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Digital Zenith Camera – a new Astrometric Instrument for Precision Measurements in Geodesy

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Detailed knowledge of local geoid surface has become increasingly important in order to fully use the potential of accurate geocentric positions, provided by GNSS. Recent advances in a number of scientific and technological fields – accurate astrometric reference star catalogs; development of digital imaging technology; high accuracy tiltmeter technology; and geocentric coordinate availability using GNSS – have made it possible to use astrometric methods for accurate, fast and automated determination of vertical deflections. Such measurements can give important contribution in determination of local geoid properties [1].

Zenith cameras for this kind of measurements have been developed by several research groups. However, accessibility to these instruments is limited. The institute of Geodesy and Geoinformatics of the University of Latvia has engaged in a project to develop its own digital zenith camera [2] that is portable and reliable using off-the-shelf components as much as possible.

All digital zenith cameras share a number of construction principles that includes an imaging system that is pointed to the zenith, and are equipped with a precision biaxial tiltmeter. In order to exclude alignment inaccuracies and tiltmeter zero-point uncertainty, the mount can be rotated around the vertical axis. Within our project a simple experimental prototype device was used to develop measurement methodology and design control and data processing software. The experimental camera has a 20 cm catadioptric telescope with a 1390 mm focal distance, imaging device with 1350×1024 6.45 mkm pixels, covering field of 0.35×0.27 dg (resolution 0.95″ per pixel). Telescope assembly is supported by 3 small precision bearings, rolling on a flat horizontal support surface. Rotating and leveling of assembly are manual. Design of the improved version uses slightly bigger optics (a 8″ catadioptric telescope with focus distance of 2000 mm) and a 3300×2500 pixel imaging device (5.4 mkm pixels; 0.56″/pixel; 0.5×0.39 dg field). Computer-controlled stepper motors are used for rotation and leveling of assembly. Rotating part includes on-board battery power source and embedded control computer, operator control is done via wireless remote desktop connection.

Fig.1. Integration of components and tests of control equipment are now underway.

Stars of brightness up to 13^m-14^m (for 0.1 sec exposure) are found on obtained images, generally ensuring presence of at least 10-20 reference stars per frame. A subset of NOMAD astrometric position catalog [3] and NOVAS software package [4] are used for astrometric reduction of star coordinates. Reference star identification is done automatically [5].

CCD shutter pulse time tags, produced by GNSS receiver's event timing mechanism, are used to determine frame exposure moments. Timing accuracy of obtained star images is estimated to be within a few milliseconds.

Measurement session includes a series of imaging system frames together with tiltmeter readings, obtained within about 10 second interval around exposure moment. In order to minimize effects of tiltmeter scale and orientation uncertainties, assembly is leveled with sub-arcsecond accuracy in each measurement position. Assembly is rotated after a group of frames is obtained, any rotation position can be used. Optimal composition of measurement sessions is yet to be found out.

Presently accuracy of vertical deflection values, measured by the instrument, is expected at about 0.1". However, actual values of accuracy remain to be found.

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