N} = \mathbb{A}^T\mathbb{M}^{-1}\mathbb{A}$
$\mathbb{n} = \mathbb{A}^T\mathbb{M}^{-1}\mathbb{l}$
($\mathbb{l}$ is the vector of constant terms)

Furthermore, the parameters yielded from the adjustment and the variance-covariance matrices of the adjusted measurements can be calculated.

Evaluation of the Measurements

The second GPS measuring campaign at Sóskút network was carried out between August 12 – 16, 1991. The first campaign was carried out again in two sessions, with the condition that PDOP≤4. Postprocessing the data, we could not find rough errors. The 1991 measurements were carried out in two sessions, but with different PDOP values. In the first sessions, PDOP≤4, while in the second the PDOP≤7 were the conditions. 6.7% of the measurements were found containing rough errors.

The coordinate differences in the two epochs did not exceed 1 mm. Moreover, former distance measurement excluding the systematic linear scale errors measured with EDM were compared. With corresponding distances derived from GPS measurements the differences were found to be less than 2 mm.

The expected tectonic movements cannot be shown at the present stage of our observation.

Height Determination with GPS

The GPS is a 3D positioning system which is able to determine the spatial rectangular coordinate differences of points above the earth's surface with a relative error of 0.1 – 1 ppm. These Cartesian coordinates — in a given reference system — can be transformed into ellipsoidal latitude, longitude and height.

Because of the strong connection of the practical life with the sea level, the third coordinate is practically separated from the reference system and it means the height above sea level. In mapping and in planning and building different industrial establishments it is the height above sea level that is needed in most cases.

A common characteristic of the different height concepts is to define the height of a point as the potential difference from a chosen potential level. This potential difference becomes a metric value — which we can use as a coordinate — by a physical quantity (by the gravity). In a geoid map with a similar accuracy as of the GPS measurements, the height above the sea level could be calculated by subtracting the geoid undulation from the height above the ellipsoid. It is clear that the most important problem is how the desired accuracy of the geoid determination could be achieved.

We would create blocks from the 1st order points of the Unified Hungarian Height Network for the geoid determination. At these points or in their close vicinity, the height above the ellipsoid of these points would be determined using GPS techniques. Adjusting the GPS network, the geoid undulations can be calculated directly.

Collecting other useful geological, geophysical and geodetical information for each block, we could have a representation of the geoid accessible.

An advantage of this method would be that the geoid determinations could be carried out in blocks, and a suitable interpolation method could be formulated, which would be sensitive to the small geoid variation of the given area. We could make accessible geoid undulations depending on the horizontal location in the form of a software to GPS users.

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