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Accurate Near-Earth-Asteroid Astrometry using Synthetic Tracking and Applications

Chengxing Zhai (1), Michael Shao (1), Navtej Saini (1), Russell Trahan (1), Philip Choi (2) and Kutay Nazli (2)
(1) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, (2) Pomona College, Claremont, CA, USA (chengxing.zhai@jpl.nasa.gov)

Abstract

Synthetic tracking is a powerful technique of detecting fast moving Near-Earth-Objects (NEOs) and generating accurate astrometry. With the Gaia catalog, we are able to demonstrate 10 mas level NEO astrometry using ground-based optical observations, compared to stellar astrometry. Accurate astrometry is crucial for NEO orbit determination, which allows us to better predict the chance of a collision with the Earth, to catalog newly discovered asteroids, and to characterize physical properties of the asteroids by measuring non-gravitational acceleration. Here we present the accurate NEO astrometry achieved using the synthetic tracking technique and how accurate astrometry improves NEO orbit determination as well as discuss potential applications.

1. Introduction

Synthetic tracking technique avoids streaked images of the moving object by taking short exposure frames, which is enabled by modern sCMOS cameras that are capable of outputting megapixel frames with rate faster than 10Hz and yet low read noise ~ 1-2e-. This allows us to replace the traditional 30-second exposure image for surveying asteroids with multiple short exposure images to "freeze" the moving asteroids and still be limited by sky background. We integrate the short exposure frames in post data-processing with flexibility to simulate tracking on any rate by shifting the frames accordingly (Fig. 1).

When searching for unknown objects, the moving rate is not known in advance, so we carry out integration of the short exposure frames and look for significant signals for a grid of velocities covering the range of rates of interest. GPU aided computing is typically used in speeding up this process of searching. Synthetic tracking improves detection sensitivity by avoiding streaked images of moving object --- the trailing loss [1], [2]. For follow-up observations of newly discovered asteroids, we already know the rate, so the frames can be integrated without requiring an exhaustive search.

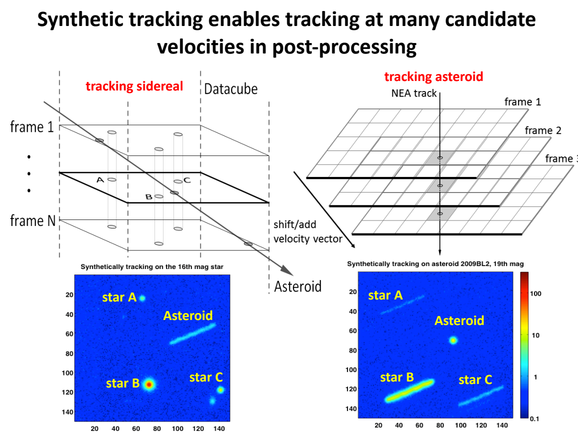

Figure 1: This chart illustrates the synthetic tracking post-processing to track reference stars (left) and the asteroid (right).

In addition to the improved signal-to-noise ratio of detection, synthetic tracking also yields accurate astrometry of the moving object because we can track both the target and reference objects (Fig. 1). Synthetic tracking completely avoids the need of estimate location of a streaked image, thus avoids degradation of signa-to-noise ratio and ensures the effect due to atmosphere or telescope pointing jitter to be common between reference and target objects, which would not be true if either reference or target objects are streaked [2], [3].

2. Applications

Accurate NEO astrometry yields accurate NEO orbit, which is important for multiple reasons. First, it helps better determine the chance for a potential collision of a potentially hazardous asteroid (PHA) with the Earth. Second, for newly discovered NEOs, it is very crucial to determine their initial orbits accurate enough so that there is no confusion at their next apparitions. This is particularly important for small NEOs whose observation window could be only a week, much shorter than three weeks, typically required for cataloging a NEO. We expect more accurate astrometry enables us to determine orbit with shorter arc of observations. In fact, to the first order this should scale as the square root of the accuracy in view of the dominant signal beyond a linear motion is quadratic in time.

Another application is to infer physical properties by measuring non-gravitational acceleration of NEOs due to solar pressure or Yarkovsky effects. Finally, future spacecraft will carry optical communication lasers for higher bandwidth, making them artificial stars. The ground optical communication terminal can track on the laser signals while communicating with the spacecraft. This allows us to measure the spacecraft position in sky plane for navigation optically.

3. Summary and Conclusions

Synthetic tracking produces accurate NEO astrometry by avoiding streaked images. Accurate NEO astrometry helps to improve the NEO orbits for better predicting the chance of impacting the Earth of PHAs, cataloging newly discovered fast moving asteroids, measuring non-gravitational acceleration to infer physical properties, and offering potential for optical navigation of future spacecraft.

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References

[1] Shao, M., Nemati, B., Zhai, C., et al : Finding Very Small Near-Earth Asteroids Using Synthetic Tracking, ApJ, 782, (2014).

[2] Zhai, C., Shao, M., Nemati, B., et al : Detection Of A Faint Fast-Moving Near-Earth Asteroid Using The Synthetic Tracking Technique, ApJ, 792, 60, (2014).

[3] Zhai, C., Shao, M., Saini, N., et al : Accurate Ground-based Near-Earth-Asteroid Astrometry using Synthetic Tracking, Astronomical Journal, 156, 65, arXiv:1805.01107, astro-ph.IM, (2018).