Exploring CNNs for Space Object Classification

Carson Hunsberger Nicholas Cotton

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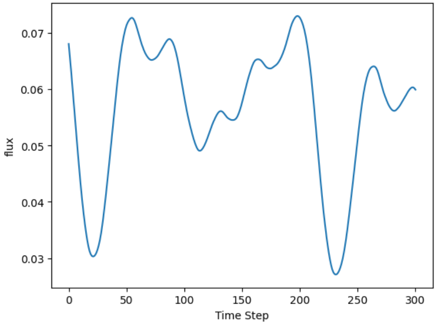
What is a Space Object?

- A Space Object(SO) is any entity or object in space, including:
  - Rocket Bodies
  - Space Debris
  - Satellites
  - Natural Celestial Bodies (Asteroids, Comets)
- SOs can vary is size, shape, and orbital characteristics

What is a lightcurve?

- A lightcurve is a way to represent variations in brightness over time
- Lightcurves are the data objects used to study SOs and their behavior
  - From lightcurves we can reveal orbit, rotation, eclipses, etc.
- A single lightcurve takes on the form of a vector $L \in \mathbb{R}^n$
  - n is the number of timesteps
  - Each component L_i is the observed flux at timestep i



Importance of Classifying SOs

Situational Awareness (SSA), the monitering of objects and events in space, has become of critical to preventing the loss, disruption, and/or degradation of space capabilities and service

- The classification of SOs is crucial to SSA for:
  - Collision Avoidance
  - Space Traffic Management
  - Satellite Safety

Inverse Lightcurve Problem

- Given observed Lightcurve data we want to infer the properties of SOs

InverseLightCurveProblem

Let $L = [L_1, L_2, \ldots, L_n]$ be an observed lightcurve.
Let M be a function that maps an unknown set of parameters SO_θ representing the physical properties of a SO to another vector $\hat{L} \in \mathbb{R}^n$ s.t.

$$\hat{L} = M(SO_\theta)$$

We seek SO_θ s.t. $\hat{L} \approx L$

Challenges in Finding Solutions to the Problem

Some challenges to finding solutions to this problem are:

- Solutions are not unique as a set of SOs may lead to similar matches in modeled and measured lightcurves
- Uncertianties in measurements and modelling can yield large variations in our solutions

For these reasons, we consider a data driven approach

- We design a Deep Neural Network (DNN) to learn the inverse relationship between Lightcurves and SO properties

K-Nearest Neighbor (K-NN)

The current method for lightcurve classification. Computationally expensive...

Why CNNs?

For Lightcurve Classification, CNNs offer a number of benefits over other methods

- CNNs are less Computationally expensive
- Convolutions are great for picking up subtle features in data.
- CNNs are very well studied for other classification problems so it seems natural to apply it to our problem.

An Overview of CNNs

Our lightcurve data is 1-dimentional and so we define CNN layers in 1 dimention.

My balls itch

Let x be a vector in $\mathbb{R}^n$

Our Model

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