

# Convolutional Neural Networks to Improve the Discovery of Near-Earth Asteroids in the Zwicky Transient Facility



Paper link

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## Context

With its extremely large field of view of  $\sim 47$  square degrees, which scans the entire northern sky every two nights, the Zwicky Transient Facility (ZTF) is a powerful tool for serendipitous detections of near-Earth asteroids (NEAs). This effort aims to both discover new NEAs and refine the orbital information of known objects, anticipating and mitigating future dangerous collisions. We present a novel pipeline for ZTF images that uses a convolutional neural network (CNN) to improve the detection capability of NEAs. Our work aims to minimize the dependency on human intervention of the current approach adopted by the ZTF, described in Duev *et al.* (2019). The target NEAs have high proper motions of up to tens of degrees per day and thus appear as streaks of light in the images.

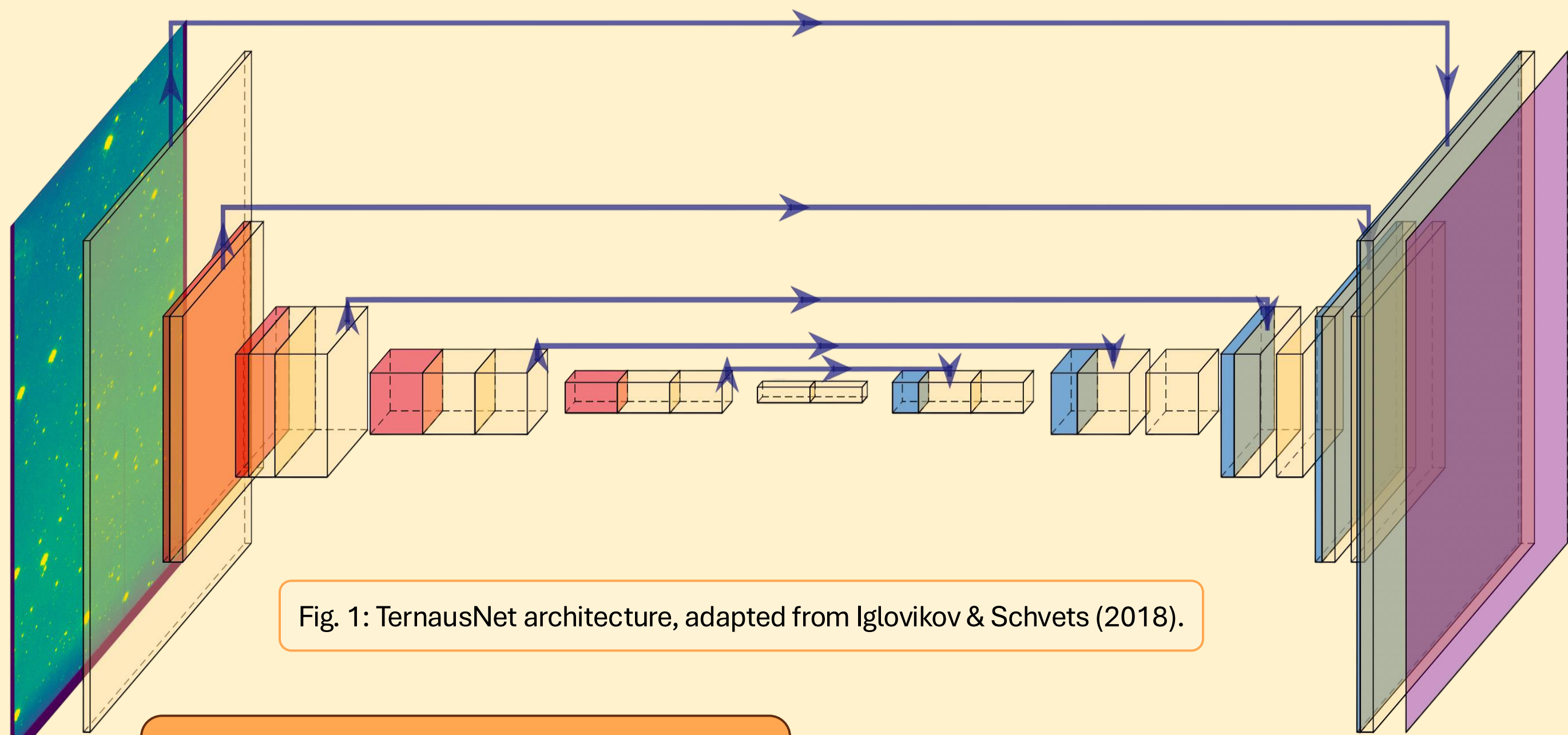


Fig. 1: TerausNet architecture, adapted from Iglovikov & Shvets (2018).

