Precise kinematic GPS positioning with Kalman filtering and smoothing

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Abstract

The Global Positioning System (GPS) has proven to be a useful tool for the determination of positions of a wide variety of moving platforms to accuracies in the order of a few centimetres. One of the critical aspects of precise kinematic GPS positioning at the centimetre level is the determination of integer carrier phase cycle ambiguities. The carrier phase observable is the most precise measurement available, but only the fractional part of the phase can be measured. In this thesis, a newly developed method at KTH for resolving the unknown integer ambiguities has been implemented and tested on real data. The results show that the method is very efficient and fast on kinematic GPS data at short baselines. In all cases, the new method was able to resolve the ambiguities within five epochs after that both L1 and L2 observables are available from at least five satellites.

For a land mobile user, however, the satellite signal is often subject to shadowing by trees, bridges, buildings, or hills. This situation will for the precise user, working with resolved ambiguities, severely degrade the accuracy of the estimated positions until enough of satellites, i.e. at least four, are available again. With respect to the necessary effort, it should be carefully investigated whether the realtime capacity is in fact needed for a given task. If it is found appropriate for the surveying task to post-process the data, a very cost-effective way to bridge the intervals with data deficiency is to use mathematical means as smoothing algorithms. In this thesis, three different smoothing algorithms have been reviewed, discussed and tested on kinematic GPS data: The Fraser-Mayne smoother, the Rauch-Tung-Striebel smoother, and the Bryson-Frazier smoother. During shorter intervals of data deficiency (some tenths of seconds), it is found that the smoothing algorithms will help sustaining the precision and estimates that are close to the true ones. In fact, their performances at these occasions are found to be remarkably good.

At short baselines, it is common practice only to use standard models for describing the influence from the atmosphere on the observables. Additionally, multipath is not easily described in the model and is another disturbing factor influencing the measurements that is left unmodelled. Consequently, it is not a wild guess that time correlations between measurements, in some cases, may exist. Aiming at accuracies at the level of some few centimetres, it is found that kinematic GPS measurement sequences should be carefully investigated in terms of existing time correlations.

In this thesis, a general recursive statistical testing scheme for measurement model errors are reviewed and discussed for Kalman filter design and error analysis. The adopted approximate adaption algorithms were found to be viable alternatives to their more rigorous counterparts. The results show that in practice it is possible to revert the filter to operate under the null hypothesis after adaption of up to threeslips, which is in contrast to what Teunissen and...
Salzmann (1989) and Salzmann (1995) found out. However, in this case, the obtained results may be sub-optimal.

Key words: GPS, Kalman filter, smoothing