GNSS Interference Domain Detection using Stochastic/Population Methods

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Problem and Motivation

Global Navigation Satellite System (GNSS) serves several safety-of-life applications in aviation such as precise navigation for landing operations, collision avoidance, and Air Traffic Control (ATC). However, GNSS signals can be subject to various types of interference that lead to a signal quality degradation or even complete loss. Losing GNSS signals on approach or landing could be catastrophic. To address this issue, the goal of this project is to design a system that can quickly detect the existence of GNSS interference events and identify the corresponding interference domains.

Approaches

In this project, we will be using data collected from aircraft Automatic Dependent Surveillance—Broadcast (ADS-B) systems during some historical interference events. Stochasticity is present in this problem due to external variables (signal blockage by terrain, equipment error, environmental noise, etc.). In addition, it is difficult to obtain gradient/derivative information about this problem.

Therefore, we decided to test and see if Stochastic/Population Methods can be applied to this problem. These methods can help improve coverage of the design space and increase the chance of searching near global minima. In addition, in order to search and guide towards local minimums, we will use direct methods which do not rely on derivative information.

In this project, we will treat the entire airspace as our design space, and all the aircraft reports as measurements. Aircraft will report low signal-quality values if encountered GNSS interference, and the value will keep decreasing as the aircraft gets closer to the jamming source. We need to identify a model that can best fit the domain of influence such that the difference between estimated signal-quality values and the true signal-quality values is as small as possible. One way is to use cross-entropy methods and try different proposal distributions. Another way is to variate the shape and size of the impact region and find the one that leads to minimum residuals.

Performance Evaluation

To analyze the performance of the approach proposed in the project, a set of metrics should be defined to evaluate the effectiveness of the population methods in identifying interference domains that impact GNSS signal quality. Some possible metrics that could be used to assess the performance of the approach include:

- **Detection accuracy:** This metric measures the ability of the methods to accurately identify interference domains that impact GNSS signal quality. The detection accuracy can be calculated by comparing the identified interference domains with the actual locations of interference.
- **False positive rate:** This metric measures the rate at which the methods incorrectly identify regions as interference domains when they are not. A high false positive rate would indicate that the method is prone to overestimating the impact of interference on GNSS signal quality.

- **True positive rate:** This metric measures the rate at which the methods correctly identify regions as interference domains where the interference does exist. A ROC Curve can also be plotted to show the performance of the model at different thresholds. It plots the True Positive Rate and False Positive Rate against each other.
- **Computational efficiency:** This metric measures the time and computational resources required to identify interference domains using the population methods. A high computational cost could limit the practical applicability of the approach.
- **Robustness:** This metric measures the ability of the approach to perform effectively under various conditions, such as changes in environmental factors or interference sources. A robust approach would be able to consistently identify interference domains despite changing conditions.