METHOD FOR EVALUATING THE ASTROMETRIC AND PHOTOMETRIC CHARACTERISTICS OF COMMERCIAL SCANNERS IN THEIR APPLICATION FOR THE SCIENTIFIC PURPOSE

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ABSTRACT. Method for estimating the accuracy of astrometric (rectangular coordinates) and photometric (diameters and magnitudes) characteristics of commercial scanners is proposed and applied. The method is demonstrated using an example of processing of sequential scans of plates, which were exposed with different telescopes and then digitized with resolution of 1200 dpi with several Epson scanners. Scanning operations were carried out in various observatories as part of development of the database of photographic observations for Virtual Observatories (Vavilova, 2012). Errors of studied scanners are equal to $\sigma_{x,\,y} = \pm$ 0.02-0.06px and $\sigma_m = \pm$ 0.015-0.024 mag for astrometry and photometry, respectively.

Key words: virtual observatory tools – astrometry – techniques: photometric – methods: data analysis

1. Introduction

We study the accuracy of commercial Epson scanners in terms of their practical application for astrometric and photometric tasks in astronomy. To capture images of star fields, six types of plates were exposed with six different telescopes:

1. Smidt Telescope (**ST**, 80/120/240) of the AO of the Inst. of Astronomy at the University of Latvia (Baldone), pl. N18103 (ORWO ZU21 + GG13), Exp = 4min, size = 24x24 cm, scale = 72"/mm; Epson Expression 10000XL.
2. Double Wide Angle Astrograph (**DWA**, 40/200) of the MAO of NASU (Goloseevo), pl. N219 (ORWO ZU21), Exp = 13.5min, size = 30x30 cm, scale = 103"/mm; Epson Expression 10000XL.
3. Zonal Astrograph (**ZA**, 12/204) of the RI NAO (Mykolaiv), pl. N4786 (ORWO ZU21), Exp = 20min, size = 24x24cm, scale = 101"/mm; Epson Perfection V750 Pro
4. Normal Astrograph (**NA**, 33/350) of Obs. AI Uz AS (Tashkent), pl. N76, Exp = 60min, size = 16x16cm, scale = 59 "/ mm; Epson Expression 10000XL
5. Wide Angle Astrograph (**WAA**, 12.5 / 170) of AO of T.Shevchenko Kiev National University, pl. NC-397-2, Exp=30min, size=24x24 cm, scale = 120 "/mm, Epson Expression 10000XL
6. Seven Wide Angle Astrograph (**SWA**, 12/60) of Astronomical observatory of Odessa National University, pl. N18303 (ORWO ZU21), Exp=30min, size=13x18 sm, scale = 313 "/ mm, Epson Perfection V700 photo

All plates were scanned sequentially six times with a resolution of 1200dpi in FITS or TIFF format. Conversion of files from TIFF to FITS format was carried out using the package GIMP (www.gimp.org) and package ImageMagic (www.imagemagick.org) (Golovnya, 2010). Processing of scans was performed in LINUX/ MIDAS /ROMAFOT (www.eso.org/sci/software/esomidas) environment by using the original software (Andruk, 2010), which was described in (Yatsenko, 2011, Muminov, 2012, Protsyuk, 2014).

2. Scan repeatability and internal accuracy

To estimate the astrometric and photometric errors of scanners, we made six scans for each of six plates. For all of 36 scans, we found rectangular coordinates X and Y, instrumental magnitudes and diameters for all objects. Then, for each of six plates we obtained averaged scan using six measurements for objects brighter than 14^m. Left part of the Figure 1 shows systematic differences in pixels of the rectangular coordinates Δx, Δy along the X-axis and Y-axis for six consecutive scans relative to the averaged scan. After correcting of systematic errors for each scan relative to the averaged scan, we obtained results, which

are presented on the same figures on the right. Columns 2, 3 of Table 1 show averaged residual errors, i. e. RMS values of differences between rectangular coordinates of objects (X, Y). Columns 3, 4 contain information about internal errors of the magnitudes and the diameter of the object. The expected errors for given angular scale of the plates are shown in the next three columns (in seconds of arc) for the coordinates and image diameters. In the Table 2, we present the astrometric and photometric errors in the TYCHO-2 system for six telescopes.

