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Developing a Recurrent U-Net for Faint Trans-Neptunian Object Detection Using Synthetic Injections

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Trans-Neptunian Objects (TNOs) are small, distant bodies beyond Neptune that provide important context on the formation and evolution of the outer Solar System. However, the faintest TNOs are difficult to detect because their weak signals can be easily confused with noise and subtraction artifacts. Manual identification of genuine TNOs is therefore a time-consuming process that can require hours of careful inspection. To automate the process, this project develops a recurrent U-Net framework for identifying faint moving sources, with particular emphasis on generating realistic and well-characterized training data. A synthetic injection pipeline, maketensor, was developed to implant artificial TNOs directly into real difference-image observations. Each source is propagated across multiple exposures with physically motivated apparent motion and injected using the point-spread function corresponding to each observation. The underlying noise, stellar residuals, detector features, and other observational artifacts are preserved to keep the training data authentic. The pipeline also reproduces characteristic subtraction effects and negative wells, allowing the synthetic objects to more closely resemble real TNO signatures. The resulting multi-frame tensors contain real observational backgrounds with exact ground-truth locations and trajectories for every injected source. These sequences are used to train a recurrent U-Net to produce pixel-wise probability maps that identify likely TNO locations across a sequence of exposures. By learning the consistent motion of a TNO across successive frames, the network aims to distinguish genuine moving sources from noise and image-subtraction residuals, enabling faster and more reliable detection of faint TNOs in large astronomical datasets.

Did you give a contributed talk at CASCA 2026?

No

If you are selected for a poster, would you be interested in giving a short flash talk on your work?

Yes

What is your career level?

Undergraduate

Which keyword describes the area of focus of this talk?

Solar System

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