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AUTOMATIC DETERMINATION OF VERTICAL DEFLECTION COMPONENTS FROM GPS AND ZENITHAL STAR OBSERVATIONS

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ABSTRACT
The known vertical deflection values can be utilised to increase geoid's accuracy. One of the methods of vertical deflection components (ξ, η) determination is to compare astronomic and geodetic coordinates. Presently it is easy possible to obtain geodetic coordinates with high accuracy from GPS observation. In the article the methods of astronomical CCD observation with aid of two different optical systems are discussed. Project realisation is in preliminary stage and there are no results available yet.

KEYWORDS: vertical deflection, CCD observation, geoid determination

INTRODUCTION

In the mountainous areas astrogeodetic method of vertical deflections determination is more effective than the gravimetric method (Gerstbach, 1996; Hofmann-Wellenhof and Moritz, 2006). Moreover, astrogeodetic method is able to provide better accuracy for the geoid on local scale. Astrogeodetic data combined with gravimetric data are optimal for geoid determination (Kuhtreiber, 2002). Main goal of the described project is developing the method of automatic determination of the astronomical site coordinates Φ, Λ based on zenithal star observations. Fully automated system for astronomical coordinates determination make possible to eliminate personal equation, shorten time needed to process data and make the method more reliable. Astronomical coordinates compared to geodetic coordinates φ, λ obtained from GPS measurements will be used for vertical deflection components determination with following equations (Hofmann-Wellenhof and Moritz, 2006):

$$\xi = \Phi - \varphi$$
$$\eta = (\Lambda - \lambda)\cos\varphi \qquad (1)$$

where ξ is north-south component and η is east-west component. Vertical deflection components are used for astrogeodetic geoid determination. With known ξ and η values, the geoid undulation difference ΔN between two points in the azimuth A separated by s (Fig. 1) may be calculated with equation:

$$\Delta N = -s\theta_A$$
$$\theta_A = \xi\cos A + \eta\sin A \qquad (2)$$

where θ_A is the vertical deflection in the direction A. Azimuth A refers to normal section of the ellipsoid (Hofmann-Wellenhof and Moritz, 2006).

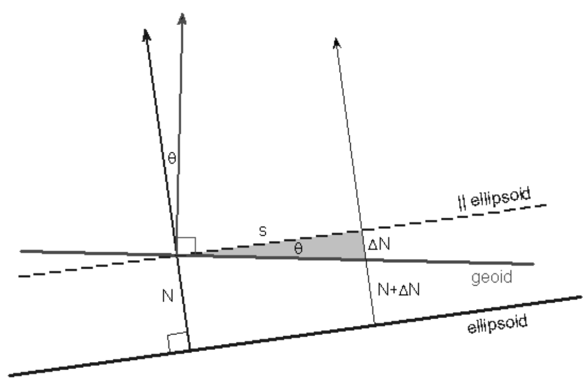

Fig. 1 Vertical deflection and geoid undulation difference.

DATA ACQUISITION

Procedure for automatic vertical deflection determination consists of 3 main tasks:

- precise GPS positioning and timing,
- CCD imaging,
- precise inclination measurements.

Figure 2 shows the system functional diagram. The GPS receiver is used for determine geodetic φ, λ coordinates and to provide precise time signal for stellar observations synchronization. Data from GPS receiver are stored directly on the PC's hard disk and it is possible to obtain geodetic coordinates with

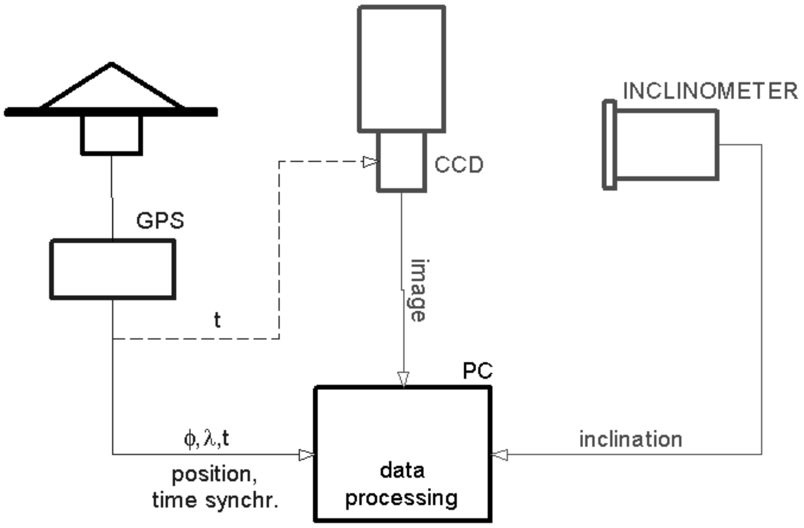

Fig. 2 Data acquisition scheme.