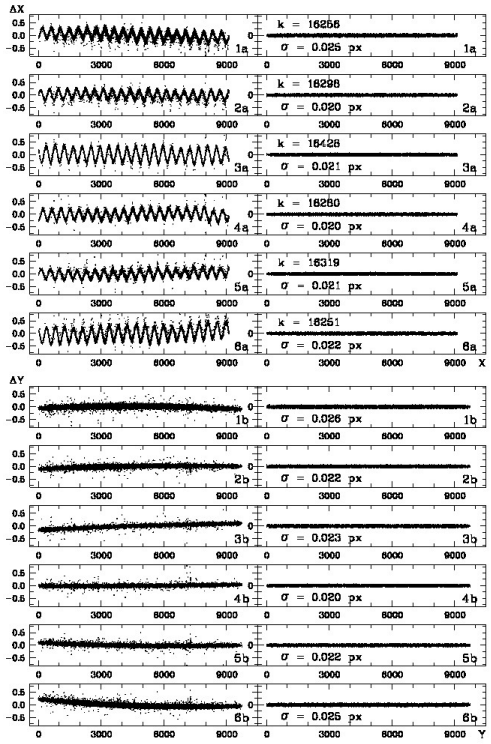

Figure 1. Systematic (left) and random (right) differences of the stellar coordinates ΔX, ΔY along the X and Y for six scans with respect to the averaged scan of one plate obtained with the Smidt Telescope (ST).

Table 1

Tel.	σX	σY	σ_m	σf	σ_α	σ_δ	σ_f
ST	0.022	0.024	0.015	0.030	0.040"	0.044"	0.055"
DWA	0.032	0.035	0.015	0.062	0.069	0.076	0.135
ZA	0.048	0.046	0.024	0.053	0.099	0.099	0.115
NA	0.037	0.039	0.015	0.040	0.047	0.049	0.050
WAA	0.061	0.064	0.030	0.074	0.156	0.164	0.189
SWA	0.029	0.053	0.023	0.059	0.213	0.388	0.432

Table 2

Tel.	σ_α	σ_δ	σ_B
ST	0.094"	0.070"	0.25^m
DWA	0.101	0.103	0.19
ZA	0.083	0.111	0.26
NA	0.113	0.098	0.30
WAA	0.174	0.190	0.26
SWA	0.440	0.375	0.35

3. Evaluation of the reduction accuracy

The accuracy of equatorial coordinates is given on Figure 2. Panels from top to bottom on the left show the systematic differences Δα and Δδ between the measured and TYCHO-2 catalog coordinates in the right ascension and declination (α,δ), which were obtained before the correction of scanner instrumental errors. The results of reduction of the measured coordinates after taking into account instrumental errors of scanner and aberrations of telescope optics are shown on the right panel.

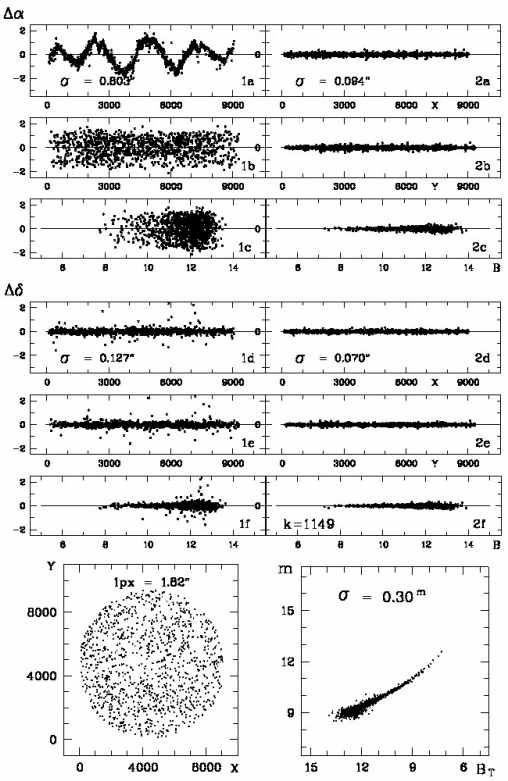

Figure 2. Systematic (left) and random (right) differences between measured and catalog coordinates Δα and Δδ. At the bottom of the left – the distribution of TYCHO-2 stars on the plate field, on the right – the characteristic curves of plate.

4. Conclusion

Epson scanners and developed software allow us to digitize, process plates and obtain astrometric characteristics of objects with an internal accuracy better than $\sigma_{\alpha\delta} = \pm 0.1$" for plates with angular scale up to 2.5"/px at a resolution of 1200 dpi. Internal accuracy of the determination of the magnitudes is $\sigma_m = \pm 0.025^m$.

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