CCD ASTROMETRY ORIENTED ANALYSIS OF DIGITIZED MULTIPLE IMAGES (PLANETS, SATELLITES, ETC.) OBTAINED WITH THE PULKOVO PVC

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The Charge Coupled Device (CCD) has become the detector of choice in astrometry. The mechanical or electronic (drift scanning) tracking of objects by the telescope leads among observing strategies developed for CCD observations (Stone and Dahn, 1995).

Another strategy can be adopted when several bright objects are available in one frame, as in differential observations of the Solar system bodies (brighter than 12^m) with respect to the Hipparcos/Tycho stars. Such observations will be the program of the Pulkovo photographic vertical circle (PVC) in the near future when the photographic camera will be exchanged with a CCD. In this case the PVC's field of 30×30 arcmin (focal scale is 0.1 arcsec/micron) will contain roughly 5 reference stars and a Solar system body. In this method the telescope is kept stationary and the objects move across the field (at the diurnal rate) providing trails. A precise vane is used to recognize simultaneously observed parts of the trails of different objects. Finally the relative coordinates of the simultaneous parts are measured and averaged. A similar method was considered in (Schildknecht, Hugentobler, Verdun, 1994) as applied to fast moving objects.

In the methods with the tracking the position of accumulated image is determined with accuracy $\sigma(T) = 0.33" \cdot (T + 0.65^s)^{-1/4}$, where T is exposure (Høg, 1968). In the method of trails the exposure T is divided into n independent exposures of t ($T = n \cdot t$), and the accuracy is higher because $\frac{\sigma(t)}{\sqrt{n}} < \sigma(n \cdot t)$. Both differential methods greatly reduce the effects of refraction and atmospheric turbulence, but the method of trails takes into account a co-turbulence of the simultaneous images.

To test the method, we used plates photographed by the PVC in 1987 – 1995 which contain trails of simultaneously observed objects: double stars,

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Jupiter with Galilean satellites and so on (a by-product of usual meridian observations). Several tens of the frames were digitized with a pixel size of about 10 microns and 256 levels of gray scale. It was proved that photographic effects are negligible (the grain size is 3 microns).

The analysis of the frames indicates that the atmospheric turbulence is of crucial importance in the shift and distortion of the images. It has a periodicity of 1 – 10 seconds and mean amplitude of ±1 arcsec. The turbulent oscillations of the trails in one frame are correlated so that a scatter of distances between trails is 0.1 to 0.5 of the scatter of a trail about its parallel. This correlation is significant everywhere over the windowed telescope's field of 6 arcmin.

The analysis demonstrates the advantage of the method of trails. The length of the trail's parts used in the treatment for unit relative coordinates was optimized for the amplitude and periodicity of the atmospheric turbulence for every night apart. In most cases we treated the trails exposed within 40 seconds dividing them into the parts corresponding to about 0.2 seconds. The centres of the parts were determined with accuracy of ±0.5 pixel because of poor signal/noise relation (this is the drawback of the method). By this means, the differential coordinates of similar-in-magnitude objects were obtained with a mean internal error of ±0.04 arcsec.

A method using informative (mainly peripheral) parts of bright images was applied for different-in-magnitude objects in one field: Jupiter (-2.5^m) with Galilean satellites (4.6^m to 5.6^m), Polar star (2.0^m) with its satellite (9.0^m) and so on. Their differential coordinates were obtained with the mean internal error of ±0.08 arcsec.

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References

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