Senior Design Project in Electrical & Computer Engineering

Kalman Integrated IMU, GPS, and LORAN System

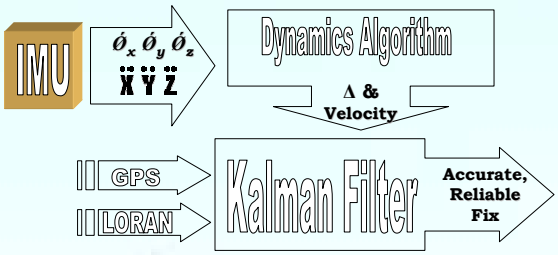
Cadet: 1/C Hunter Atherton

Advisor: CAPT Hartnett, Mr. Johnson, & LT Teixeira

Sponsor: FAA and DHS

Project Background

There are three major systems available for electronic navigation. The radio-navigation system, Long Range Navigation (LORAN), was developed in the 1940's to help ships and airplanes navigate. It was the primary electronic navigation system until Global Positioning System (GPS) was developed by the DOD in the 1970's. GPS is a satellite based system with lower costs for the end user. Over the past several decades, the third system, the inertial measurement units (IMU) use a combination of accelerometers and gyros. This system has recently become more and more practical with fewer costs, smaller size, and increased accuracy. Though the technology for all three of these systems is currently available, GPS is by in large the sole means of electronic navigation for the majority of sea-going vessels. GPS, however, is highly vulnerable due to both intentional and unintentional jamming by interference. It is imprudent to rely solely on one (easily jammed) system for navigation. A viable alternative to this is to augment the GPS fix with LORAN and an IMU to improve the reliability, integrity, and accuracy of the data used for navigation.



Proposed Project Diagram

Project Work

- Mathematically capture the dynamics of the Inertial Measurement Unit. The IMU outputs angular rate and linear acceleration (depicted above as $\acute{o}$ and $\ddot{X}\ \ddot{Y}\ \ddot{Z}$) which must be translated into a geographical displacement vector and unit velocity (depicted above as Δ & Velocity)
- Design tests to calculate errors of IMU and determine data statistics.
- Integrate IMU, LORAN, and GPS data into a Kalman filter.
- Develop a unit that contains all hardware required for all three systems and the Kalman filter.

Inertial Measurement Unit

Project Plan

A new micro electro mechanical (MEMS) IMU, manufactured by Crossbow Technology was recently procured by the department. It has been integrated into the MATLAB environment, and the plan is to process the IMU's data and combine it with GPS and LORAN systems using a Kalman filter. A Kalman filter is a mathematical algorithm that uses known observable sensor statistics to make optimal state estimations. It efficiently minimizes the mean squared error. The integration of all three systems will increase the accuracy and integrity of the final data and also allow vessels to coast through GPS outages. The major milestones under this plan are to develop Kalman integrated IMU-GPS-LORAN unit, and install it on major seagoing assets and major airframes.

Rudolph E. Kalman

Project Deliverables

- A viable prototype of the actual system
- Dynamics data conversion algorithm for IMU.
- Error and stochastic analysis of IMU
- Documentation for work progress
- Documentation on proper maintenance and troubleshooting.