Lecture

Navigation Equations: An Overview

EE 565: Position, Navigation and Timing

Lecture Notes Update on Spring 2023

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The Fundamental Problem

- The fundamental inertial navigation problem:
  - Using inertial sensors (accels & gyros) and an initial position and orientation, determine the vehicle's (i.e., body frame) current position, velocity, and attitude (PVA)
  - Assumptions:
    1. Know where we started (initial PVA: $\vec{r}^{\,?}_{?b}$, $\vec{v}^{\,?}_{?b}$, & $C^{?}_{b}$)
    2. Inertial sensors ($\vec{\omega}^{\,b}_{ib}$ and $\vec{f}^{\,b}_{ib}$)
    3. Have a gravity ($\vec{g}^{\,?}_{b}$) and/or gravitational ($\vec{\gamma}^{\,?}_{?b}$) model
  - Where am I? Current PVA?
    - With respect to which frame?

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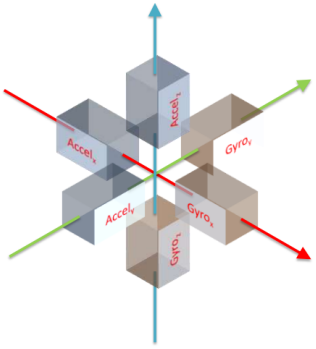
Inertial Navigation

- The process of "integrating" angular velocity & acceleration to determine one's position, velocity, and attitude (PVA)
- To measure the acceleration and angular velocity vectors we need at least 3-gyros and 3-accels
  - Typically configured in an orthogonal triad
- The "mechanization" can be performed *wrt*:
  - the ECI frame,
  - the ECEF frame,
  - the Nav frame, or
  - the tangential frame.



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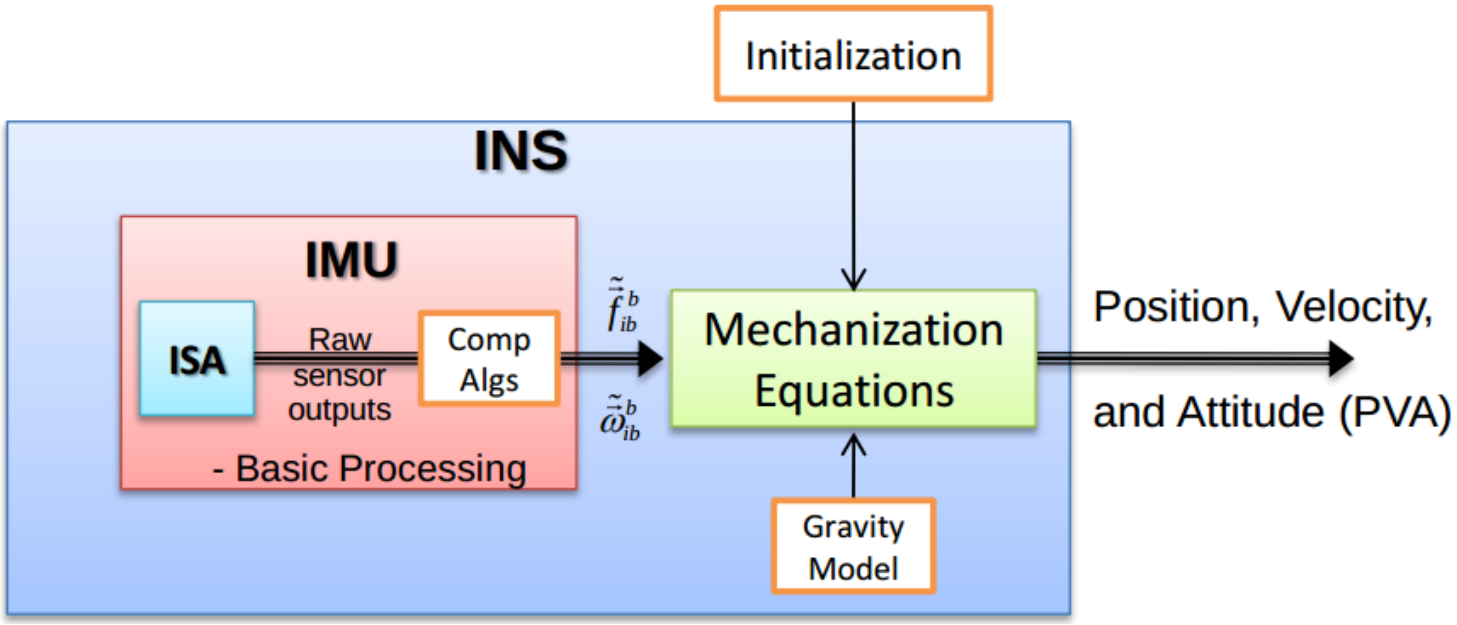
ISA, IMU, & INS

- An Inertial Navigation System (INS)
  - ISA — Inertial Sensor Assembly
    - Typically, 3-gyros, 3-accels, and basic electronics

- IMU — Inertial Measurement Unit
  - ISA + compensation algorithms (i.e., basic processing)
- INS — Inertial Navigation System
  - IMU + gravity model + "mechanization" algorithm



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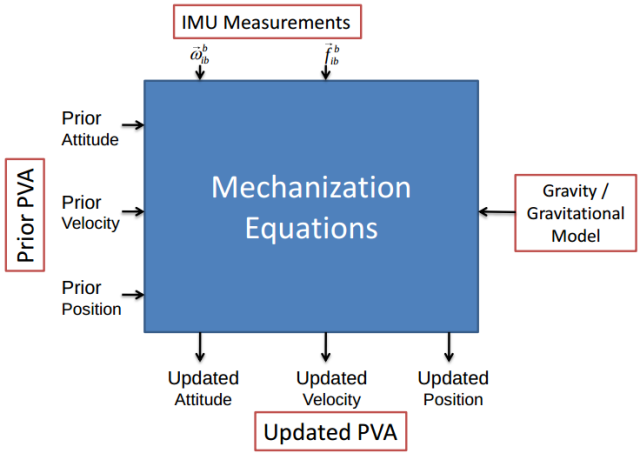
Mechanization Process



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A Four Step Mechanization

1. Attitude Update
   - Update the prior attitude using the current angular velocity
2. Transform the specific force measurement ($\vec{f}_{ib}^{\,?} = C_b^? \vec{f}_{ib}^{\,b}$)
   - Typically, using the attitude computed in step 1
3. Update the velocity

- Essentially integrate the result from step 2 with the use of a gravity/gravitational model ($\vec{f}_{ib} = \vec{a}_{ib} - \vec{\gamma}_{ib}$)

4. Update the position
   - integrate the result from step 3

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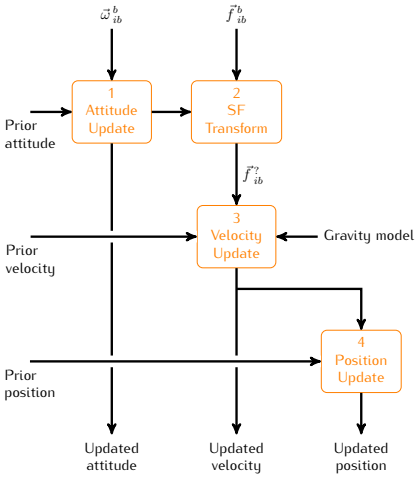
A Four Step Mechanization



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