PATH PREDICTION FOR AN EARTH BASED DEMONSTRATION FLIGHT

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The project involves an extremely interesting proposition of Path Prediction for an Earth-based Demonstration Balloon Flight, with a hope that someday the same could be utilized on Titan, Saturn's largest moon.

Saturn's moon Titan has been revealed by the Cassini-Huygens mission as an exotic world, unlike any other, but with some uncanny similarities to the Earth. The Cassini orbiter radar penetrating the ubiquitous Titan haze layer has revealed vast expanses of equatorial sand dunes and high latitude seas believed to contain liquid methane and ethane. This is one of the reasons why Titan is of such great interest amongst scientists.

The idea of this project is to demonstrate that a balloon can autonomously navigate in the Earth's atmosphere (where we are familiar with the wind patterns) and thus hopefully show that it might be possible to do the same on Titan (for which we currently possess very limited knowledge about atmospheric conditions).

The project will use 2 components to assist in this - the WRF (Weather Prediction & Forecast) model - developed at NCAR (National Center for Atmospheric Research) – and the MANGEN software - created within Caltech.

Using the WRF model, wind fields will be obtained, which will, along with the MANGEN code, be used to calculate LCS (Lagrangian Coherent Structures). MANGEN (MANifold GENerator) enables one to easily load velocity data sets (obtained from WRF) - which will be used to quickly initiate FTLE (finite-time Lyapunov exponents) calculations and computation of LCS. Using the LCS computed and optimization tools such as DMOC (Discrete Mechanics and Optimal Control), it shall be seen whether it is possible to get from one particular point to another point of interest, and if it is - what is the most optimal trajectory to follow. The MANGEN code enables us to track the path taken by different tracers from their release points. This will help to ascertain and predict the optimal path to be followed for particular start and end points.

One of the mainstays of this project is to apply LCS (Lagrangian Coherent Structures) in a fresh way to atmospheres - the way it is applied to ocean currents. This involves the use of inputs from WRF.

The very first step will, thus, be obtaining wind fields in which the path followed by the balloon shall be predicted. The WRF model will provide the wind fields. Thus, at present, I am working in the Geology and Planetary Science Department, learning how to use the WRF model to simulate wind fields.

I began with familiarizing myself with WRF and LINUX operating systems. I have, thus far, downloaded and installed WRF successfully and have run a test simulation to familiarize myself with its operation and various parameters. I ran a test simulation involving the winter storm in the United States in January, 2000. Once the WRF model was run successfully for this test case, I analyzed the WRF output using MATLAB. The changing wind pattern with time was analyzed, along with changes in pressure at different times.

The Earth based simulation flight will, tentatively, be held in the Mojave Desert. Thus, it would be best to check for optimal trajectories using wind field data from the Mojave Desert. Thus, for my next simulation, the area of interest is within the Mojave Desert. I am currently running a Mojave Desert simulation (of two week duration). I shall analyze the output files generated to get a feel for the wind pattern and weather conditions in the Mojave. Once wind field data from the Mojave Desert for the desired day and time has been obtained, I will use it, along with MANGEN code, to compute LCS.

In the next one month, I will try and use the wind fields to compute and then analyze the LCS generated, applying optimization tools such as DMOC to calculate optimal trajectories. I will try to use this method to analyze various different situations, using wind field models from different times, different days, different altitudes, etc. to make the tests robust and to obtain reliable results. Beyond that, if time permits and results are favorable, I will attempt to evaluate the relative benefits of adding extra control features to the balloon - such as the ability to change altitude, for example, or to install sensors - with the ability to sense winds in a vertical column or within a particular radius - which might help the balloon get back on track in case it deviates from its path.

An ensemble of experiments with different starting conditions will be performed to analyze the effect of changing wind field patterns. We will explore the uncertainty due to the natural and expected weather variations, in the WRF wind field, e.g. by looking at results for the same starting location and time but different days. Also, the effect of initial conditions on the path prediction results will be looked at, e.g. by starting a multitude of balloons at slightly different times and locations. We will, thus, explore the effect of different initial conditions on the final position of the balloon.

In order to continue my research, I will need the MANGEN software in addition to the WRF software that I already have. I will also need to use optimization tools such as DMOC to calculate optimal trajectories. I will need an understanding of how optimization methods such as this work and how to apply it to optimize the path taken by the balloon. The optimization I am interested in is optimization for least power consumption as opposed to optimization for least time taken.

I hope to be able to achieve a lot within the next month. I plan to perform an ensemble of experiments for path prediction with various different conditions. Hopefully, my research will give me conclusive and favorable results. If it is possible to use only local wind fields to predict optimal paths to reach our desired destination, I hope to be able to analyze additional control features as mentioned before. The project is highly interesting and may provide a very useful and practical method for a balloon to be able to navigate on Titan, in the future. I look forward to continue working on my project and hope to come out with positive results.

REFERENCES

- http://www.lekien.com/~francois/software/mangen/

- http://www.wrf-model.org

- http://saturn.jpl.nasa.gov/science/moons/moonDetails.cfm?pageID=16

- http://147.162.229.1/project/hasi/welcome.html

- http://www.cds.caltech.edu/~shawn/LCS-tutorial

- http://gc.caltech.edu/public/Titan_SURF.