Astrometric tests based on data from Event-Based Sensor camera

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Monitoring of artificial earth satellites is an important task, because the amount of active satellites and space debris is constantly growing, which increases the risk of collision, and in the long term will significantly hinder the use of the most popular orbits. Optical observations are a cheaper alternative to other expensive tracking systems based on radars or laser ranging. Due to the high temporal resolution, EBS cameras have the potential to use them in observations of artificial Earth satellites. Especially in the area of detecting and tracking satellites in low orbits. We present novel algorithms of astrometric measurements designed specifically to analyze the EBS data stream. The basic variant uses only x,y positions recorded by the camera, the advanced version is also using timing data of each individual event. The algorithm has been tested on real observational data recorded in 2018. The accuracy of position measurements has been estimated at about 1.5 arcesc when using data with a pixel scale of 7 arcsec/pix.

1 Introduction

Event-Based Sensor (EBS) - is a type of camera inspired by animal vision mechanisms that only record significant changes in the image. The output of these cameras is a non-synchronous data stream containing information about changes in light intensity at individual pixels along with the time of their recording. Thanks to this the data occupy less memory than traditional solutions consisting of a large number of frames per second and can be processed quickly even in real-time. One type of EBS cameras - Dynamic Vision Sensor (DVS) - is being developed by the Sensors Group from the Institute of Neuroinformatics, as a result of cooperation between the University of Zurich and the Swiss Federal Institute of Technology in Zurich (Lichtsteiner et al., 2008). The first astronomical application of EBS cameras was a series of tests to check usability in SST observations, which gave positive results for observations of satellites ranging from LEO to GEO (Cohen et al., 2017). Following that the first astrometric measurements based on EBS camera were performed with successful star field identification (Cohen et al., 2018). Another contribution to evaluating the usefulness of EBS cameras in astronomy is a comparison of the magnitude limit of DVS camera and classic CMOS camera, in this tests, DVS (EBS camera) showed 4 times lower sensitivity (Zolnowski et al., 2019). It is worth to note that no existing EBS camera is equipped with either passive nor active cooling.

2 Observations

Test observations of Pleiades were made using a 90mm f/5.5 telescope and a BSI-DAVIS camera (Taverni et al., 2018), published by Zolnowski et al. (2019) see Tab. 1.

Tab. 1: Summary of camera parameters BSIDAVIS. Parameters marked with (DVS) are defined as in Lichtsteiner et al. (2008)

	BSIDAVIS
Pixel array	346x260
Pixel size	18.5x18.5 μm
Peak QE	92%
Minimal threshold (DVS)	15 %
Dynamic range (DVS)	>120 dB

3 Astrometric tests

To perform astrometric analysis a dedicated program - aedat2fits - was created to convert the EBS data stream into a series of FITS images. Afterward, a standard astrometric analysis of recorded stars was performed using the Poznań Satellite Software Tools package. Comparing catalog positions to those derived from observations we estimated astrometric accuracy presented in the next chapter.

4 Results

In Fig. 1 we present estimated astrometric accuracy for two data collection ("exposure") times when starfield was moving with an angular speed of $15''$/s. Longer data collecting time resulted in improved accuracy (Right panel of Fig. 1) perpendicular to the movement direction. In Fig. 2 we present estimated astrometric accuracy when starfield was moving with a high speed of $480''$/s and $960''$/s, simulating observations of a low Earth orbit satellite. Gaps in the data result from the lack of enough reference stars.

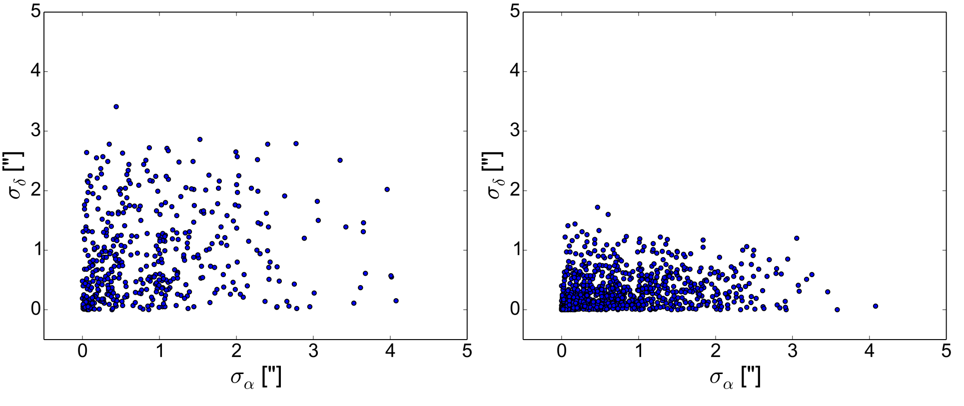

Fig. 1: Comparison of uncertainty in right ascension and declination for the movement of the telescope at a speed of $15''$/s. σ means the deviation of the determined position from the catalog position, respectively for each of the coordinates. Length of compared data collection times equals 0.25s and 5.0s respectively for the left and right panel. Longer intervals mean more stretched traces of objects in the right ascension, which is accompanied by an improved determination of the position in declination.

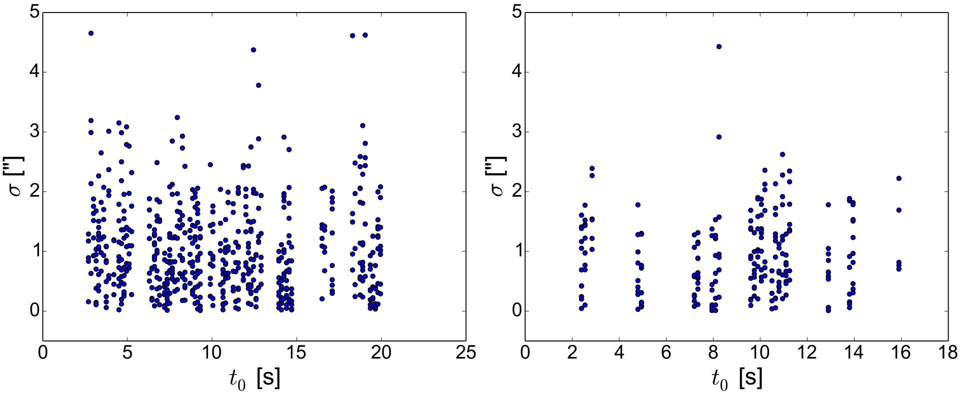

Fig. 2: Uncertainties for the telescope's various speeds. In the graphs, t_0 marks the beginning of the selected interval in seconds from the start of the observation, σ deviation from the catalog position. Apparent speed of stars movement equals $480''$/s and $960''$/s respectively for the left and right panel. Clear gaps are due to the lack of comparison stars in the field of view to identify the field.

5 Summary

Astrometric tests show that using tested hardware configuration one can perform relative astrometry with an accuracy of 1.5 arcsec. The main factors limiting the camera's accuracy are: not optimal image scale for astrometry, a complicated pixel structure of the EBS camera and short seeing averaging time. The analysis showed that EBS cameras are an interesting alternative to conventional cameras, especially when observing very fast-moving objects such as artificial satellites because they offer greater time resolution with a smaller data stream sent to the computer. At the present stage, however, the use of these cameras in astronomy is limited by the small size of the detectors and the lack of active cooling in available models, causing considerable noise.

References

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