Davidson

Davidson Technologies, Inc. (Davidson), a 29-year-old small business, leads in digital engineering, data-driven decision support, and mission-enabling algorithms. Davidson delivers agile solutions to the Department of Defense's (DoD) toughest challenges, focusing on multi-domain operations and contested environments. It is assumed the work for this proposal will be performed at the Colorado School of Mines, and any intellectual property derived from this effort will remain with Davidson Technologies.

Project Introduction

The objective of this software development activity is to design, implement, and validate integrated tracking algorithms that would utilize a constellation of multiple Low Earth Orbit (LEO) satellites to acquire and track objects operating in the endo-atmosphere and the low exo-atmosphere. This system must fuse heterogeneous sensor modalities, namely, radio frequency (RF) and infrared (IR) and optimize observational geometry to ensure estimation accuracy close to the theoretical limits defined by the Cramer-Rao Lower Bound (CRLB). Additionally, the tracking and fusion algorithms need to be optimized for deployment on a single, low-powered compute platform (e.g., Raspberry Pi or Nvidia Jetson), imposing constraints on computational resources, memory footprint, and power consumption.

Objectives

Acquisition and Tracking:

Develop robust algorithms to reliably detect and track objects within varying atmospheric regions using space-based sensors. Incorporate multi-target tracking capable of handling dynamic object trajectories and the inherent uncertainties of the environment.

Sensor Fusion:

Integrate complementary observations from both RF and IR sensors, leveraging their distinct phenomenologies. RF-based sensors typically generate 3-dimensional measurements where IR-based sensors provide angle-only measurements. Optimize the data fusion pipeline to mitigate sensor noise differences and enhance overall measurement accuracy.

Geometric Optimization:

Analyze and design the satellite constellation layout considering optimal viewing geometry. Make realistic assumptions about the number of satellites available. Ensure that the spatial distribution of satellites provides diverse angular perspectives to minimize estimation errors.

Theoretical Performance Benchmarking:

Employ CRLB analysis to establish theoretical lower bounds for the estimator's errors. Validate that the tracking algorithms approach these bounds under realistic operational conditions through analysis efforts for specific scenarios.

Embedded Deployment:

Optimize and adapt both the tracking and fusion algorithms for implementation on a single low-powered compute platform (e.g., Raspberry Pi or Nvidia Jetson). Ensure that algorithms maintain real-time performance, efficient resource management, and robust error handling within the constraints of limited processing power and memory. This will approximate the compute platforms available on satellite systems.

Expected Outcomes

Robust Tracking Software:

An integrated system capable of real-time object acquisition and tracking in complex atmospheric conditions. Efficient handling of multi-sensor data with minimal latency and robust error correction, all within a constrained computing environment.

Enhanced Measurement and Track Accuracy:

Demonstrated improvement in track and velocity estimation accuracy via optimal sensor fusion, with measurement errors approaching the CRLB. Quantifiable improvements stemming from strategic constellation designs, where diverse viewing angles minimize estimation variances.

Optimized Embedded Deployment:

A tracking and fusion solution that meets the computational and power constraints of a single low-powered compute platform (Raspberry Pi or Nvidia Jetson) without compromising performance. Successful real-time data processing and sensor fusion achieved through code and algorithmic optimizations tailored for embedded environments.

Validation through Theoretical and Practical Testing:

Comprehensive analysis showing that both the tracking algorithms and embedded platform deployment meet or approach the performance benchmarks as established by the CRLB. Development of guidelines for future enhancements in satellite constellation design, sensor configurations, and embedded computing optimization.