A Two-Stage Deep Learning Detection Classifier for the ATLAS Asteroid Survey

National Science Foundation Research Experiences for Undergraduates

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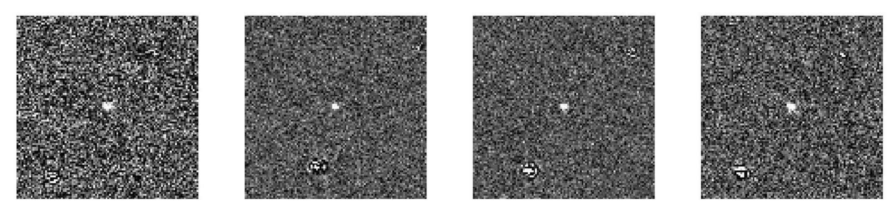
Introduction

The “Asteroid Terrestrial-impact Last Alert System” (ATLAS) is an all-sky survey system for detecting near-Earth objects and gathers new data every night on the order of 10^7 images. Several detections of an astronomical source at different times form a tracklet which is the fundamental unit of all post-processing done by ATLAS. However, several types of electronic and optical artifacts cause false detections in the system which means experts have to manually go through incoming tracklets and confirm them before sending them to the Minor Planet Center. The goal of this work is to use deep learning to reduce the amount of NEO candidates that experts have to comb through.

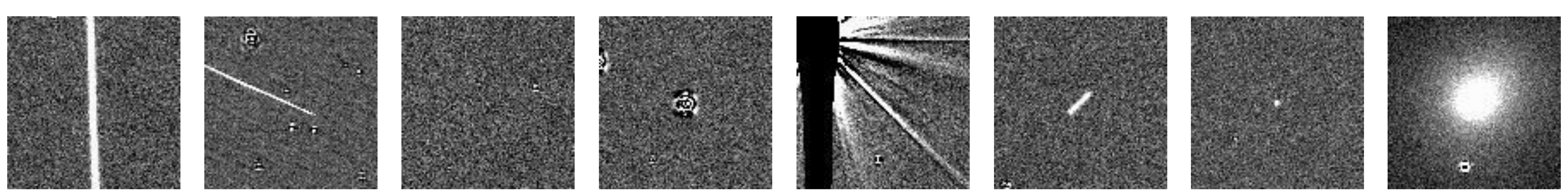
Example tracklet of asteroid (4700) Carusi



Methodology

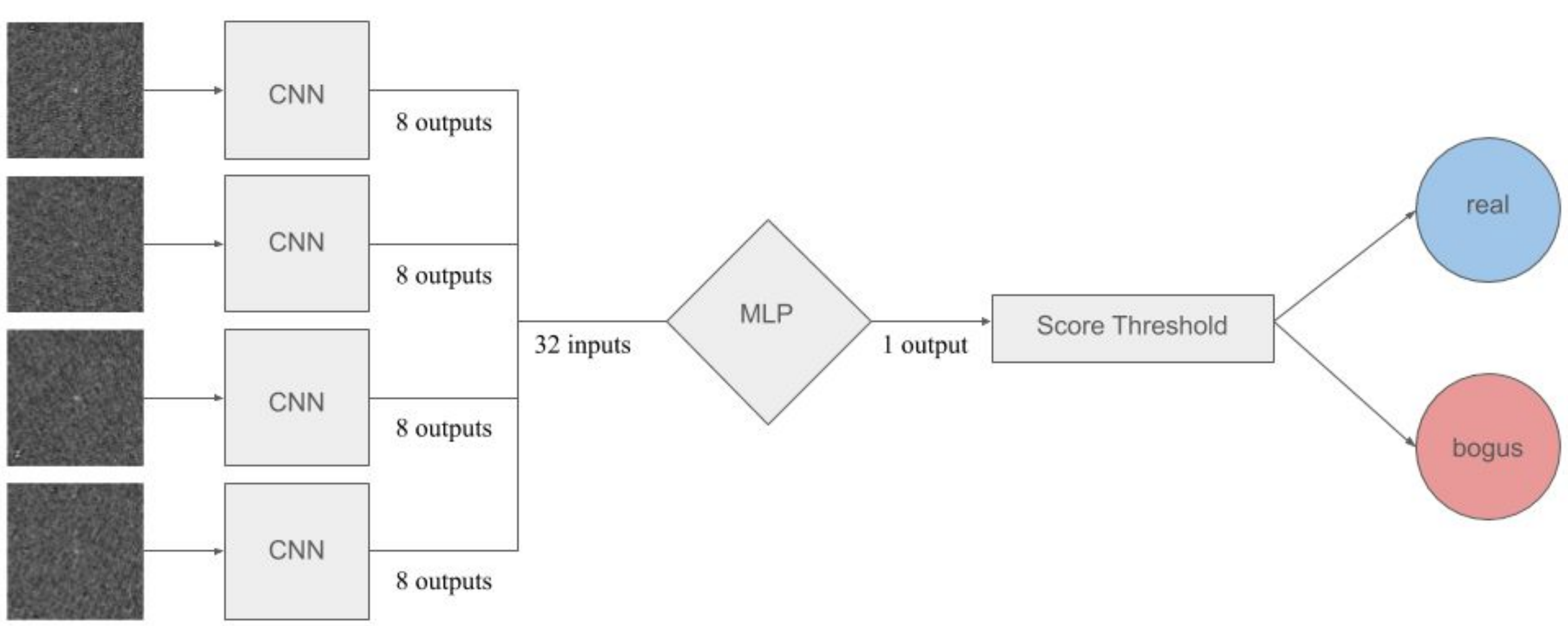
Each image in a tracklet is passed through a Convolutional Neural Network (CNN) and 8 confidence scores for 8 different image types (classes) are generated. The 8 classes represent almost all the type of images that can be found in a tracklet. Burns, cosmic rays, noise, scars, and spikes represent false detections that are not caused by a moving astronomical source. Streaks, asts, and comets represent image types that that experts would report to the Minor Planet Center because they contain eitehr a comet, satellite, or asteroid. TA pre-trained resnet-18 architecture was finetuned using a curated data set of 3,500 images.

