



An efficient solution for fast generation of multi-GNSS real-time products

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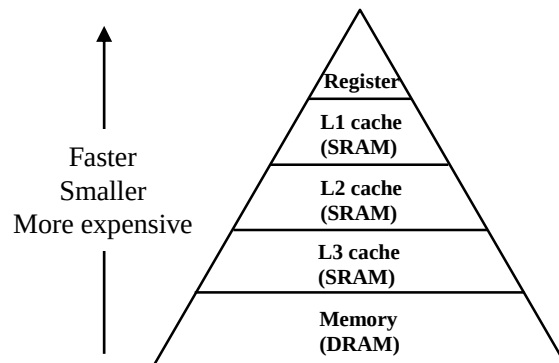
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Overview

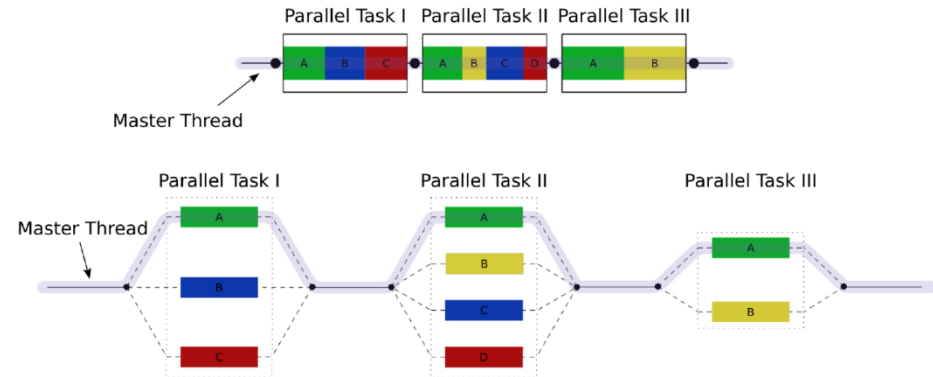


- ❑ In this study, we proposed an efficient solution to realize the **fast updating** of multi-GNSS real-time products by making full use of the **computing techniques**, which has been applied to our **orbit products** and **clock products**.

Level-3 Operations of BLAS



Parallel Mode For Multi-core CPU



- Using **matrix operations** instead of vector operations as much as possible.
- Serial model has been transformed to **parallel model** to adapt to multi-core architecture.
- **OpenBLAS** matrix library is recommended for its good performance on parallel environment.

