GPS and Inertial Navigation System

Functional Requirements and Specifications

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Introduction

The GIN project is a fusion of two forms of navigation, a GPS and an inertial navigation system (INS), to provide a robust navigation platform. Recent advances in microelectromechanical systems (MEMS) technology has allowed inertial measurement units (IMU) to be miniaturized. An INS will accumulate errors in measurements and experience drift, rendering the navigation solution unreliable. The other navigation system used for this project is GPS. GPS will not experience the drift problem of the INS, but a GPS does rely on an external signal which may become blocked or obscured by terrain and other limiters. The goal of this project is to combine these two navigation systems to create a single, complimentary system that can mitigate the drawbacks of the two individual systems. While sub-meter accuracy will not be achieved with the GIN system, it will be accurate to within a few meters and still be ideal for basic navigation needs such as driving or hiking. The main features of this system are that it will be a robust solution, and also provide a near instantaneous value for position and orientation of a vehicle (or an object or a body).

Description

The GIN system will have four major components; the data logger, the GPS, and the navigation computer. The overall diagram for the connections of these systems is shown in Figure 1. The first component, the data logger, gathers the measurements from the IMU and GPS, and provides time stamp for when a data point is collected. The inputs to the data logger include the three accelerations, three angular rates, and three magnetometer readings, along the (x,y,z) axes,

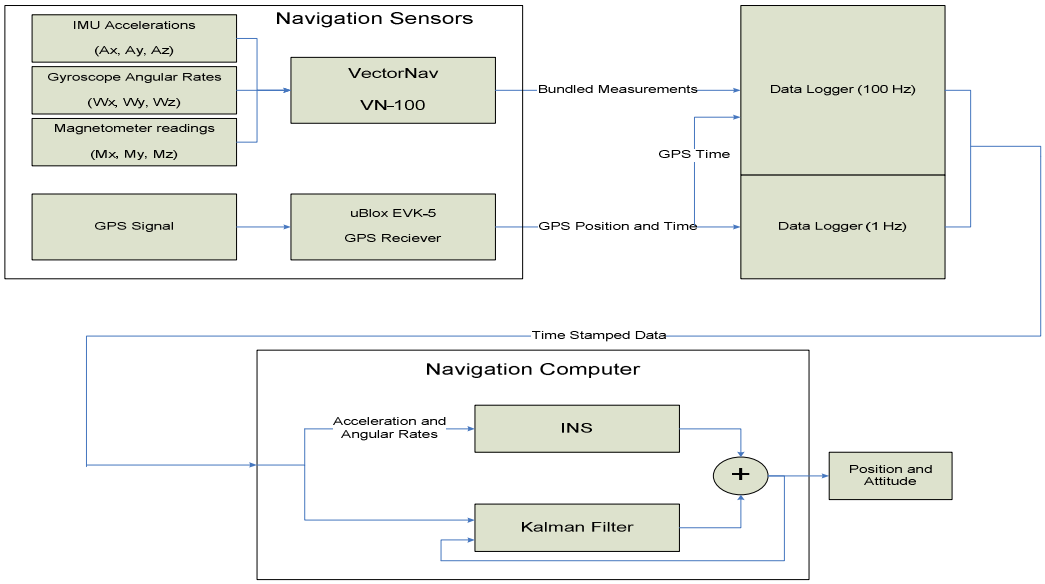

Figure 1: Overall System Diagram

as well as the GPS position provided by the GPS receiver. The data logger reads these values from the two sensor packages, the VectorNav VN-100 and the uBlox EVK-5, and time stamps these data points. The alignment of the data time-wise is the crucial function of the data logger; without correctly aligned data, the statistical analysis and error estimates will not function properly. The second component is a standalone GPS receiver and only the output from the receiver will be used. Performance specifications from the manufacturer are available. The navigation computer is the final component. This component takes all the IMU and GPS data and produces the body's position and attitude. Within the navigation computer is the INS and Kalman Filter. A strapdown INS is used for this project. This system is detailed in Figure 2. This type of INS has the INS sensor package mounted directly to the body. An INS utilizes three accelerometers and three gyroscopes oriented along the (x,y,z) axes to provide the accelerations and angular rates that the body is experiencing. Through numerical integration and system modeling, the body's position and attitude can be determined. The INS output is combined with the error estimates from the Kalman filter to determine the final position and velocity output.

