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GPS AND INERTIAL NAVIGATION SYSTEM

Presentation Outline

- Project Summary
- Navigation Systems Introduction
- Kalman Filter
- System Block Diagram
- Functional Description
- Functional Requirements
- Current Work
- Schedule of Tasks
- References

Project Summary

- Utilizing multiple navigation systems to compliment individual system weaknesses

- GPS
  - Highly accurate position and velocity information
  - Lower update frequency (~1Hz)
  - Relies on external signal

- INS
  - Provides position, velocity, attitude, and heading information
  - Higher update frequency (~100Hz)
  - Self contained system
  - Positioning error based on sensor error and drift

Navigation Systems Introduction

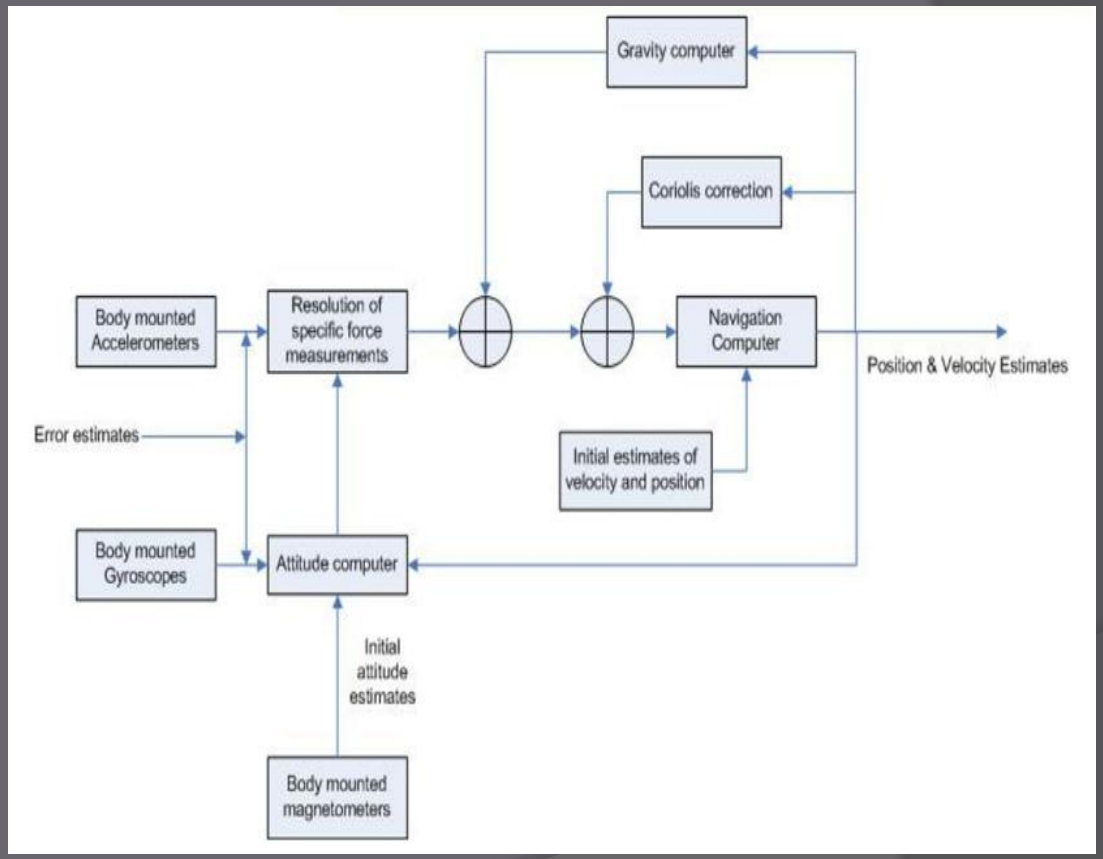
- Two systems
  - GPS – Global Positioning System
  - INS – Inertial Navigation System
- GPS
  - Constellation of 32 transmission satellites
  - Position solution based on signal travel time from satellites

