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APPLICATION OF MACHINE LEARNING FOR PLANETARY DEFENSE – Three Case Studies

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ABSTRACT

The emergence of GPU enabled machine learning has unlocked a range of opportunities for the development of new tools and approaches for Planetary Defense. NASA's Frontier Development Lab (FDL) was established to explore the possibilities offered by the application of convolutional neural nets, Bayesian, deep generative models, machine vision and other AI techniques to asteroid shape modeling, defection efficacy and meteorite hunting. We present three projects conducted at the FDL in 2016 an applied research accelerator designed to enhance NASA's capability set by matching emerging talent from academia with peers and technologies within the private sector.

1. Meteorite Hunting.

Fireball tracking networks have been established around the world, tracking meteors to determine a source orbit and an impact target region. But to date only 31 meteorites have been found that can be linked to a source orbit. The problem is that Meteorite searches in target regions can require hundreds of hours to possibly find one fresh fall.

The NASA FDL team applied machine learning to design an autonomous drone to find meteorites in the field. The team built 25,000 training images of meteorites and incorporated six deep learning models, along with a 15 million image library, to build a prototype of an automatic meteorite detection system, all driven by a user-friendly app for use in the field.

2. Accelerated NEO Shape Modeling.

Modeling the shape of an asteroid using radar is a labor intensive process, requiring long computer runs and about 4 weeks of human guided iterations to get one asteroid shape. Asteroid shapes are critical for asteroid deflection techniques - as any mitigation plan needs to know the three-dimensional form. Should an object be too close to shift, shape is critical for understanding the potential for damage and planning effective disaster response.

The FDL team attacked two parts of the problem with deep generative networks (3D-VAE) and bayesian optimization, reducing the search for the asteroid shape and spin axis to a few hours of computing, achieving better results than 3 weeks of work by one of the world's experts.

This approach enables a rapid determination of the shape of an asteroid - while it is still being tracked by radar, even as an incoming object.

3. NEO Deflector Efficacy

Up until FDL, the effectiveness of NEO deflection techniques (such as nuclear, kinetic and gravity tractor) had been studied analytically, but the community lacked a tool that could be used autonomously compare and predict the efficacy of specific techniques.

The FDL team built a tool that uses a machine learning to analyse the effects of 1.5 million simulated deflection missions, and determine which methods were the most effective based on several initial parameters (such as warning time before impact, asteroid mass, orbit, etc).

This approach of using machine learning to explore the parameter space of asteroid deflection techniques provides a new tool to inform on the deflection technologies that should be prioritised, and what asteroid characteristics are the most important to be known in advance to select the most appropriate mitigation strategy.

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