Searching for Near-Earth Objects in NASA WISE and NEOWISE Data Using Our Own Deep Neural Network

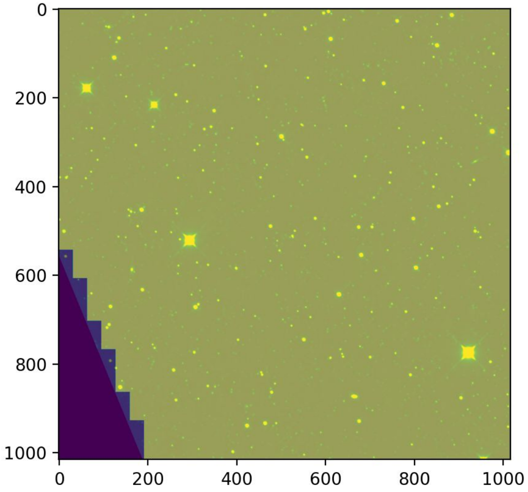
HS-MAPH-110-T2

Introduction

- There have been numerous discoveries of Near Earth Objects (NEOs) in the night sky over time, yet there are still many more to be found.
- Our goal is to use machine learning to identify NEOS that may have been missed within NEOWISE and WISE data.
- NASA's space telescope during the NEOWISE mission produce images in 2 electromagnetic wavelengths. The images are currently scanned by the NEOWISE Moving Object Tracklets, which identifies moving NEOs by connecting chains of identical objects in photos taken close to each other.
- Because of the way the NEOWISE team designed their framework, the NEOs they could find were primarily very bright and large.
- Their system only would identify NEOs that had been observed at least 5 times, and weren't obstructed by another object in the background (i.e. a star).
- This project aims to build a neural network that can detect the faint NEOs that may have been missed, analyzing the W1 infrared band images in the catalogue.

Methods

- A region of the sky is picked that is not within the Galactic Bulge (the Bulge makes the backgrounds of images noisy)
  - ra dec: 194.593101, -9.096606
- One “coadd” image and “single exposure images” that overlap are downloaded
  - Single exposure: a picture of the sky taken at one instance like a snapshot, Coadd: an image produced by averaging many single exposures together so that the noise is gone
- Software is used to align codes and single exposures since they are not already aligned.
- The realigned coadds and single exposures are split into 32x32 images.
  - We chose 32 because we needed the model to be accurate but not take forever to train so it was a medium sized image.



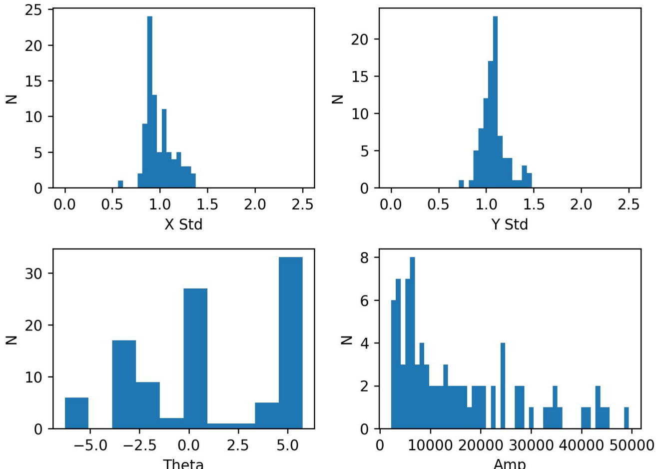
All graphs and plots taken by student researcher with image data supplied by WISE Image service https://irsa.ipac.caltech.edu/applications/wise/

(Above) In yellow: parts of the coadd that were used to slice into 32x32 sub-frames
In dark purple in the bottom left corner: parts of the coadd that didn’t align with the single exposure after alignment

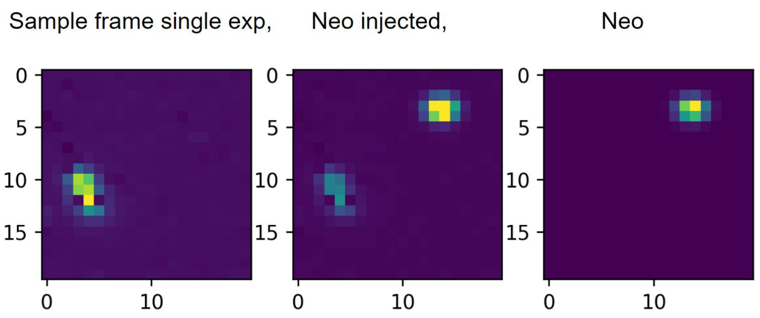
Methods contd.

