High Precision Attitude Determination using Multi-antenna GNSS Receiver

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Introduction

Satellite positioning has been widely used since the last decade. The arrival of WAAS and other satellite constellation have greatly improved the precision. Another area of research has emerged, using the same GNSS signals, to determine the attitude (3D orientation) of an object using multiple antennas and carrier phase differential.

Here we present the different challenge of the attitude determination.

Baseline Length

Wide antenna separations improve pointing accuracy. But most of the time, large baseline are not convenient (~10m) and can have structural flexibility issues and have a wider search area which degrade the possibilities of using in a real-time environment.

The main advantages of short baseline (2-3 wavelengths) are reduced search area and simpler algorithms. The side effect of such system is it’s noise sensitivity to phase measurements. Noise level is not negligible for short baseline.

Ambiguity Resolution

Although data differencing is useful to have fewer parameters to solve, the number of wavelength cycles between the satellite and antenna, called ambiguity, remain unknown. Ambiguity resolution represents one of the biggest challenge of attitude determination.

Advantages

- Inherently Driftless
- Not as expensive as other high precision systems (ex: INS, Star Trackers) [1]
- Differentiation process remove common errors
- Fewer unknown parameters
- Take advantage of low level noise measurements (compared to pseudorange measurements)
- Can benefit from multi frequency receiver to make the integer ambiguity search more efficient.

Research Problem

- Resolving integer ambiguities is a non trivial problem
- Measurements gets correlated in the differenntation process (double and triple difference) and consequently attitude solution is noisier.
- Cycle slip detection is needed if not resolving ambiguities in a single epoch basis (which is inherently immune to cycle slip) but single epoch may not attain high success rate while trying to find the correct ambiguity parameters
- Shorter baseline length means higher angle errors
- At millimeter measurements resolution, antenna phase center variation is no longer negligible.

Objectives

- Resolving ambiguities using GNSS carrier phase differential measurements
- Increase the performance of ambiguities estimation (Capability to discriminate a correct ambiguity set from all candidate sets)
- Improve the computational efficiency of the ambiguity search process
- Use the known baseline length

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Step 1. Least-squares adjustment from double difference measurements to obtain the “Float solution”

Step 2. Obtain “Integer Solution” from Pull-In region

Step 3. Obtain “Fixed Solution” and candidate validation (very high computational aspects)

- Ratio test
- Will not test the correctness of the fixed ambiguities but rather the correctness of the LAMBDA method [6]
- IA validator

Validation of the fixed ambiguities considering the fail, success or undecided rate [7]

Conclusion

The attitude determination from a GNSS system using CDGPS is an active area of research but much remains to be done to improve the measurement accuracy and minimize sources of error. The ultimate goal is to use ultra short baseline and low cost sensor to enable embedded solution such as portable device like cell phone and other uses in augmented reality for everyday use.

References

7. Verhagen, Emm. 2005. - The GNSS integer ambiguities: estimation and validation. -