Doctoral Dissertation
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Design of Advanced Positioning Solutions: A Bayesian Approach

By

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Abstract

In today's connected world, Global Navigation Satellite Systems (GNSS) have become an indispensable tool for a wide range of modern applications. From enabling autonomous vehicles, to guiding commercial aircraft to enabling precise location on smartphones, GNSS play a central role in many activities of our daily lives. As reliance on satellite navigation continues to grow, it becomes increasingly important to improve the accuracy and precision of the positioning solution, and to ensure its integrity for the reliability and safety of the applications relying on such information. In light of this, the thesis focuses on the positioning unit of the receiver, and in particular on the use of Bayesian inference to estimate Position, Velocity and Timing (PVT). Nevertheless, the investigations presented here also extend to other aspects related to the estimation of location parameters. First, the theoretical background involved in the estimation process is explored in detail, so as to gain a solid theoretical base and obtain insights for the development of novel measurement processing methodologies.

Using the theoretical analysis as a starting point, application-specific improvements of state-of-the-art filtering algorithms are introduced first by exploiting the structure of the measurement model to devise a more efficient estimation in terms of computational load. Then, novel techniques are presented, spanning different topics and different receiver architectures, from stand-alone GNSS, to cooperative techniques and sensor integration. Ultimately, the common goal is to increase the precision, accuracy, and robustness of PVT estimation by exploiting different approaches and with different degrees of architecture complexity.

One of the main limitations and challenges of stand-alone GNSS is to provide accurate positioning information in harsh urban environments with complex signal reflection phenomena, leading to multipath and Non line-of-sight (NLoS) effects. For this reason, the scenarios addressed include the detection and mitigation of multipath and NLoS based on the consistency between redundant measurements, with applications both for real time and for post-processing. Furthermore, one of the solutions that have been considered to overcome the limitations of GNSS is exploiting additional

information from other sensors or from other users. In particular, the tight integration of Ultra-Wide Band (UWB) with GNSS has been considered, with a focus on time synchronization between the two technologies to enable accurate positioning for autonomous vehicles or drones. To conclude, more practical aspects often neglected by research effort are considered. Namely, the exchange of cooperative data among networked receivers is addressed by presenting a dedicated and open protocol for the exchange of positioning information from both GNSS and other sensors, thus enabling numerous cooperative applications.