9th IAA Planetary Defense Conference – PDC 2025
5-9 May 2025, Stellenbosch, Cape Town, South Africa

IAA-PDC-25-04-103

NEO DETECTION USING IMAGE STACKING METHOD IMPLEMENTED IN CELESTIAL COORDINATES

Diana Haritonova[1], **Ansis Zarins**[1], **and Augusts Rubans**[1]
[1] *Institute of Geodesy and Geoinformatics, University of Latvia, Raina Blvd 19, Riga, LV-1586, Latvia, +371 67034777, diana.haritonova@lu.lv*

Keywords: *Frame Stacking, Astrometry, Image Processing*

Abstract

We propose the method of CCD frame stacking, which is implemented in a celestial coordinate system and has several advantages for NEO detection and tracking. The software package used in this study was developed at the Institute of Geodesy and Geoinformatics of the University of Latvia. Observation results were obtained using the twin 41-cm telescope system.

I. INTRODUCTION

In this work the methodology of astrometric processing is presented. We propose the method of frame stacking, which is implemented in celestial (equatorial) coordinates. This method allows to prolong the “effective exposure time” of near-Earth objects (NEOs), increasing the efficiency of capturing faint objects. Additionally, it can be realized using CCD frames obtained via several optical systems simultaneously or at different epochs.

II. METHOD

Stacking of CCD frames is quite common practice in astronomical imaging. It is usually done by comparing patterns on frames or directly overlying images and requires images obtained via the same telescopes and in similar circumstances. As all the summed pixel intensities contain a random noise component, stacking leads to a relative decrease in the noise level (up to a factor of 1/√N), resulting in better contrast of the target object.

The proposed use of equatorial coordinates allows stack frames, which have different epochs, scales, distortions and framing.

The method requires an astrometric solution for all involved frames, i.e., transformation from image (pixel) coordinates to equatorial coordinates. The stacked image is generated in a rectangular coordinate system, with coordinates of right ascension and declination. The outline of frame stacking process is shown in Figure 1.

Thus, implementation of this approach ensures the possibility to combine frames obtained at different epochs and using different optical systems. It allows to increase the brightness of NEOs in situations, where circumstances such as weather, astroclimate, hardware capabilities, specific locations, force to put up with short exposures, small sensors and bright sky background.

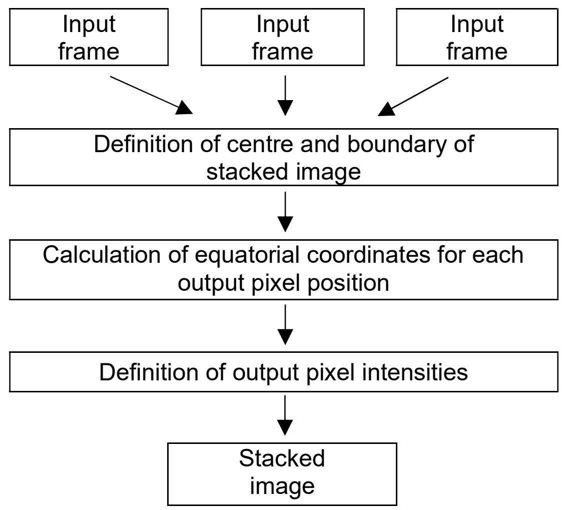

Figure 1: Outline of the proposed method of frame stacking.

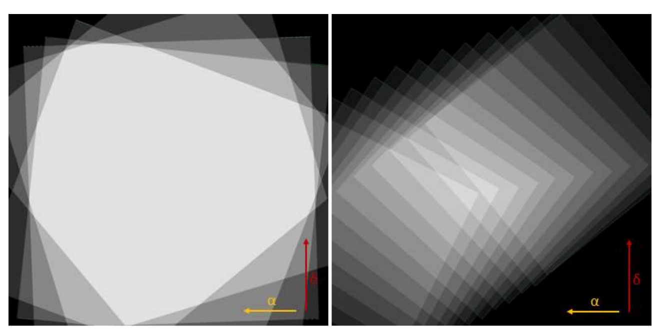

Figure 2: Frame outlines in stack coordinate system. Two cases of observation: slow-moving asteroid (left) and fast-moving NEO (right). CCD matrix ensures FOV of 0.5° × 0.5°. As the mount is not of equatorial type, rotation of FOV is present.

III. RESULTS

In Figure 2, the orientations and overlaps of the frames are shown for two cases of observation. In the case shown on the left, a slow-moving asteroid was observed.

This is a stack of 25 frames obtained in star tracking mode during a 5-hour period in 5 batches (5 frames per batch). The proposed method of frame stacking increases the brightness of the asteroid within one session (batch) with a set of consequent images with relatively short exposure (5-s exposure is used) and provides the trajectory of its movement during the entire observation period, as shown in Figure 3.

