Augmentation of a global navigation satellite system (GNSS)

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Introduction/Objective

In dense urban environments, utilizing Global Navigation Satellite System (GNSS) for localization presents numerous challenges due to:

- Signal obstructions caused by tall buildings and vehicles.
- Multipath interference from surrounding structures.

This study addresses these challenges, particularly in context of data collected from smartphones equipped with GNSS receivers.

- Investigating outlier detection methods to enhance reliability of GNSS data in urban settings.
- Highlighting differences between each technique to give insight about advantages and disadvantages.

Methodology

Our data consists of 132 satellites and 1631 epochs, collected by driving a vehicle equipped with Xiaomi and Samsung smartphones around urban areas.

Outlier detection methods were implemented to identify and mitigate localization errors caused by non-line-of-sight and multipath anomalies. The methodology of this study goes beyond the limitations of prior studies and has never been implemented in context of GNSS before.

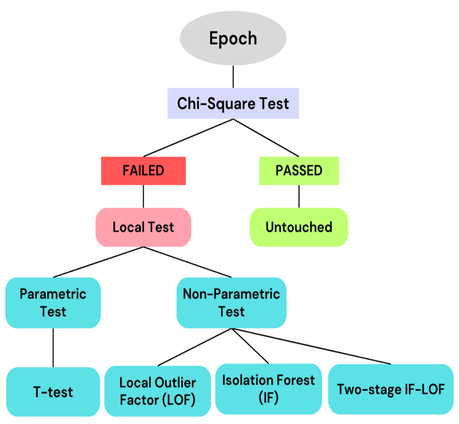

Figure 1. Diagram of methodology

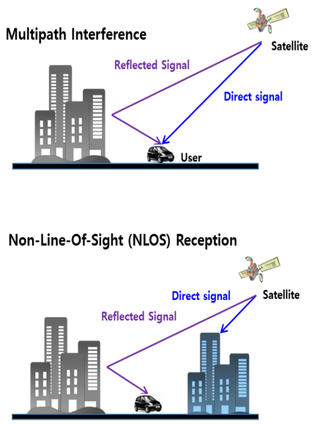

Figure 2. Multipath and NOLS

Analysis

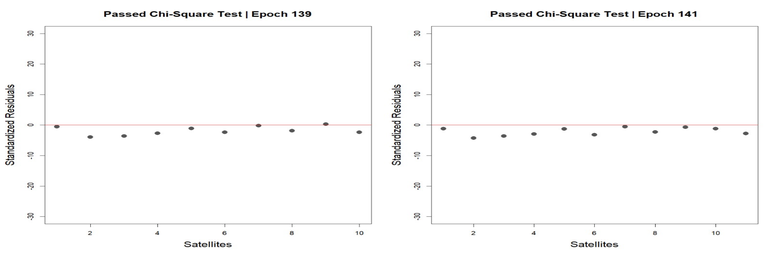

Figure 3. Stage 1: Random sample of epochs that passed the global chi-square test

Analysis

T-test, LOF, and IF-LOF methods used predetermined threshold values of 90%-97% confidence levels. Observations under 90-97 region were transformed by a 3-segment adaptive factor technique, and beyond 97 was considered an outlier.

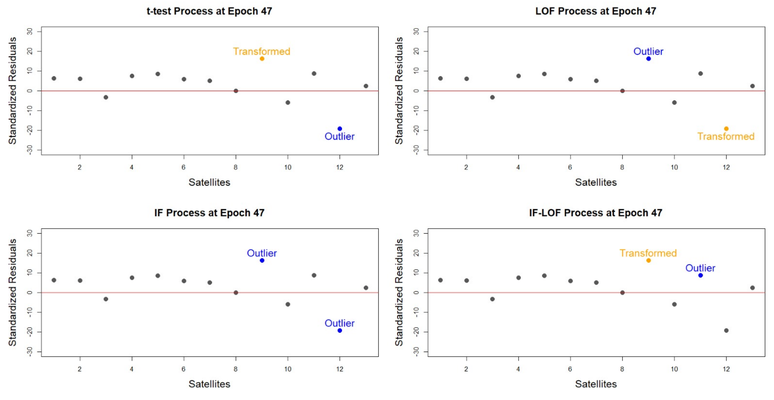

Figure 4. Stage 2: Random sample of epochs that failed the global chi-square test