Background

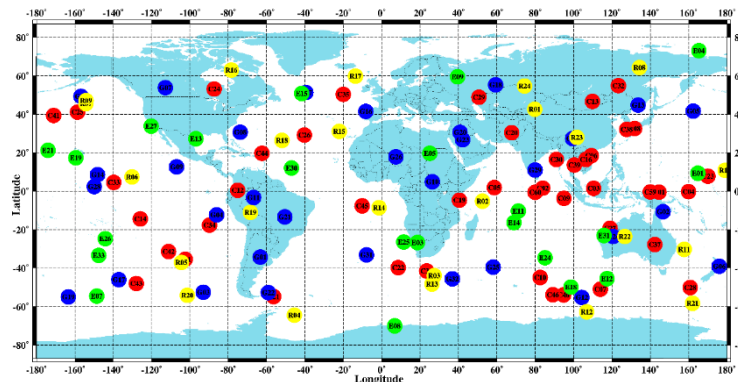


Figure. Current Satellite Position of GNSS at 23:00 on 31th Dec 2020

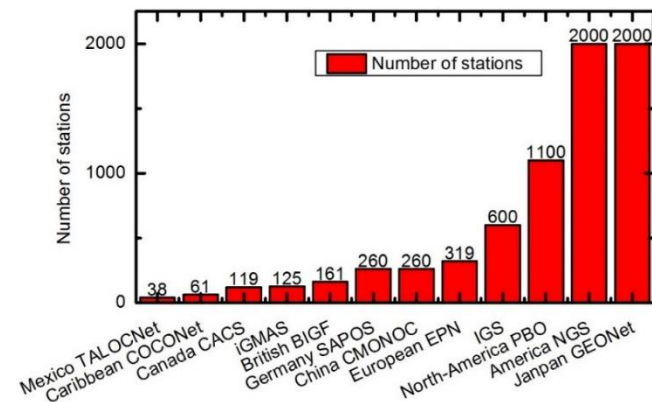


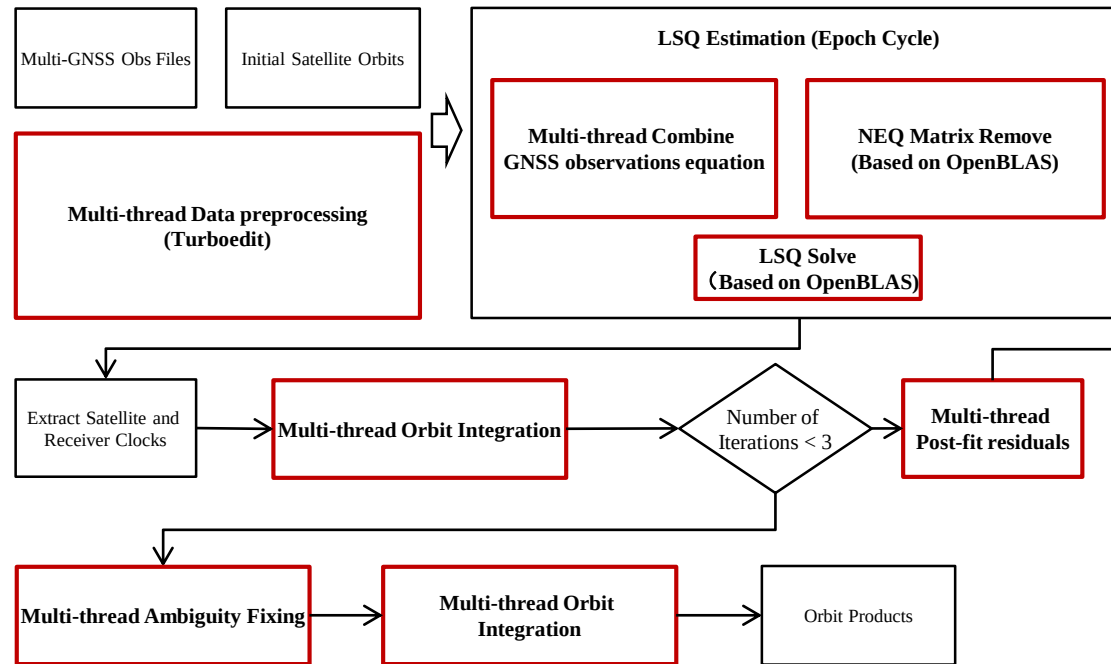
Figure. Major CORS networks worldwide and the scale of each CORS network

System	Blocks	Frequency Bands	Operational
GPS	II-R	L1, L2	8
	IIR-M	L1, L2	7
	II-F	L1, L2, L5	11
	III-A	L1, L2, L5	4
GLONASS	M	FDMA: L1OF, L2OF	14
	M+	FDMA: L1OF, L2OF; CDMA: L3OC	9
	K1	FDMA: L1OF, L2OF; CDMA: L3OC	1
BDS-2	GEO	B1I, B2I, B3I	5
	IGSO	B1I, B2I, B3I	7
	MEO	B1I, B2I, B3I	3
BDS-3	GEO	B1I, B1C, B2a, B2b, B3I	3
	IGSO	B1I, B1C, B2a, B2b, B3I	3
	MEO	B1I, B1C, B2a, B2b, B3I	24
Galileo	IOV	E1, E5a, E5b, E5, E6	3
	FOCe	E1, E5a, E5b, E5, E6	2
	FOC	E1, E5a, E5b, E5, E6	19

Table. Multi-GNSS constellation and frequency list

➤ GNSS have been rapidly developed with **abundant networks, modern constellations, and multi-frequency** observations, which raises a great challenge to the **fast generation** of multi-GNSS products.