## Methodology

For the main detection stage of our pipeline, we used a CNN tailored explicitly for object segmentation, TerausNet. The CNN would input a wide-field image and output a detection probability map. The exact endpoints of the candidate streaks detected were found using an MCMC algorithm. For the training, three datasets were used: a set with 450 real asteroids, a set with 20 000 synthetic asteroids, injected into the real images, and a set containing a mix of synthetic and real asteroids. To test the performance of the CNN trained on the different datasets, the completeness and precision on a test set of real streaks were evaluated. In addition, we compared the performance of our pipeline to that of the human scanners who vet ZTF candidate streak detections by analyzing a larger set of images containing 317 streaks flagged as valid by the scanners.

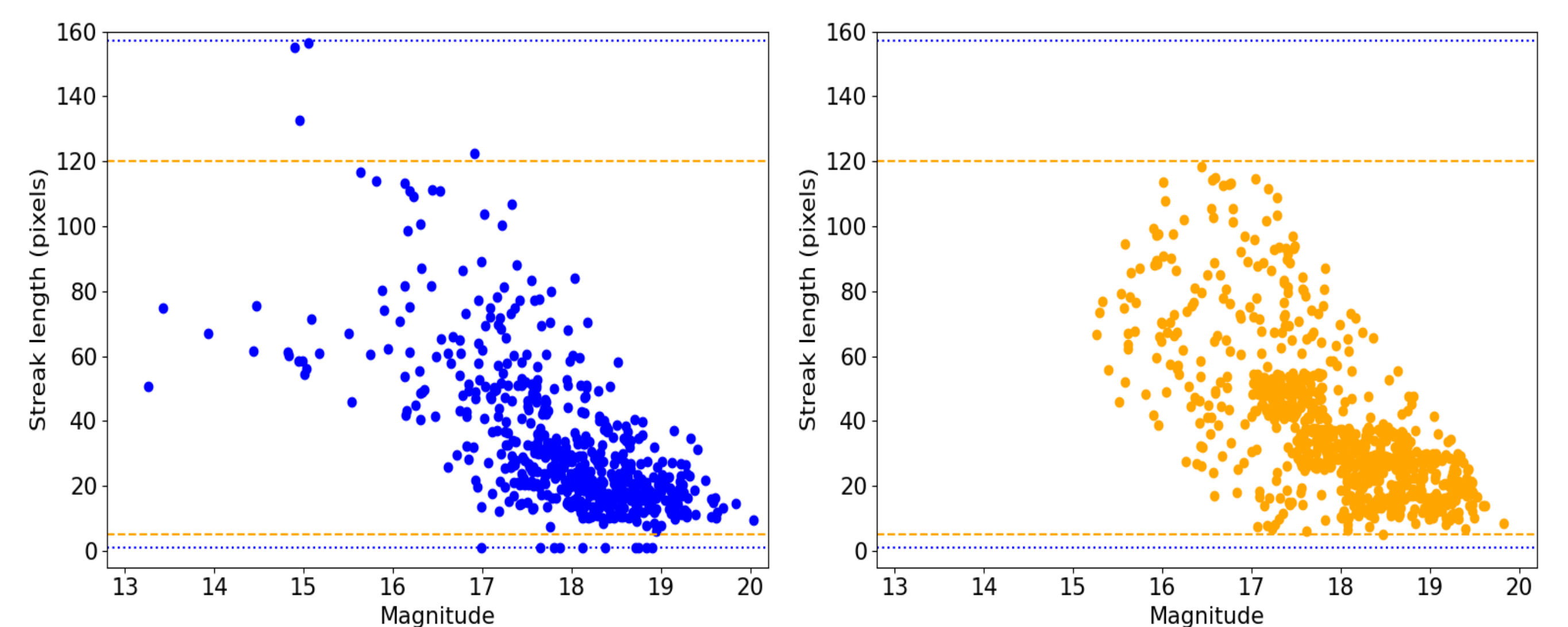


Fig. 2: Distribution of the real (left) and synthetic (right) asteroid population used for training.

## Results

The results were almost identical across the three models:  $0.843 \pm 0.005$  in completeness and  $0.820 \pm 0.025$  in precision. The bias on streak measurements reported by the CNNs was  $1.84 \pm 0.03$  pixels in streak position,  $(0.817 \pm 0.026)^\circ$  in streak angle and  $-0.048 \pm 0.003$  in fractional bias in streak length (computed as the absolute length bias over the streak length, with the negative sign indicating an underestimation). We compared the performance of our CNN trained with a mix of synthetic and real streaks to that of the ZTF human scanners by analyzing 317 streaks flagged as valid by the scanners. Our pipeline detected 80 % of the streaks found by the scanners and 697 additional streaks subsequently verified by the scanners to be valid streaks.