Inertial Navigation Systems

- Employs dead reckoning for navigation solution
- Consists of the inertial measurement unit (IMU) and the computational component
- IMUs will generally contain:
  - Accelerometers – linear accelerations
  - Gyroscopes – angular rates
- Focus on Strapdown INS for this project

Strapdown INS

- IMU is fixed to the body in a known orientation
- Allows for translation into different navigation frames



Computational Component

- Perform integrations of accelerometer and gyroscope measurements
- Additional computation of local gravity, corialis effect, etc.
- Outputs position, velocity, and attitude

Inertial Measurement Unit

- Previous IMUs were ‘floating’ units
- Most current IMUs contain:
  - Accelerometers
  - Gyroscopes
  - Magnetometers
- MEMS based IMU
  - Smaller package
  - Cheaper
  - Not as robust

INS Error

- Error Sources
  - Noise
  - Sensor biases
  - Sensor drift
  - IMU misalignment
- INS Integrates accelerations
  - Drift error accumulates according to

$$\frac{1}{2} e_a t^2$$

  - e_a is the sensor bias

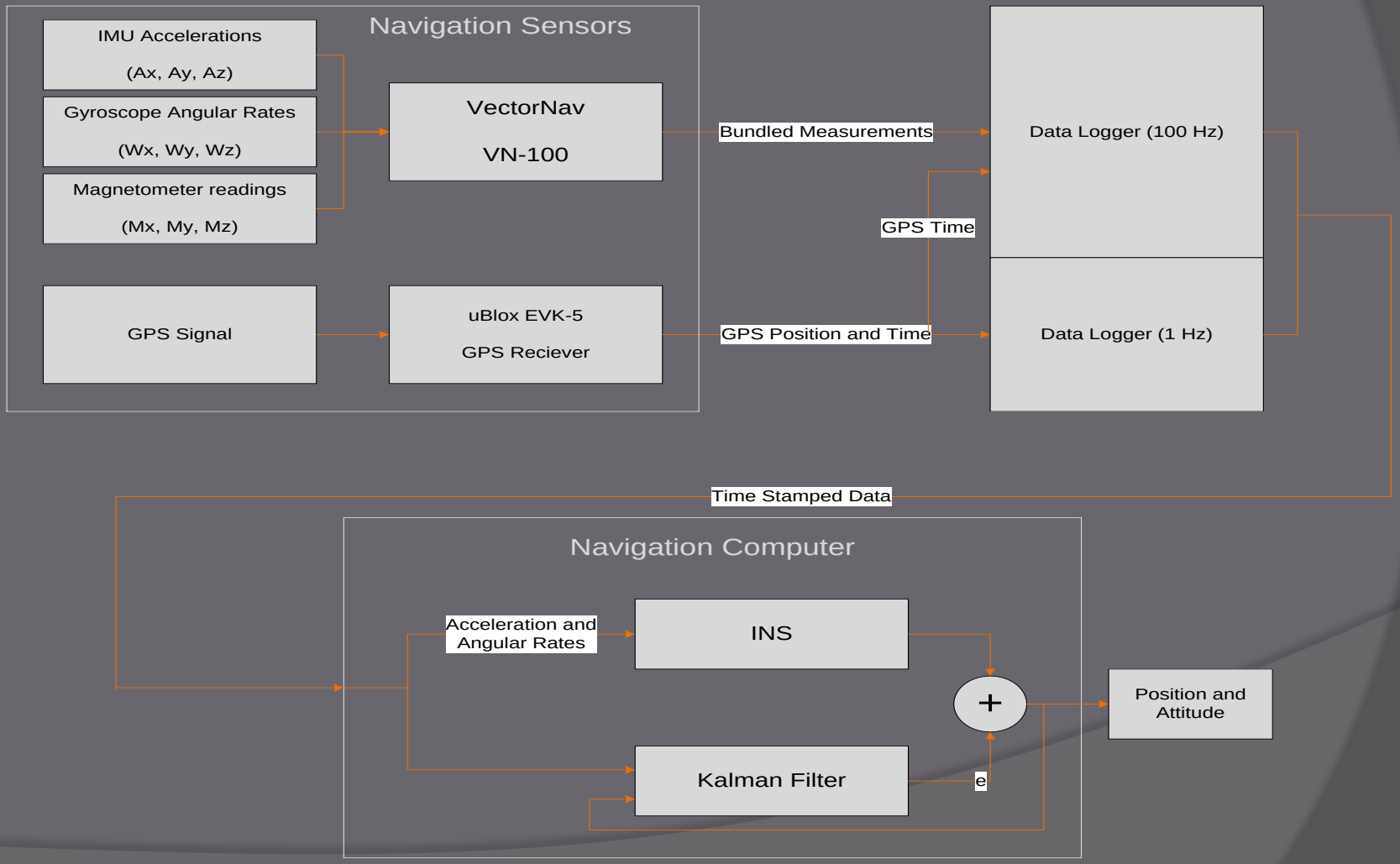
Kalman Filter

- Linear quadratic estimator
  - Estimation instantaneous state
  - System disturbed by white noise
  - Linearly related measurements
- Recursive algorithm
  - Predict
  - Evaluate
  - Update
  - Estimate

Types of Kalman Filter

- Linear systems
  - Basic Kalman filter
- Non-linear systems
  - Extended Kalman filter
  - Unscented Kalman filter
    - High level of non-linearity in state transition and system model