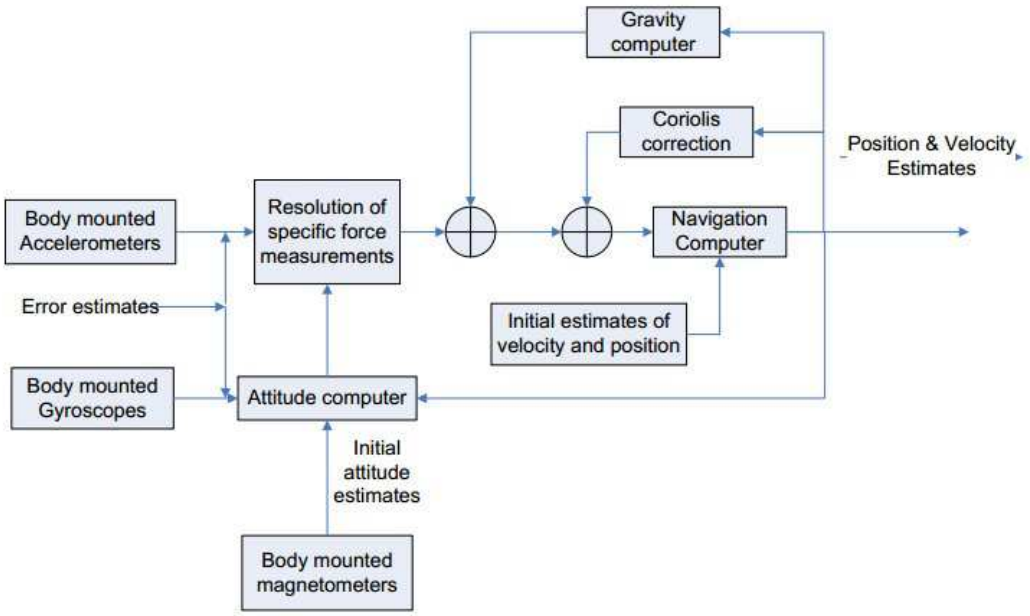

Figure 2: INS Diagram

Project Goals:

- Design and construction of an FPGA data logger
- Implementation of a strapdown system in MATLAB
- Modeling of overall system dynamics
- Error state modeling and Kalman filter design
- Implementation of GIN system in MATLAB with IMU and GPS data collected

System Requirements

Overall System Requirements

- Provide a body's position accurate to within 3 meters, and orientation to within $\pm 5°$
- Ability to maintain accuracy without GPS for 30 seconds

Data logger Requirements

- FPGA implementation
- A free running clock shall be synchronized to the GPS PPS (pulse per second) for data time stamping
- Simultaneous UART communication with two peripherals shall be required
- Retrieval of data from the IMU shall be completed before next data set is available (10 ms @ 100 Hz IMU update rate)
- A Buffer for storing retrieved data and augmenting a timestamp to the data shall be implemented
- The data shall be output to a storage medium for retrieval and analysis
- The data shall be organized in a manner denoting the individual measurements

GPS Requirements

Because the GPS is a standalone package (uBlox EVK-5), the system specifications are provided by the manufacturer and are not necessary to further specify.

Navigation Computer Requirements

- Calculations shall be performed in MATLAB
- A minimum of six states shall be used for the Kalman Filter
- The IMU bias stability of 0.5*mg* for the X/Y components and 1.6*mg* for the Z component shall be corrected with the Kalman Filter

References

D.H. Titterton and J.L. Weston, *Strapdown Inertial Navigation Technology, 2nd Edition*, The Institution of Electrical Engineers, 2004.

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