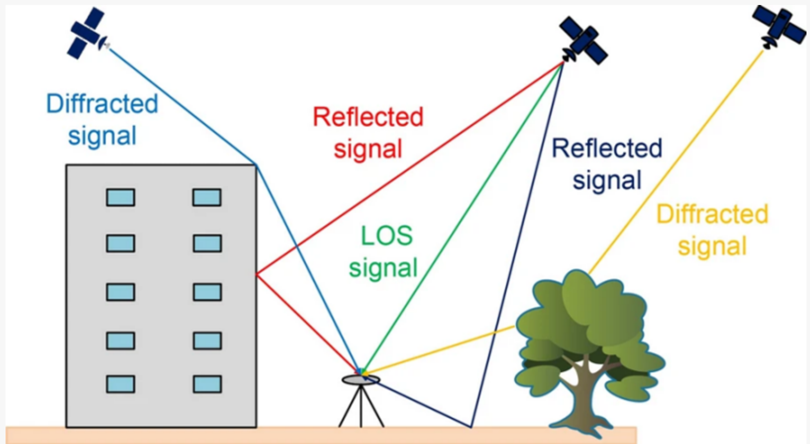
AI tackles GNSS errors in urban and rough terrains

GA, UNITED STATES, March 24, 2025 /EINPresswire.com/ -- A pioneering study has introduced a data-driven approach to tackling site-specific unmodeled errors in Global Navigation Satellite Systems (GNSS), a persistent challenge in urban canyons and rugged terrains. These errors, caused by signal reflection and diffraction—such as multipath effects and Non-Line-of-Sight (NLOS) reception—significantly degrade GNSS positioning accuracy. By harnessing AI techniques, including random forest regression and transformer model, researchers have developed a high-precision prediction model that enhances GNSS reliability in complex environments. This advancement paves the way for more accurate navigation and positioning systems, benefiting applications ranging from autonomous vehicles to precision surveying.



GNSS signals caused by reflection and diffraction. The signals: green denotes LOS signals, red and purple denote reflected signals, and blue and yellow denote diffracted signals

Global Navigation Satellite Systems (GNSS) has revolutionized modern navigation, yet its accuracy remains vulnerable in environments where signals are distorted by surrounding structures, such as skyscrapers, dense forests, and uneven landscapes. Conventional error mitigation techniques, including sidereal filtering and hemispherical map models, have provided partial solutions but fail to fully address site-specific unmodeled errors, particularly in short and ultra-short baseline GNSS positioning. These unmodeled errors pose significant challenges for applications that demand high precision. Given these limitations, researchers have been searching for a more effective, data-driven approach to mitigate GNSS positioning errors.

On March 10, 2025, Satellite Navigation published a new study (DOI: 10.1186/s43020-025-00161-0) by researchers from Hohai University, introducing a data-driven method to characterize and model GNSS site-specific unmodeled errors. By systematically analyzing correlations between potential error-inducing factors, such as elevation, azimuth, and signal quality metrics, the team developed a robust predictive model that significantly enhances positioning accuracy. Their approach leverages cutting-edge techniques, including random forest regression and transformer models, to provide deeper insights into the factors driving GNSS errors in complex environments.

To achieve this, the researchers examined a wide range of potential error-related features, including elevation, azimuth, carrier-to-noise density ratio, between-frequency differenced carrier-to-noise density ratio, number of visible satellites, position dilution of precision, geometric dilution of precision, innovation vector, between-epoch differenced ambiguities, and between-frequency differenced phase observations. Their analysis revealed that the innovation vector (fIV) was the most critical factor for code unmodeled errors, while elevation (fELE) and azimuth (fAZI) played a dominant role in phase unmodeled errors. Notably, the study also uncovered variations in error correlations across different satellite systems, such as GPS and BeiDou. By integrating a transformer model, the researchers significantly improved prediction accuracy, demonstrating the power of combining multiple features for comprehensive GNSS error modeling. The results indicated that the top six identified features accounted for approximately 88% of the total correlations, underscoring the necessity of a multi-feature approach for precise error characterization.

"This research represents a major leap forward in GNSS error modeling," said Dr. Zhetao Zhang, the study’s lead author. "By integrating machine learning and deep learning, we can more accurately predict and mitigate site-specific unmodeled errors, a crucial step toward improving GNSS performance in urban environments and rough terrains."

The implications of this study extend across a range of fields that depend on precise GNSS positioning. Autonomous vehicles, urban navigation systems, and geodetic surveying stand to benefit significantly from improved accuracy, particularly in signal-challenged environments. Enhanced GNSS precision could improve the safety and efficiency of autonomous driving systems, making them more reliable in densely built urban landscapes. Moreover, the data-driven approach holds promise for real-time GNSS applications in emergency response, logistics, and construction, where reliable positioning is critical. This research not only strengthens existing GNSS systems but also lays the groundwork for future advancements in data-driven error mitigation, shaping the next generation of high-accuracy navigation technologies.

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