Ewan Saw

BSc Project Progress Report

Title: Haze formation in Titan's upper atmosphere
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Supervisor: Ravindra T. Desai
Assessor: Jonathan P. Eastwood

Week 1 & 2

We carried out some literature review in this part of the project by reading over materials provided in the reading list:

- Mihailescu et al., (2020): Spatial variations of low mass negative ions in Titan's upper atmosphere.
- Desai et al., (2017): Carbon Chain Anions and the Growth of Complex Organic Molecules in Titan's Ionosphere.

This allowed us to identify the main goals of the project as well as the next steps be taken.

Week 3

Goals:

Following the initial couple of weeks, the goals for this week involved learning the fundamentals of neural networks as well as familiarising ourselves with the external python library for neural networks (Keras):

- Read through some documentation for Keras / learn the basics
- Demonstrate a simple prediction of linear and quadratic functions using a linear regression model

Results:

My partner Rayan already had some previous experience working with neural networks, hence he was able to create a simple linear regression model with ease.

Instead, I spent an extra week to familiarise myself with the techniques and material as we went into the following week of the project.

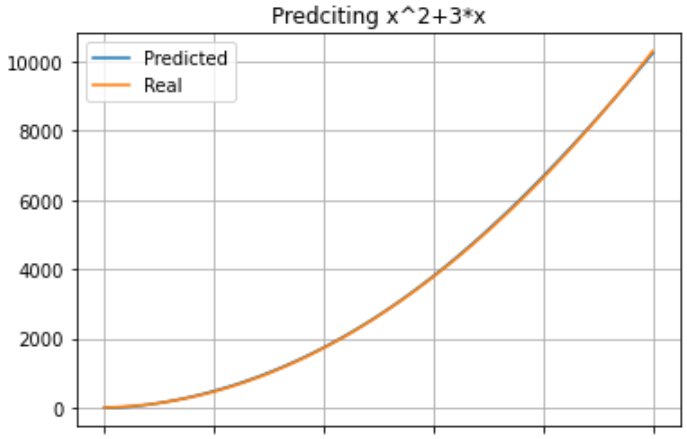

Figure 1: Prediction of a quadratic function which is validated as it lines up with the true function.

Week 4

Goals:

This week involved modifying the simple model created previously in order for it to work with the processed Cassini data which we intend to analyse and predict. By adding a Long short-term memory (LSTM) layer of 50 nodes, and a Dense layer of 1 node, we trained this model using 80% of the data (chosen at random) and used it to predict the remaining 20% and compared the results.

Results:

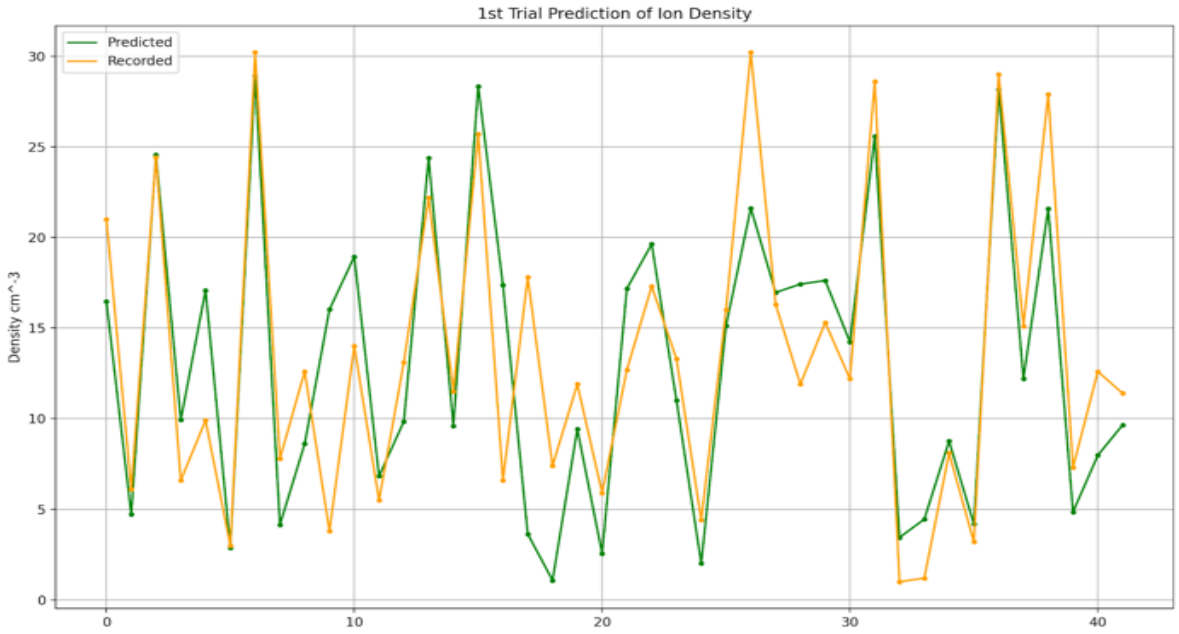

Figure 2: 1st Trial prediction of Ion Density using our model, comparing our prediction (green) to the recorded data (yellow).