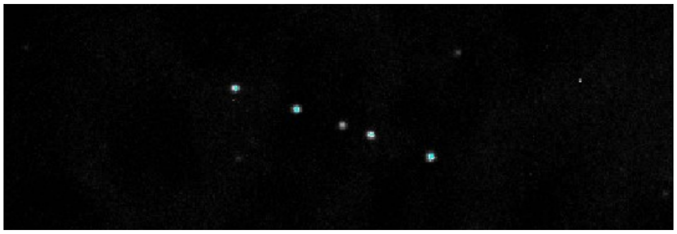

Figure 3: Stacked image obtained using 25 5-s frames (the case is shown in Figure 2, left).

In the case shown on the right in Figure 2, a fast-moving asteroid was observed. Due to the speed of this asteroid (and local astroclimate as well), it is not practically visible on a single frame, and stacking doesn't lead to detection of it, as shown in Figure 4a (6 frames are used).

To detect such NEOs, frame stacking must be performed by applying a shifting technique. The results are shown in Figures 4b (6 frames are used) and 4c (23 frames are used). This is realized using a shift, which corresponds to the speed of the observed NEO.

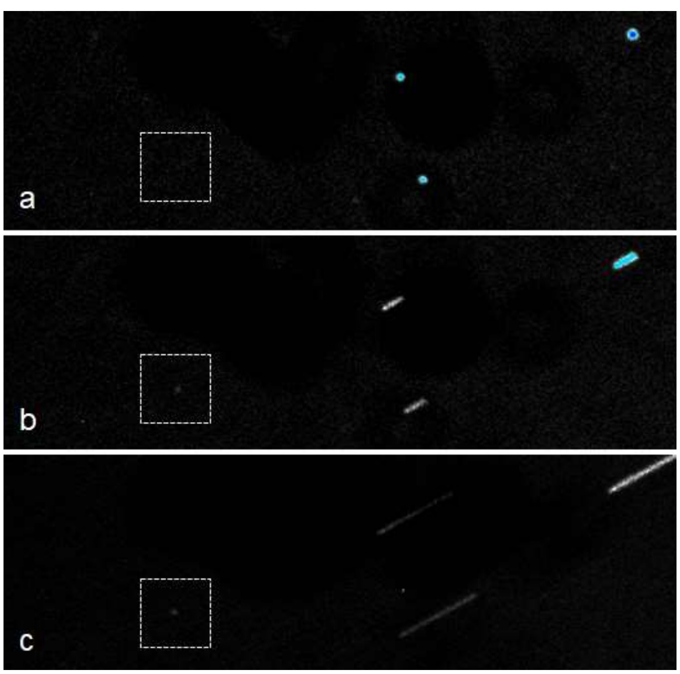

Figure 4: Stacked images with fast-moving Apollo-class asteroid 1999 VF22: a) 6 frames are stacked without shifting; b) 6 frames are stacked applying shifting; c) 23 frames are stacked applying shifting.

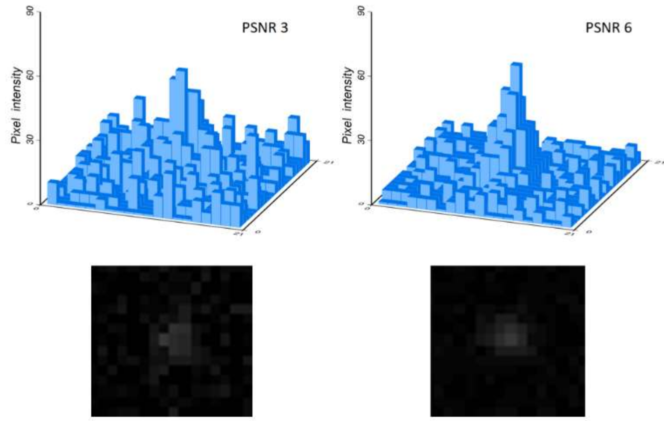

Figure 5: Pixel intensities and PSNR values for the stacked images shown in Figure 4b (left case) and 4c (right case).

Pixel intensities and PSNR (peak SNR) values for the stacked and shifted images are given in Figure 5. The data indicates an improvement of PSNR for a factor of 2 if 23 frames are stacked.

To increase the brightness of unknown small and fast-moving NEOs (if NEO speed is unknown), the proposed method can be very effective, ensuring combination of CCD frames, which are obtained using several telescopes simultaneously (with similar technical parameters). In the case where input frames obtained using telescopes with different technical parameters, the question of differentiating the weights of input data in the stacked image arises. More experimental results obtained via different optical systems are needed to evaluate this.

IV. CONCLUSIONS

In this study, the new method for astronomical imaging – the method of CCD frame stacking in equatorial coordinates, is presented. It has several advantages in detecting NEOs and can be adapted for various observation strategies. The main strengths are the ability to increase the brightness of faint NEOs using also small sensors and the ability to combine frames obtained via multiple optical systems simultaneously, ensuring the detection of small and fast-moving NEOs.

More results obtained using different optical systems and their combinations are needed to fully evaluate the effectiveness of the proposed method.

ACKNOWLEDGMENT

The research is financed by the Recovery and Resilience Facility project "Internal and External Consolidation of the University of Latvia", No. 5.2.1.1.i.0/2/24/I/CFLA/007.

Valuable support was given by MikroTik and the University of Latvia Foundation in the procurement of a new CCD matrix and focuser. Project No. 2283.