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SATELLITE CONSTELLATION-BASED REGIONAL GNSS POSITION AUGMENTATION FOR AUTONOMOUS VEHICLES WITH A KALMAN FILTER

Abstract

Distributed small satellite missions are gradually catching up to larger space missions due to emerging autonomous systems. Autonomous vehicles rely on accurate and reliable positioning to operate safely and efficiently. However, current Global Navigation Satellite Systems (GNSS) are not sufficient for satisfying the needs of emerging autonomous systems. Due to the vulnerability of GNSS signals to interference and signal blockage, GNSS-dependent systems require augmentation, greater robustness, and precise synchronization in terms of positioning, navigation, and timing (PNT). In this research, we present a Low Earth Orbit (LEO) small satellite constellation-based regional position augmentation system. This system utilizes specialized payloads, to receive, process, and retransmit GNSS signals to the ground, resulting in an augmented signal that provides improved accuracy and reliability of the positioning solution for autonomous vehicles. CubeSat constellations are able to deploy miniaturized GNSS receivers that simultaneously receive and process data from the majority of navigation constellations, including GPS, Galileo, and Beidou. Such a technology broadens the applications of autonomous vehicles in specific regions depending on constellation design, and leads to less expensive ground infrastructure.

To investigate regional coverage characteristics of the augmentation system, we simulated five constellations with different satellite numbers including hybrid configurations with inclinations of 30°, 60° and 97.5°. This system utilizes a Kalman Filter algorithm which takes dynamics of the system including position and velocity of the LEO satellite as state variables, to determine its precise position with centimeter/decimeter-level accuracy. The shorter signal transmission path from LEO satellites to ground receivers allows for transmitting stronger signals with minimized cycle slip occurrence. Additionally, due to the fast motion of LEO satellites, their spatial geometry changes quickly, which enables the use of Precise Point Positioning (PPP) techniques in Precise Orbit Determination (POD) for faster convergence in high-precision applications. Within the scope of this study, autonomous navigation related concerns are extended to GNSS+LEO case by anomalous measurements detection including cycle slips, PPP ambiguity estimation and complementary study of those errors.

This paper covers combination of the Kalman Filter algorithm with the proposed LEO-based augmentation system which increases the safety and effectiveness of autonomous vehicles by improving the accuracy and reliability of the existing GNSS constellations.