The results obtained from our first trial prediction was able to capture majority of the peaks and troughs represented in the data. From this point onwards, we needed to adjust our model (varying the activation function, number of layers & nodes) in order to improve our predictions.

More literature review would be required in order to learn how to better optimise our model, as well as review of Titan's atmosphere to better understand the data & results.

Week 5

Goals:

In this week, my partner and I worked separately. He worked on:

- Improving the prediction accuracy of the model
- Converting the spatial variables of the data into a periodic function, such that the model would recognise the periodic nature of coordinates on a sphere.

I then worked on using the model to produce a contour map of the predicted ion densities at different altitudes, in terms of longitude and latitude.

Results:

Upon discussing our results we found:

- We were able to significantly improve the prediction accuracy by adjusting which variables to include in training the model (namely electron density & electron temperature).
- By fitting the spatial variables into a periodic function, more extreme predictions such as predictions of negative ion densities from the model was reduced.
- A Random Search algorithm was also implemented to find an optimal combination of hyperparameters that reduces prediction error

Using 100% of the data to train our model, we used it to predict the Ion density of Titan at various altitudes and produced contour maps of the results.

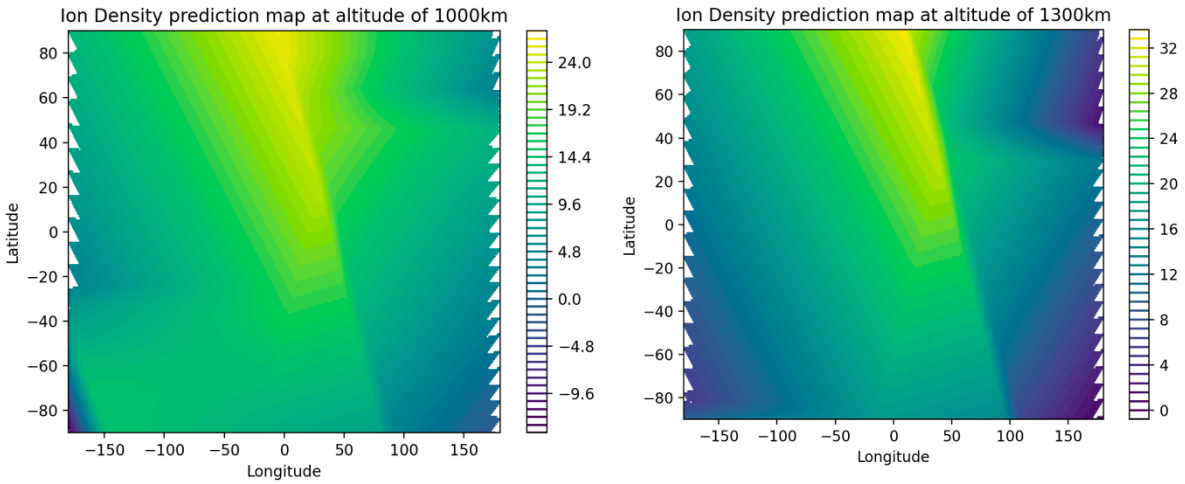

Figure 3a & 3b: Initial contour maps of the predicted ion densities at altitudes of 1000km and 1300 km respectively.

Given Figure 3, there are a couple of noticeable issues with our predictions:

- The contour map at 1000km altitude predicts negative ion densities, which are unphysical. As Rayan and I have yet to combine our code over this week, his improved model parameters should be able to correct for this issue.
- We have yet to introduce a factor of 0.25 which corrects for the efficiency of the detector, which gives rise to the high magnitudes of ion densities in our prediction.

As such, the goals for the following weeks are to account for these errors and to continue experimenting with different numbers of neurons/ activation functions / training times to improve the neural network. It was also suggested that we slice our predictions to plot contours of altitude against latitude. This should be achieved by the following week.