System Block Diagram



Functional Description

- Fusion of GPS and INS
- Provide short and long term navigation stability
- Provide navigation through GPS outage
- Kalman filtering for state estimation
- Three major components
  - Navigation sensors
  - Data acquisition
  - Navigation computer

Functional Requirements

- Overall system
  - Position accuracy within 2 meters
  - Maintain accuracy through 3 minute GPS outage
- Navigation sensors
  - IMU: Vectornav VN-100
  - GPS: Ublox EVK-5
- Data logger
  - UART communication
  - Capable of accepting IMU data at 100 Hz

Functional Requirements

- Data logger (continued)
  - Data string shall be amended with timestamp
  - Internal counter synchronized with GPS PPS
  - Removable storage medium (SD card)
- Navigation Computer
  - Post processing of data in MATLAB
  - Minimum of 12 states for Kalman filter

Current Work

- Data logger
  - Possible solutions
    - Custom VHDL based logger
    - Commercial off the shelf logger
  - VHDL
    - Provides simultaneous logging from 2 UART ports
    - Data synched through use of GPS PPS
    - Complex and requires large amount of development time

Current Work

- Data logger
  - Logmatic V2 data logger
  - Commercial logger
    - No logger had dual UART communication
    - Use two cheap loggers and synchronize
  - Internal count on separate loggers synchronized using GPS PPS
  - IMU data and GPS data tagged with count value
  - Data correlation achieved in post processing