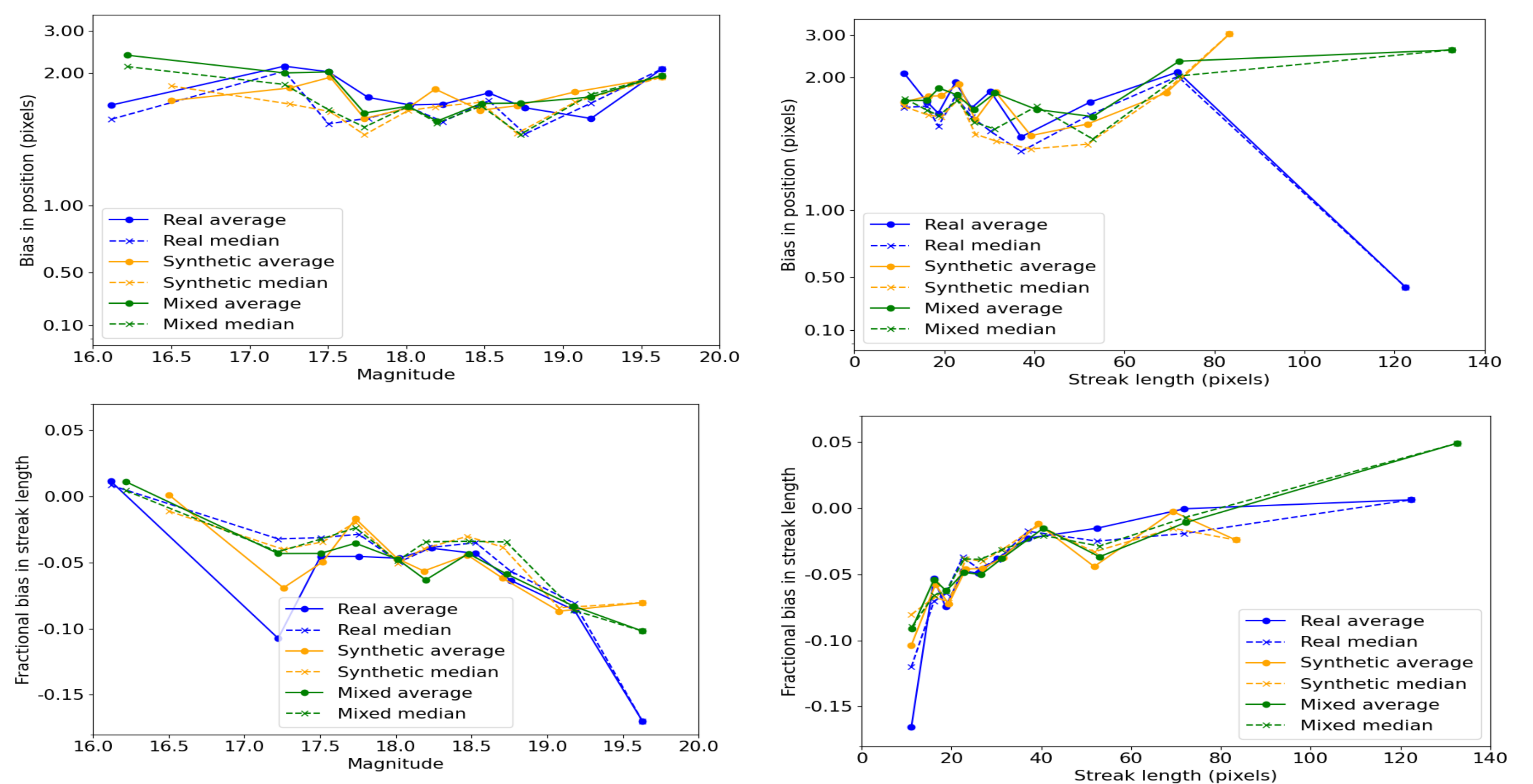


Fig. 3: Detection biases as a function of magnitude and streak length.

## Discussion

Our results indicate that the new automated pipeline can complement the work of the human scanners at no cost for the precision and find more objects than the current approach. They also prove that the synthetic streaks simulated were realistic and can be used to enlarge training sets with insufficient real streaks or explore the simulation of streaks with unusual characteristics that have not yet been detected. Our pipeline not only shows a strong potential to make new findings in the ZTF data but also can be scaled up to other wide-field telescopes, setting the stage for fast and automated NEA discoveries in the next generation of astronomical surveys.

## Future Work

Future work will focus on enhancing the pipeline with photometry capability and analyzing the new detections to verify whether they belong to asteroids in the MPC database. This will further test the effects of introducing synthetic streaks and help identify trends in the characteristics of the new detections. We aim, with this work, to improve our ability to foresee any future NEA impactors.

## References

Duev, D. A., Mahabal, A., Ye, Q., et al. 2019, Monthly Notices of the Royal Astronomical Society, 486, 4158  
Iglovikov, V., & Shvets, A. 2018, arXiv preprint arXiv:1801.05746

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