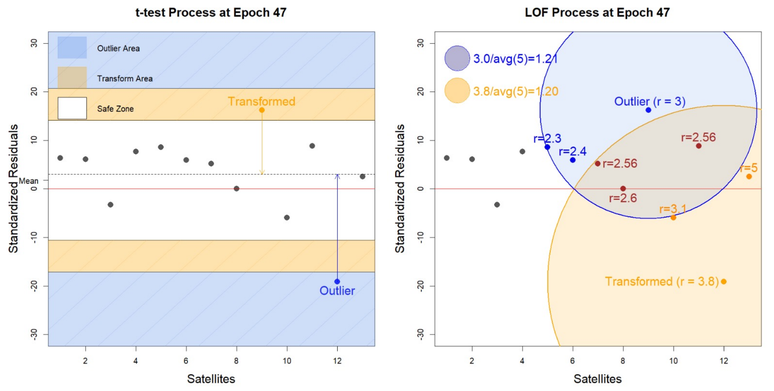

Figure 5. Root cause of discrepancy between t-test and LOF

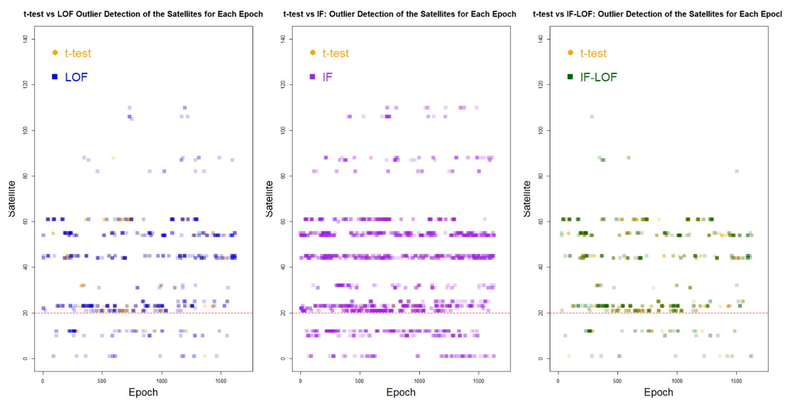

Figure 6. Outlier detection of Satellites for each Epochs

Results

In the dataset, total number of observations for Xiaomi smartphones is **19,188**, whereas for Samsung smartphones is **17,878**.

	Outlier %	Transformed %
t-test	2.47%	10.89%
LOF	2.98%	4.77%
IF	12.26%	NA
IF-LOF	2.13%	3.38%

Table 1: Xiaomi Outlier Detection

	Outlier %	Transformed %
t-test	2.20%	11.63%
LOF	3.89%	6.30%
IF	15.25%	NA
IF-LOF	1.92%	3.81%

Table 2: Samsung Outlier Detection

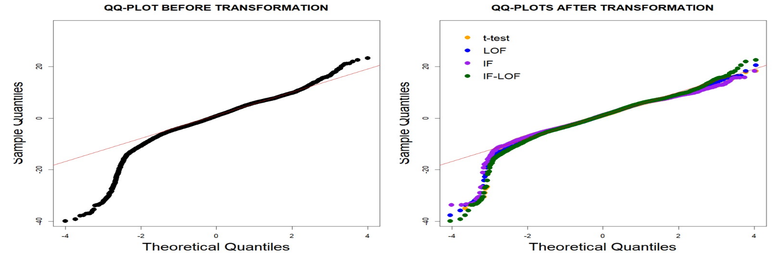

Figure 7. Xiaomi Outlier Detection - Before and After

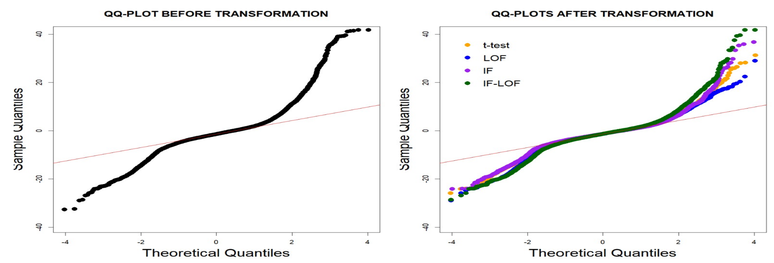

Figure 8. Samsung Outlier Detection - Before and After

Conclusion

In the study, we investigated outlier detection techniques to enhance the reliability of GNSS data in dense urban environments.

- IF-LOF test performed the worst results due to small data set of epochs
- While isolation forest (IF) performed relatively well, it removed significantly more observations, which resulted in deduction of degrees of freedom
- The main difference between t-test and LOF is caused due to data behavior.
- For the local tests, LOF has the most successful results, especially under large quantile values. However, it removes a small set of reliable GPS satellites

In conclusion, t-test and LOF have the most optimized results, LOF being slightly more robust. Thus, t-test or LOF methods can be implemented depending on our confidence about the assumption of data behaviour. Under uncertainty, with this newly introduced methodology in GNSS context, LOF would be the best option. These findings can significantly improve GNSS data's reliability in dense urban environments. It's a step forward in enhancements to the positioning algorithm.