GPS Integrity Monitoring

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Abstract

This paper seeks to explore the potential of evolutionary algorithms for determining hard error bounds required for the use of GPS in safety-of-life circumstances.

1 Introduction

The Global Positioning System (GPS) has proved to be very useful in a number of applications. Aircraft navigation is among the most important. But in the safety-of-life circumstance of precision approach and landing, we do not have sufficient guarantees of accuracy. While differential GPS (DGPS) is precise enough much of the time, a controller needs to be able to put strict error bounds on the position estimate in order to be able to use DGPS for precision approach or landing. This paper explores the use of an evolutionary algorithm to determine these error bars.

2 Problem Specification

Rather than solve the "Is it safe to land, or not?" question, I will attempt to answer a slightly more general problem, "What is the worst

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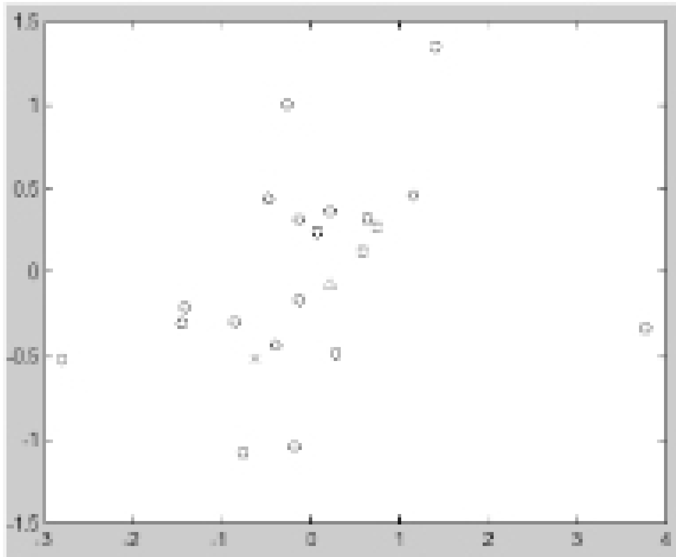

Figure 1: The 2-dimensional projection of the distribution of positions calculated from subsets of the pseudo-ranges. The green triangle is the estimate using all of the pseudo-ranges and the red x is the true position. The axis are in meters.

that the error could be?" Given a set of satellite ranges, we would like to estimate an upper bound on position error. We are allowed to underestimate the bound no more than once in 10 million trials. Simultaneously, one would want the service to be available as much of the time as possible. In other words, we would like to keep overestimation to a minimum while maintaining the strict rule on underestimation.

As the number of satellite ranges available increases, the set of equations that the receiver must solve become increasingly over-specified. The goal is to use this over-specification to generate a number of partially independent estimates of position. The distribution of these estimates can be used to estimate the distribution from which the position measurement (using all satellites) was selected.

Figure 1 shows the two-dimensional projection of the distribution of twenty subset positions. As one might expect, the true position lies within this distribution. Given such a distribution, the goal is to draw the smallest circle that surely contains the true position.

3 Previous Work

I am primarily building on work by Misra and Bednarz[3]. They proposed an algorithm, called `LGG1`, which consists of three elements.

- A method of selecting subsets of satellites with good geometrics
- A characterization of the distribution of subset positions
- And a "rule" function that turns this distribution into an error-bound.

They demonstrated that such an algorithm, if sufficiently conservative, could give an error bound that was sufficiently stringent. If the rule function was a linear function, the error bound was sufficiently stringent regardless of the underlying range error distribution. The recent subject of my research has been testing and improving the algorithm.

I retain all three elements of `LGG1` algorithm but will change each of them. For this work I will be focusing on determining the rule function. I will explore using an evolutionary algorithm to determine a rule function that exploits more expressive characterizations of the subset position distributions.

The original algorithm used a single metric to quantify the distribution of subset positions. The number that it used was the distance between the furthest two positions and they called it "scatter." The rule was a constant times this scatter. Such a rule could be found quickly given a dataset with millions of error–scatter pairs.

4 Current Extention

The current work seeks to explore using a more expressive description of the subset position distribution. We would like to utilize the fact that there is much more information in the distribution than the scatter metric. So rather than characterize the distribution with one