appropriate accuracy in real time with DGPS/RTK method. The PC's internal clock is synchronised with 1PPS signal from GPS receiver. The GPS 1PPS signal may be used also for triggering the shutter of the CCD camera. CCD sensor provides zenithal stars field images and inclinometer continuously measures the inclination of the telescope axis of rotation from vertical. The inclinometer readings are stored in the PC together with time tags. The local zenith may be localized in the star images after comparison of four images taken in different telescope positions with a difference of 90°. Stars extracted from the images must be identified with the star catalogue to obtain their equatorial coordinates α, δ. With known star and zenith position in the image plane it can be zenith equatorial coordinates α_z, δ_z calculated. Finally, astronomical coordinates may be calculated as an equivalent to equatorial coordinates of the zenith:

$$\Phi = \delta_z \qquad \Lambda = \alpha_z - S \tag{3}$$

where α_z – right ascension of the zenith – is equal to local apparent sidereal time and S is Greenwich apparent sidereal time of the observation epoch.

SYSTEM DESIGN

The project assumes design of two different apparatus for star imaging. Comparison of the results obtained from two independent systems may be helpful in accuracy verification. Main difference between systems is in optical lenses used for imaging. First one consists of Maksutov-Cassegrain telescope (photographic lens) with CCD camera attached and mounted on the rotating base. The CCD sensor is placed in the prime focus of the telescope. On the rotating base the precise inclinometer is also mounted (Fig. 3). The base makes possible telescope to rotate and stop in directions of 0°, 90°, 180°, 270°. In that positions the inclinometer measures inclination of rotation axis. Because it is only one inclinometer in the designed system it is needed to determine inclination in 4 positions. Inclinometer used for vertical line determination is Wyler Zerotronic 0.5 with accuracy of 0.1" (www.wylerag.com).

The telescope used in surveys is MTO-11CA photo lens with 1000 mm focal length and 100 mm aperture. Together with Starlight Xpress SXVF-M25C CCD camera gives field of view of 82' x 54' with resolution of 1.63" per pixel. Pixel size is 7.8 μm x 7.8 μm and CCD sensor is 3024 x 2016 pixels.

First tests show that the MTO-11CA with SXVF-M25C is able to image stars of 9.5^m with 1 sec exposure time. Calculation made by TheSky software shows that the number of stars of that magnitude observed with one exposure (in the one randomly chosen night) may vary from 2 to 15 depends on observation epoch. Limiting magnitude may be increased switching CCD camera into 2x2 binning mode or by stacking multiple exposures. At this stage of project stars identification has been performed with Tycho-2 and GSC catalogues with aid of Maxim-DL and Astroart software. It should be noticed that the tests has been conducted in the light polluted area and no calibration of the image has been performed.

For the precise timing the internal PC's clock is synchronized with GPS time using Tac32 software (www.cnssys.com). For accurate exposure time determination the shutter latency must be also measured accurately. Latency depends on camera design and on software used for triggering the shutter.

