Determination of rotation angles and geographic orientations in geomagnetic observatory instruments using digital camera images

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A digital image-based method is suggested as a possible alternative way for angle and orientation measurements in geomagnetic observatories and in field measurements. The suggested method is contact-free, fast and continuous, the results are immediately in digital form: these are some of the advantages compared to the optical theodolite readings. It offers some ways to relate the relative measurements to geographic reference orientations. Calibration procedures and straightforward digital algorithms are available to efficiently reduce the effects of the potential error sources, like the non-parallelisms between the plane of rotation, the recorded objects plane, the lens and the image sensor.

At absolute geomagnetic measurements, the rotations of a magnetometer sensor and a reference geographic orientation must be accurately measured. In this application the measuring device must be non-magnetic that complicates the instrument design and the realization of the measurement. In today's practice non-magnetic optical theodolites are used for this purpose, the operation of which requires experienced observers.

Photogrammetry techniques are used for a long time to determine the position of objects. Taking repeated exposures, the movements and rotations of the objects can also be estimated.

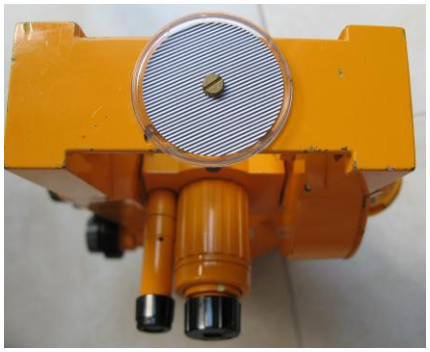

Figure 1: Multi-parallel line pattern fixed on the top of a Zeiss theodolite

As the camera can be far from the sensor, the set-up can be made non-magnetic. Recognizing this fact, we started a project to try to develop a camera-based method that can be used together or in lieu of the theodolite measurements. After some first tests, we have elaborated and selected a computational method that is a bit different from the classical photogrammetry and digital image processing methods. A multi-parallel line pattern is fixed on a rotable magnetometer sensor holder. A camera continuously records this pattern and a computer program processes the grayscale images in real time.

The angle of an image is determined by finding the angle along which the standard deviation of the image pixel values is the minimum. This angle practically corresponds to the average of the angles of individual lines. With this type of averaging, the errors due to the final pixel resolution and to the pixel noise could be greatly reduced.

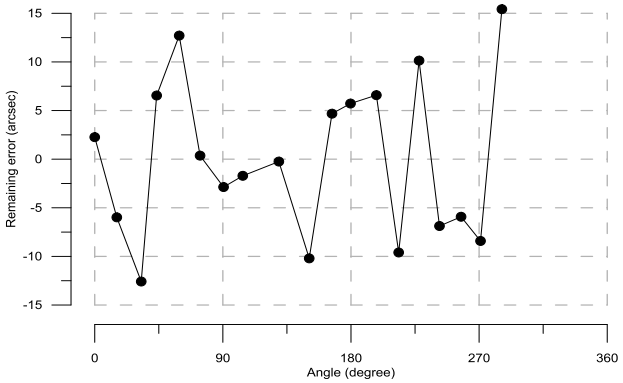

Figure 2: The differences between the theodolite readings and the angles determined by the method, after applying corrections from a calibration

Fig. 2. shows the results of one of our tests, made by the instrument seen in Fig. 1. and a commercial CCTV camera. The recent accuracy is about ±15 arcsec, after making a calibration that is required to get the 0° position and to remove errors due to the non-parallelism in the system. We are on the way to improve the accuracy by using, e.g. lens calibration, professional photogrammetry cameras, complex patterns and better calibration procedures.

Using free-hanging strings and Sunlight shadows of free-hanging strings projected on a horizontal surface as line patterns, the vertical and True north can be determined, then used as references for inclination and declination measurements. We are also testing these possibilities.

References:

T. Schenk, 2005. Introduction to Photogrammetry, The Ohio State University.

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