An Efficient Approach to Minor Planet Recovery, Detection, and Characterization Using N-body Integration and the Probabilistic Hough Line Transform

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Advances in the field of planetary science, particularly concerning our own solar system, have been dramatic over the last few decades. However, with these copious amounts of new data comes a need for more effective methods of analysis. This project offers a solution to the issue by presenting an efficient Python-based approach to aid with the detection, recovery, and characterization of minor planets in the solar system (asteroids, trans-neptunian objects, Kuiper Belt objects, etc.). The work utilizes data from the DES and DEEP surveys to accomplish the following: 1) recovery/orbit enhancement of known minor planets 2) detection of 22.0-25.0 magnitude objects and 3) object characterization (light curve generation, rotational period analyses). First, an extensive database of known minor planets is used to obtain orbital elements for all bodies. Orbital elements are evolved using an N-body symplectic integration scheme. Evolved elements are used to predict minor planet positions at the time of the exposure(s). Computed celestial positions and positional uncertainties allow for objects to be matched to single epoch detections. New object detection is achieved by approximating intra-night trajectories as straight lines. The probabilistic Hough line transform, a modified version of the standard Hough transform (edge detection using random sampling), is used on coadd catalog of object detections as an efficient line detection algorithm. Finally, detected/recovered objects are characterized through light curve generation, by extracting V-band magnitudes from SQL database of detections. More complete object characterization requires period determination of produced light curves. For this, an efficient version of the Lomb-Scargle periodogram is utilized.