- Half of those images are injected with artificially made NEOs
  - Artificial NEOs are made with measurements collected from measuring real NEOs collected from the NASA WISE database
  - Outliers are removed since they are produced primarily when the measurement code fails
- Images with no Neos and images with artificial Neos are training data for the neural network
- After training, we used Tensorflow’s built in functions to calculate accuracy

Plots of measurements from real NEOs

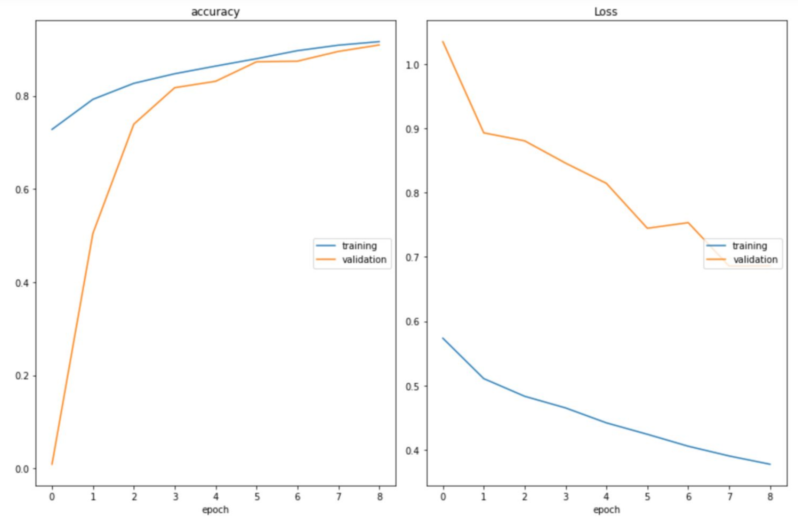


Neo Injection Process



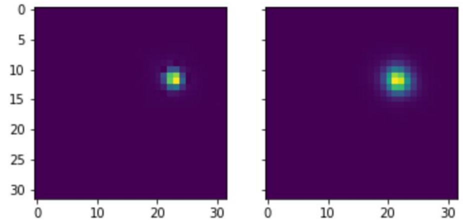
Results

- We made a 3 separate datasets to test the accuracy of the model
  - All synthetic NEOs, all images without NEOs, a selection of images containing real Near Earth Objects
- Most recent optimized model has good accuracy for all three tests, all meet the original goal of greater than 90% accuracy
  - No NEOs test accuracy: 0.9022, Synthetic NEOs test accuracy: 0.9786, Real NEOs test accuracy: 0.9474
- The model predicts a number 0-1 that shows whether it think it is a NEO (1) or does not contain NEOs (0)
- Ran the model on the NEOs testing dataset to scan for potential candidates



Current best model that takes in 2 separate images: a coadd and a single exposure

Results contd.



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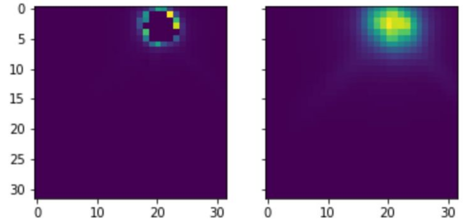

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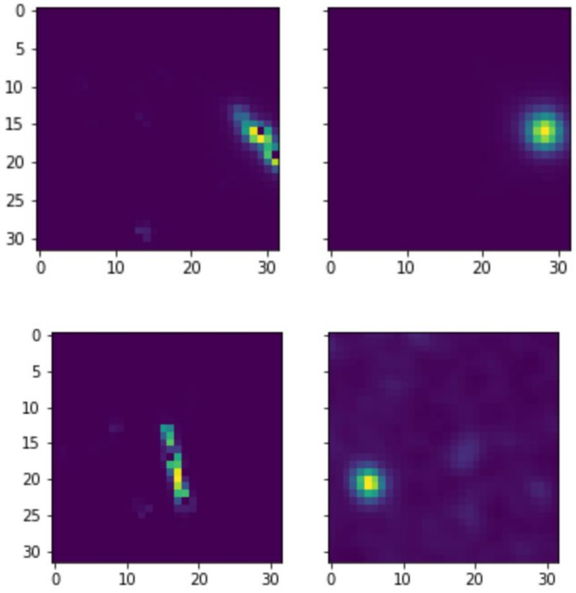
2 frames that were classified as NEOs when they were not (single exp left, coadd right)

Several of false positives were produced.