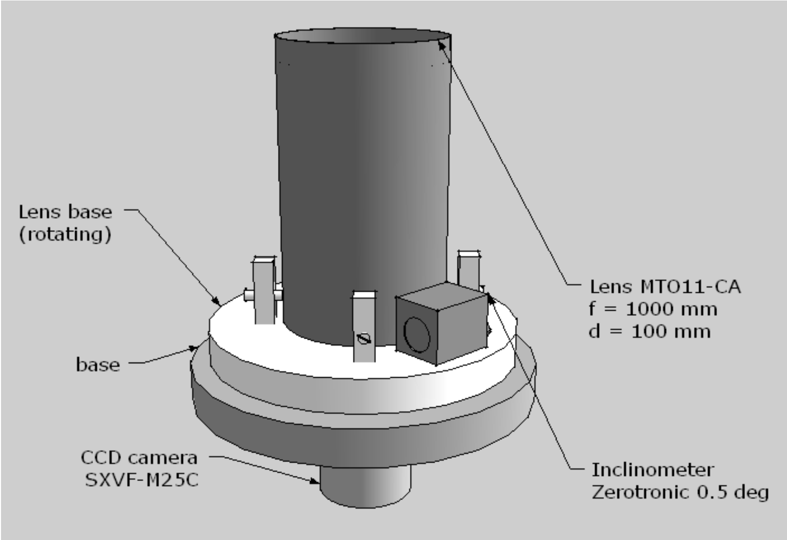

Fig. 3 Design of apparatus with photo lens.

Fig. 4 Field test of the apparatus based on PZL-100.

In the laboratory tests conducted with Maxim-DL software the shutter of SXVF-M25C shows latency of 1.67 second.

Second system is based on PZL-100 Zeiss lens. It is an attempt to adapt ordinary geodetic apparatus for astronomical observations with CCD camera. Due to PZL-100 construction it is eyepiece projection used for star imaging (Fig. 4). The imaged star magnitude is slightly less compared to obtained from the first apparatus, and there is a large field distortion due to eyepiece projection. Main advantage of this construction is the pendulum compensator used for vertical determination in the PZL-100.

DATA PROCESSING

The data are processed in the field just after collecting all needed star images. The following scheme describes main steps in data processing:

- zenithal star imaging in 4 telescope positions with time and inclination recording,
- image star recognition and determination of the star plane coordinates (x, y),
- determination of centre of rotation (x0, y0) after four image taken comparison,
- star identification and reduction to observation epoch (α, δ),
- image calibration – transformation (x, y) ↔ (α, δ); in this step an optical distortions of the lens are also minimized.
- equatorial coordinates of centre of rotation (α_0, δ_0) determination,
- applying the inclination corrections to obtain zenith equatorial coordinates (α_z, δ_z),

- astronomical coordinates determination (eq. 3),
- vertical deflection components determination (eq. 1).

Described procedure make possible to determine vertical deflection components in half a hour with accuracy of 0.2” (Fosu et al., 1998; Hirt, 2001). Recent researches show that statistical processing of results of repeatedly performed observations may increase system accuracy to 0.05-0.1”. Systems for deflection of the vertical determination with such accuracy are used since 2003 at ETH Zurich and University of Hannover (Hirt and Bürki, 2006).

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REFERENCES

Fosu, C., Eissfeller, B. and Hein, G.W.: 1998, CCD to marry GPS. ION GPS 1998, Nashville, Tennessee, 69-80.

Gertsbach, G.: 1996, How to Get an European Centimeter Geoid (“Astro-Geological Geoid”). Phys. Chem. Earth, Vol.21, No.4.

Gerstbach, G.: 2003, Geoid monitoring by Zenith camera and geology. Geoscientific Cooperation Projects of Austria, Slovakia and Hungary, TU Bratislava.

Hirt, C.: 2001, Automatic determination of vertical deflections in real-time by combining GPS and digital zenith camera for solving the “GPS-Height-Problem”. ION GPS 2001, Salt Lake City, Utah, 2540-2551.

Hirt, C. and Bürki, B.: 2006, Status of geodetic astronomy at the beginning of the 21st Century. In: Festschrift Univ.-Prof. Dr.-Ing. Prof. h.c. Günter Seeber anlässlich seines 65. Geburtstages und der Verabschiedung in den Ruhestand (ed. C. Hirt). Wissenschaftliche Arbeiten der Fachrichtung Geodäsie und Geoinformatik an der Universität Hannover Nr. 258, 81-99.

Hofmann-Wellenhof, B. and Moritz, H.: 2006, Physical geodesy, Springer Wien New York.

Kühtreiber, N.: 2002, High precision geoid determination of Austria using heterogeneous data, gravity and geoid 2002. GG2002 3rd Meeting of the International Gravity and Geoid Commission, August 26 - 30 2002, Thessaloniki, Greece, 144- 149.

Rogowski, J.B., Barlik, M., Kujawa, L., Margański, S., Pachuta, A., Piraszewski, M. Walo, J., Hefty, J. and Husar, L.: 1997, Determination of geoidal heights in a part of test field at Grybów – Status Report’95. Reports on Geodesy, No 2(25).