Methods



Item	Old strategy	New Strategy
Data preprocessing	Single-thread	Multi-thread
Combine equation(LSQ)	Single-thread	Multi-thread
NEQ Remove(LSQ)	Vector operation	Matrix operation
Solve Equation(LSQ)	C-LAPACK	OpenBLAS
Orbit Integration	Single-thread	Multi-thread
Ambiguity Fixing	Single-thread	Multi-thread
Post-fit Residuals	Single-thread	Multi-thread

Table. Comparison of the old and new strategy of POD

- Most steps of multi-GNSS data processing on precise orbit determination (POD) are transformed from serial model to parallel model and all matrix operation are based on OpenBLAS matrix library.
- The processing efficiency of precise clock estimation (PCE) can also be significantly improved under the above the optimized Least Square (LSQ) Estimation.

Results-POD



- ❑ The proposed method is then applied to the POD with 150 stations and GREC satellite systems on a 3.30 GHz AMD CPU with 6 cores.

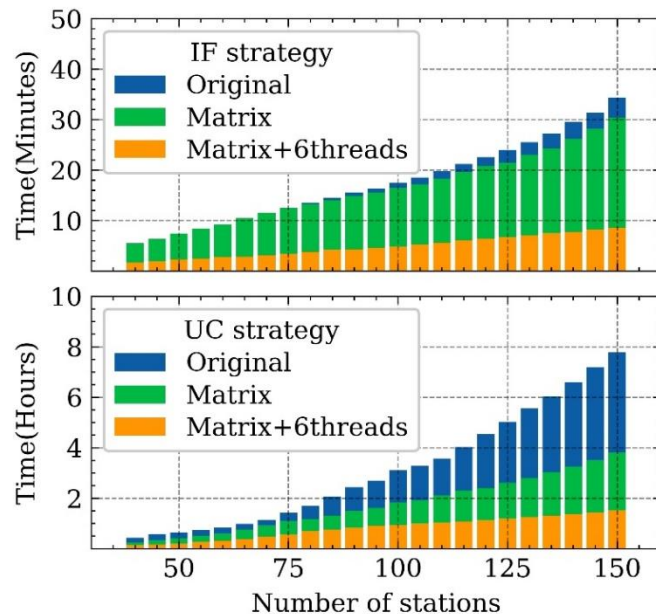


Figure. Matrix operation and multi-threading to improve the efficiency of LSQ estimation on POD with IF model (top) and UC model (bottom)

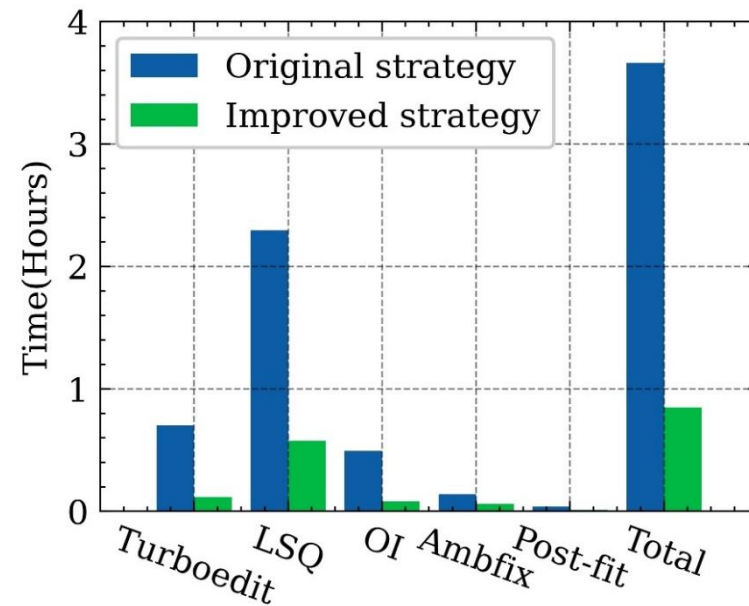


Figure. The comparison of original and improved processing strategies for multi-GNSS POD with IF model in terms of computational efficiency