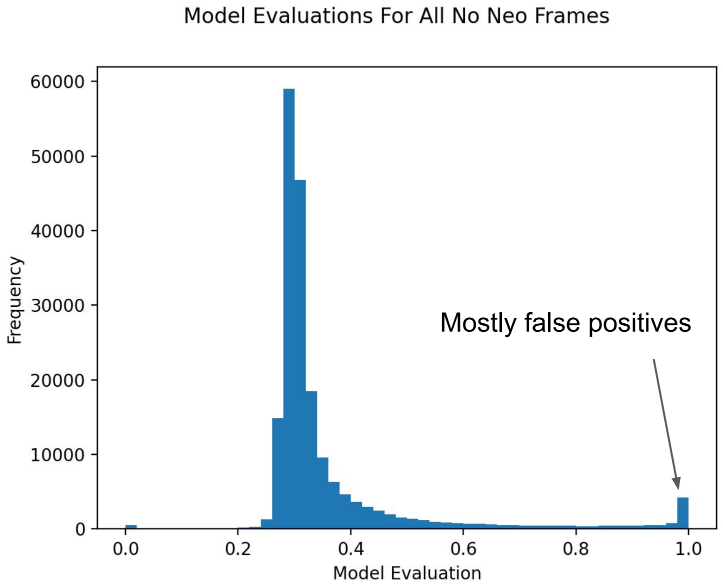
A few potential NEO candidates were found (below)



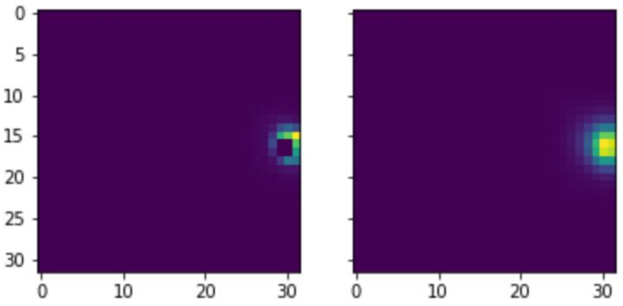
- There is a possibility that they are "streaks," fast-moving NEOs that become stretched when the camera exposure is too long
- These could also be artifacts or glitches in the single exposure data

Discussion

- The results regarding accuracy from all 3 tests showed that the model had good accuracy.
- When the model is asked to identify that the frame has no NEO in it, it is less accurate, which indicates that it has tendencies to generate false positives
- The brighter stars in single exposure data are so bright that the centers are NAN values instead of having a proper brightness value
  - Causes a “donut” shape that will create false positives for the neural network sometimes, needed to add more data so that the model can understand that the donut shapes don’t count as missing stars



Single exposure contains star so bright that the middle pixels are NANs, creating the “donut”



Discussion contd.

- One of the largest problems that we wasn't expecting was how different the single exposure and coadded images would look like
  - Single exposure has much more noise and defected pixels → makes it harder for the model to distinguish NEOS and removes information
  - Instead of subtracting the coadd and single exposure, we worked around this by making a neural network that instead analyzed the coadd and single exposure separately
- Our model design is unique in that it compares coadds to single exposures separately without the methods used in previous NEO finders like the NEOWISE Moving Object Tracklets
  - Doesn't rely on merging images together

Conclusion

- The project turned out pretty well, however there is still a lot more that can be done.
- The accuracy is good, but the model produces several false positives.
- So far, our programs searches a single square of the sky.
- Searching a larger region of the sky will improve the chances of finding good NEO candidates since there that covers more area.
- The model accuracy can also be improved with more data from other regions of the sky
- This work of this project has many important outside applications such as finding harmful NEOs that can be detrimental to life on Earth.
- Moreover, discovering new asteroids and other moving objects expands scientific knowledge on the solar system and is key to finding out the detailed origins of the solar system.

References

- *NEOWISE Documentation* - wise2.ipac.caltech.edu/docs/release/neowise/expsup/sec1_5.html
- *Moving Object Search Tool Instructions* - irsa.ipac.caltech.edu/applications/MOST/instructions.html
- INITIAL PERFORMANCE OF THE NEOWISE REACTIVATION MISSION - iopscience.iop.org/article/10.1088/0004-637X/792/1/30
- THE WIDE-FIELD INFRARED SURVEY EXPLORER (WISE): MISSION DESCRIPTION AND INITIAL ON-ORBIT PERFORMANCE - iopscience.iop.org/article/10.1088/0004-6256/140/6/1868
- *DeepStreaks: identifying fast-moving objects in the Zwicky Transient Facility data with deep learning* - arXiv:1904.05920 [astro-ph.IM]