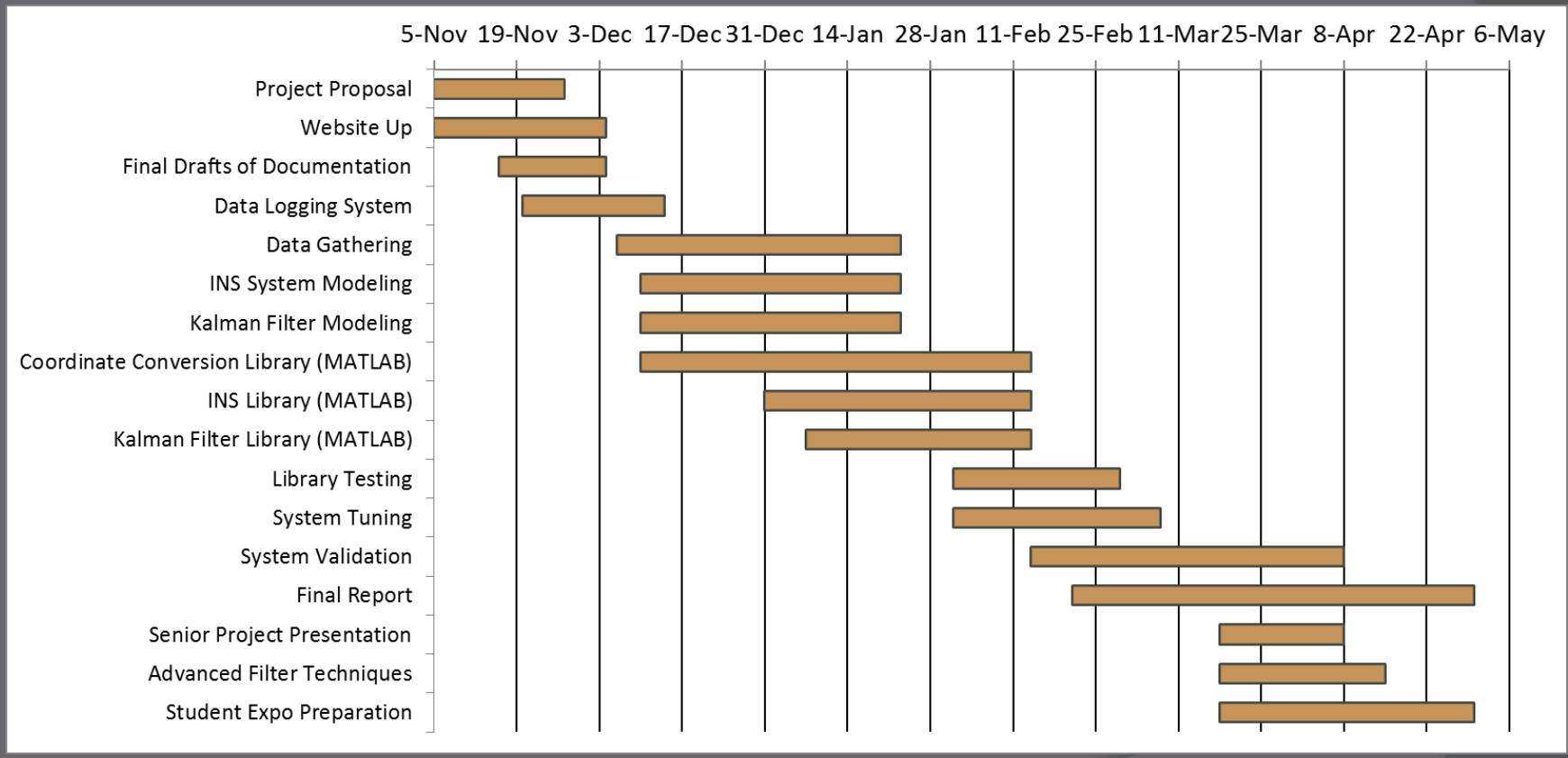
Current Work

- IMU
  - Sensor characterization
  - Measure inherent sensor noise
  - Measure sensor bias
- INS
  - Algorithm development for linear model

Future Work

- IMU
  - State space model of error sources
- INS
  - Full dimensional system
  - Correction computations for Coriolis effect
  - Attitude computations
- Integration
  - Loosely coupled system
  - Kalman filter design

Schedule


5-Nov
19-Nov
3-Dec
17-Dec
31-Dec
14-Jan
28-Jan
11-Feb
25-Feb
11-Mar
25-Mar
8-Apr
22-Apr
6-May
Project Proposal
Website Up
Final Drafts of Documentation
Data Logging System
Data Gathering
INS System Modeling
Kalman Filter Modeling
Coordinate Conversion Library (MATLAB)
INS Library (MATLAB)
Kalman Filter Library (MATLAB)
Library Testing
System Tuning
System Validation
Final Report
Senior Project Presentation
Advanced Filter Techniques
Student Expo Preparation

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