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(Re)linking the Past: A Second Look at NEAT

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Abstract

The Near-Earth Asteroid Tracking (NEAT) survey operated from 1995 to 2007. NEAT was one of the first surveys of its kind, and discovered 41,227 minor planets, and reported observations of 258 comets [9].

Despite the landmark achievements of NEAT, it was limited by the technology of its era. Therefore, we are reprocessing archival NEAT data [8] with modern technology. We expect that this reanalysing will increase NEAT near-Earth Object (NEO) detections by >150%.

To complete this reprocessing, we are building asteroid-linking software. This software takes cleaned detections and assembles them into tracklets for Minor Planet Center submission. There are several methods of linking asteroid detections described in the literature [2, 3, 5, 6, 7], but none of the code is freely available. We will publish our software on GitHub, making it open-source, when this project is complete.

1. NEAT

NEAT was one of the first automated systems for detecting NEOs, and images from the NEAT survey are routinely still used for precovery of new object discoveries [1]. The program consisted of a remotely controlled telescope that surveyed the sky, collected wide-field images, and analysed the data for NEOs. Each portion of the sky was subject to three 20 second exposures, 15 minutes apart [10].

NEAT's asteroid detection software was designed for efficiency in order to enable timely follow-up observations. Each analysis unit (consisting of three exposures of the same field of view) took between 2 and 10 minutes to run, and four analysis units could be analysed concurrently.

In order to achieve such output rates, NEAT's data processing pipeline was conservative in their detection of asteroids. For example, their object finding subroutine, STARCAT, identifies objects consisting of 2x1 contiguous pixels that have count rates that are larger than 3 sigmas over the local median. The NEAT subroutine TABEDIT removes object clusters, defined as more than one object in a 20 pixel radius, because these clusters were assumed to be diffraction spikes around bright stars. The linking subroutine, NEOFIND, limited the observation linkage parameter space by assuming mostly non-accelerating motion, as well as imposing an angular speed limitation of $0°.15\ \text{day}^{-1} < \omega < 6°\ \text{day}^{-1}$.

2. Reprocessing NEAT

Our detection linking software is a Python-based program that also incorporates Find_Orb, an orbit determination program by Bill Gray [4]. The bulk of the program identifies plausible tracklets based on exposure-to-exposure object movement. The program runs through all possible combinations of observation linkages and identifies plausible tracklets based on pre-defined criteria. These plausible tracklets are then fed through Find_Orb, which fits an orbit to each of them. A tracklet is accepted if Find_Orb's orbit fit gives a residual that is below a threshold; this threshold can be adjusted.

This linking software is designed to be used with the NEAT asteroid detection pipeline designed by the Nugent Lab at Olin College. By the linking stage, the pipeline will have point sources extracted using Source Extractor, astrometry calibrated with SCAMP, background stars removed, and potential asteroids identified using machine learning. Point source extraction allows us to overcome NEAT's original pixel resolution limit, while machine learning allows us to classify potential asteroids without having to eliminate objects based on clustering. Furthermore, since we are working with archival data, we are free of the time constraints in data processing that is typically placed on detection software used with active surveys. Therefore, we are able to cast a wider net on NEOs, and we expect to see an increase in detections as compared to the original NEAT results. An additional benefit to reprocessing the NEAT archive is recalibra-

tion of its photometry and astrometry using data from the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS). We will be submitting the re-analysed data in Astrometry Data Exchange Standard (ADES) format, which will allow us to also contribute photometric and astrometric uncertainties.

As there is currently no open-source linking software available, we hope that by making our entire pipeline open-source, our work has a greater contribution beyond new asteroid detections from NEAT. By allowing the pipeline to be available for all, especially smaller observatories and citizen scientists, we hope that we can increase asteroid detections on a broader scale.

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