Research Papers for NLOS correction

Classical Methods

1. **Hsu et al. (2015)** – *"NLOS Correction/Exclusion for GNSS Measurement Using RAIM and City Building Models"*: This paper uses 3D ray tracing models plus pseudo-rance for each satellite to do NLOS detection.

2. **Yu et al. (2018)** – *"A New Method for GNSS Multipath Mitigation with an Adaptive Frequency Domain Filter"*: They analyze code-minus-carrier divergence (CMCD) for GNSS in frequency domain. It uses short time Fourier transform (STFT) to process to filter out the signals and reconstruct pseudo range

3. **Wang et al. (2018)** – *"Advanced Sidereal Filtering for Mitigating Multipath in GNSS Short Baseline":* Authors introduce Advanced Sidereal filtering technique for a short baseline based on dual antenna GNSS receivers. They take differing dual-antenna receivers and repeat intervals, ASF cancels repeating multipath travel of signals.

4. **Gupta & Gao (2024)** – *"Reliable Urban Vehicle Localization under Faulty Satellite Navigation Signals":* In this authors, introduce a particle filter that is robust to multipath/NLOS. It models GNSS pseudorange with a Gaussian Mixture Model (GMM) likelihood and uses an EM-like (Bayesian) update inside the filter to mitigate the biases.

Machine Methods

1. **Ozeki & Kubo (2022)** – *"GNSS NLOS Signal Classification Based on ML and Pseudorange Residual Check":* This paper uses support vector machine (SVM) classified for and GNSS pseudorange check to detect NLOS signals which are later eliminated.

2. **Li et al. (2023)** – *"Machine Learning based GNSS Signal Classification and Weighting in Built Environment":* This paper uses quality indicators (such as standard deviation of pseudorange, CN0, elevation, azimuth) with ML classifier to pre-process the GNSS data to predict the probability of NLOS using regression methods. They compare classifiers gradient boosted decision Trees, K Nearest Neighbour, Support vector regression and Random Forest.

3. **García Crespillo et al. (2023)** – *"Robust design of a machine learning-based GNSS NLOS detector with multi-frequency features":* In this paper, logitstic regression models are trained on pre-normalized, multi-frequency GNSS features (pseudorange, CN0,…) to detect NLOS signals. The authors normalize features using open-sky models to enhance

generalization, and employ separate branches for each frequency to handle intermittent features.

4. **Nunes & Sousa (2024)** – *"Deep Learning Soft-Decision GNSS Multipath Detection and Mitigation":* This recent paper uses a correlator output grid with different code delays and doppler frequencies. The existence of multipath provokes the change in correlator outputs and features are captured by a Convolutional Neural Network.

5. **Pan et al. (2024)** – *"Machine Learning Based Multipath Modeling in Spatial Domain":* This work treats GNSS multipath as a regression problem in the spatial (azimuth/elevation) domain. It extracts satellite-by-satellite multipath errors from post-fit residuals over several days and fits a model using XGBoost regression on satellite az/el (and optionally SNR). In processing, the model predicts each pseudorange's multipath bias, which is then subtracted before positioning.

6. **Qi et al. (2024)** – *"Random Forest–based Multipath Parameter Estimation"*: In this approach, a random forest regressor predicts the parameters of reflected multipath (e.g. delay and amplitude) from multiple correlator outputs. The predicted multipath components are then subtracted from the received signal waveform, effectively isolating the direct-path component.