- Due to more parameters and equations, **matrix operations** is more efficient for UC model. **Multi-threading** will significantly improve the computational efficiency of both model.
- The **hourly update** of multi-GNSS ultra-rapid orbit products is achievable under the improved strategy.

Results-PCE



□ The proposed method is applied to the PCE on a 3.30 GHz AMD CPU with 6 cores.

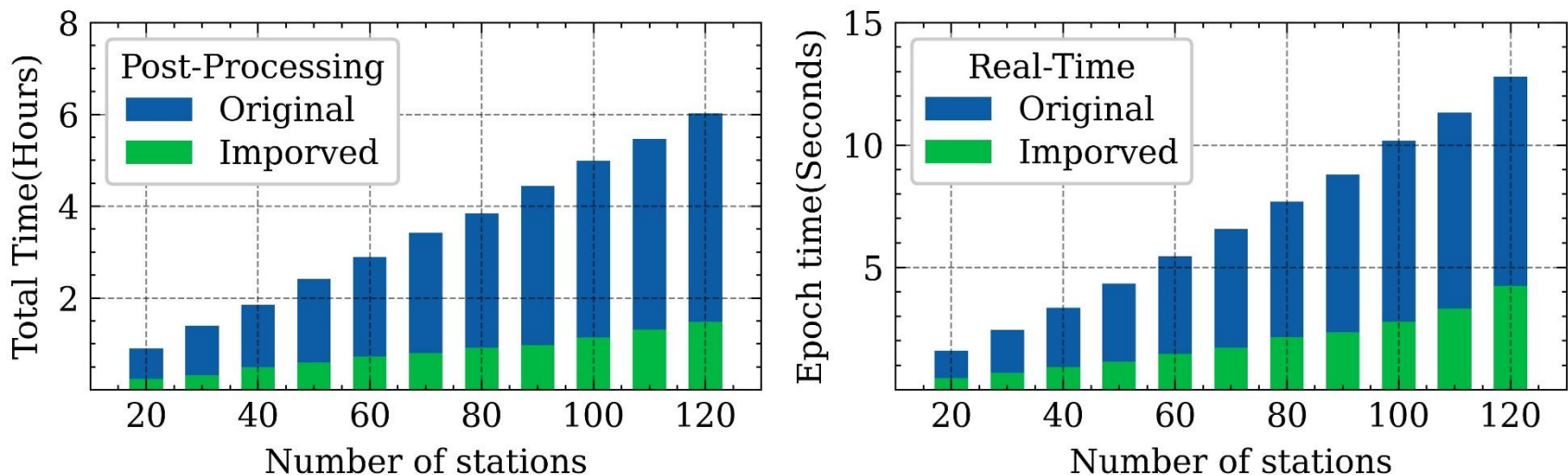


Figure. The comparison of original and improved processing strategies for PCE with GREC satellite systems. The figure on left shows the 30s sampling PCE result, and the figure on right shows the real-time PCE result.

- The improved strategies can effectively shorten the processing time of PCE with 30s sampling from **6 hour to 1.5 hour**.
- The single epoch processing time of multi-GNSS real-time PCE can be shortened to **less than 5 seconds** in case of no more than 120 stations.

Summary



- ◆ Matrix operations are more friendly to memory access.
- ◆ Parallel model can substantially improve the processing efficiency in the case of a large amount of GNSS observations.
- ◆ Multi-GNSS ultra-rapid orbits can be hourly updated and the processing time of uncombined POD can also be reduced by about 80%.
- ◆ The multi-GNSS real-time clock products can be easily generated in 5 seconds.



Thanks!