Abstract

Over the decades, Global Navigation Satellite Systems (GNSSs) have evolved to features multi-constellation and multi-frequency bands, advanced signal structures, and sophisticated ground segments. Its capacity to deliver high-precision Positioning, Navigation, and Timing (PNT) services on a global scale has made GNSS indispensable for various emerging applications, such as transportation, precision agriculture, and smart wearables.

Despite its widespread use, GNSS remains susceptible to faults that compromise the accuracy and reliability of its PNT services. The most common faults include multipath and Non-Line-of-Sight (NLoS) interference, which is prevalent in urban environments with intense signal reflections. Additionally, satellite clock faults and ionospheric scintillation can introduce errors in raw measurements, degrading PNT services.

The primary objective of this dissertation is to explore methodologies for delivering high-accuracy PNT services under challenging GNSS conditions characterized by significant faults. The research is divided into two main areas: the tight integration of GNSS with Ultra-Wideband (UWB) technology and the application of advanced techniques to address signal faults in standalone GNSS positioning solutions. The Thesis is organized in different parts:

Part One focuses on the tight integration of GNSS/UWB systems. It investigates how classical filtering algorithms, specifically the Extended Kalman Filter (EKF) and the Particle Filter (PF), affect the performance of tightly integrated GNSS/UWB systems in various scenarios. Additionally, this section examines the issue of time synchronization within these systems, identifying specific factors that may exacerbate time offsets and demonstrating the necessity of resolving these issues in certain situations. Two filtering-based algorithms are proposed to address these time offsets, with their effectiveness validated through simulations and real-world experiments.

Part Two addresses the extraction of measurement biases caused by multipath and NLoS in a post-processing manner. This research introduces an observable named the 'leftover term', which encompasses not only the pseudorange biases from multipath/NLoS but also unknown receiver clock biases and hardware delays. A clustering algorithm-based method is proposed to estimate these biases in order to apply suitable corrections. The effectiveness is also demonstrated using a real-world dataset from an environment with heavy GNSS signal reflection.

Part Three is dedicated to the real-time detection and mitigation of GNSS faults, primarily multipath and NLoS, using a standalone GNSS receiver. The research extends the concept of innovation from the EKF to the framework of the PF and devises a strategy to compute a thresholding strategy innovation to effectively detect GNSS faults. Two novel PF-based methods, the Corrected Likelihood (CL) and Mixed Likelihood (ML) methods, are introduced to refine likelihood functions for measurement functions. Furthermore, a compressed process noise parameter design tailored to the specific motion model of a land vehicle is proposed to enhance the fault mitigation capabilities of PF-based methods. The effectiveness of these methods is tested using an open-source real-world dataset collected in a dense urban setting.

This dissertation aims to enhance the robustness and reliability of GNSS systems in environments where traditional methods fall short, by leveraging both integrated and standalone technologies to overcome the challenges posed by common GNSS faults.