Abstract
The computational efficiency becomes a critical issue due to the increasing number of satellites and stations and it could hinder the further development of GNSS applications. In this contribution, we overcome this problem from the aspects of both dense linear algebra algorithms and GNSS data processing. First, in order to fully explore the power of modern microprocessors, the Square Root Information Filter (SRIF) solution based on the blocked QR factorization employing as many matrix-matrix operations as possible is introduced. In addition, by exploiting design matrix of pseudo-random, as well as performing the real-time ambiguity resolution, the algorithm complexity of GNSS data processing is further reduced. Then, the processing efficiency is validated in multi-GNSS (GPS, BDS/Galileo) satellite clock estimation with over 80 globally distributed stations. As for the unblocked method, it suggests that it will cost about 31 s per epoch. With the increase of matrix dimension it only takes 0.5 s and 0.3 s for multi-GNSS clock estimation per epoch for fixed and float clock solution, respectively, without any loss of accuracy.

Objectives

- Find an efficient GNSS LSQ solution for general-purpose applications with limited computing resources
- Analyze the performance of the new algorithm in Multi-GNSS real-time clock estimation

Basic Model

SRIF with QR factorization
LSQ problem can be solved by either Kalman filter/Ther or SRIF with identical result theoretically. However, the SRIF based on QR factorization is suggested in GNSS data processing as numerically more stable. The traditional unblocked algorithm is rich in vector-vector, matrix-vector multiplication. While, for effective use of the power of most modern computer, the granularity of these operations is too small compared with the blocked operations.

By optimizing the arrangement of ambiguity and carrier-phase, the Blocked-front and Blocked-end methods are expected to benefit since the zero elements are centralized. Concerning the comparison between these two methods, the filter is more time-consuming with the Blocked-end method, while, the prediction is more time-consuming with the Blocked-front method. Actually, the difference whether the Blocked-front or the Blocked-end method should be applied depends on the ratio of the parameter number of ambiguities ($n_a$) and other unknowns ($n_p$), which is denoted as $r = n_a/n_p$ in this study.

As suggested in Fig. 4, the algorithm complexities are almost identical when $r$ is less than 1 for the Blocked-front and Blocked-end methods. In summary, for an efficient GNSS data processing, the Blocked-front method with ambiguity parameters in front of all unknowns is suggested.

Experiments and results

Data collection and processing strategy

- Data collection and processing strategy
- Clock products with ambiguity resolution
- With about 1588 parameters for each epoch, it takes about 31.38 s for SRIF with unblocked method per epoch. While, the average time used for SRIF per epoch with the Blocked-end and Blocked-front method is almost 4 s and 0.4 s for the Blocked-end and Blocked-front method, respectively, which implies a significant improvement for real-time data processing