Real time position estimation of a rocket for tracking

The rockets launched by the Carleton Rocketry Team (CuInSpace) collect telemetry from on board sensors, included are a gps, a barometer, an IMU and a magnetometer. Alongside the student built solution a commercial solution is present as a backup for data validation. The rockets provide real time telemetry over low frequency radio to the on-ground personnel, who point a receiving antenna towards the rocket to get a higher quality signal. The manual steering of the antenna is daunting and flawed, a nominal flight is estimated to last about 10 minutes, which is a considerably long time if you have to hold a 1kg weight up to the sky, beyond that, 5-10 seconds in the flight the rocket breaks the cloud line, making the operators lose line of sight and consequently lose telemetry.

The objective for this project is to find a way of approximating and predicting the position of a rocket so that a motorized antenna tracker can follow it in real time. The tracker receives downlink telemetry infrequently enough that heavy approximations have to be used, such approximations can be modelled via artificial intelligence.

Position estimation can be implemented via a Kalman Filter, a special case of Bayesian inference that assumes Gaussian distributions and dynamically adjusts gains. Kalman filters are heavily used in industry for guidance, navigation and position estimation based on noisy or infrequent sensor measurements. Several types of Kalman filters, such as Extended, Standard and Unscented, will be evaluated. For the current system the Kalman filters will be used to predict geographic coordinates and altitude of the rocket, in addition there is a potential to predict spin and inclination.

The data collected by CuInSpace, in addition to publicly available amateur flights, can be used to test the proposed implementation. An artificial time delay will be added to the data to simulate time taken for the telemetry to reach the rocket tracker. CuInSpace is in possession of 1 nominal and 1 exploded mid air flight dataset recorded at about 100hz each; public sources such as rocketry forums contain hundreds of additional datasets, usually in the range of 10-100hz.

The system will be evaluated by having the train split consisting of a downsampled version of the telemetry (1-5hz) and the test split being the full speed telemetry, downsampling will happen by averaging the data points through variable intervals, providing a sort of cross validation. The mean square error between predicted and observed positions will be calculated and plotted for a variety of downsampling rates. An initial constraint can be put in place that dictates that the estimation shall not be more than 50 meters away from the target, on average.

This project is as unique as it can get. The only other attempts I'm aware of are made by the ETS and uOttawa rocketry teams, although I have no knowledge on their method of choice for position estimation. If successful, this research will be integrated by CuInSpace in a fully fledged tracker and used in national and international high powered rocketry competitions.

Timeline:

- Week of Nov 4: Research Kalman filter theory and implement Standard Kalman Filter
- Week of Nov 11: Implement Extended and Unscented Kalman Filter variants with parameter optimization
- Week of Nov 18: Run validation experiments across multiple flights and downsampling rates
- Week of Nov 25: Analyze results, document code, and prepare demonstration
- Week of Dec 2: Complete final report and polish implmentation

The project will be completed by a single individual