Training classes



burn cosmic ray noise scar spike streak ast comet

A Multi-Layered Perceptron (MLP) takes the confidence outputs of the 4 images in a tracklet as an input. The outputs is a single value prediction of whether the tracklet contains a moving astronomical source (real) or not (bogus). A threshold of 0.9 was used to determine whether the tracklet is real or bogus (e.g. prediction of 0.6 is bogus). The MLP was trained on month of ATLAS tracklets from May 5 to June 4 2020.



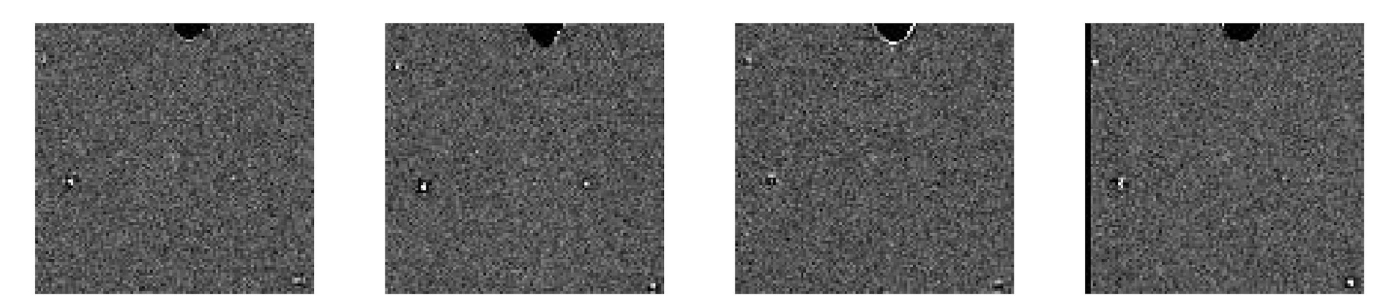
Results

The model was tested on 30 nights of ATLAS data from June 5 to July 5 2020. The model successfully classified almost all real tracklets which minimized the false negative rate (742 out of 183,198 real tracklets). From these results we can deduce that on an average night of ATLAS data, this model would reduce the amount of tracklets experts have to check by 89.1%. In light of these achievements, the model has been fully deployed on ATLAS and is currently undergoing an evaluation phase where astronomers can opt into using the data set generated by the deep learning model.

	Predict Real	Predict Bogus
Real Tracklet	182,456 (99.6%)	742 (0.4%)
Bogus Tracklet	2,688 (9.1%)	26,800 (90.8%)

A qualitative analysis of the false negative tracklets shows that the model often classifies faint asteroids as noise. Additionally, some nights contain rare artifacts and other image types that are not represented by the 8 classes the CNN was trained on.

Tracklet of an unknown asteroid that was classified as noise



Conclusion

In this work we presented a two-step deep learning model for classifying sets of images containing near-Earth Objects and disruptive artifacts. A 99.6% true positive accuracy has shown that the model is extremely consistent on an average night of ATLAS data and can reduce the amount of data experts must check by 89.1%. The CNN’s confidence scores for each image is available due to the structure of the two step model. Therefore, we can identify which of the eight training classes are miss-classified and correct for them with non-machine learning rules. This would further boost the robustness of the model while taking advantage of deep learning

Acknowledgments

This work has been supported by the National Science Foundation Research Experience for Undergraduates and the NASA Planetary Defense Coordination Office under grant 80NSSC18K0284.