SENSORS: Networked Micro-Navigation Sensors and Laser Alignment In Space

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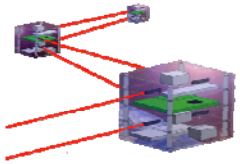
Objective

To design and build a position and orientation sensor network for small satellites using a Global Positioning System (GPS) receiver, a solid state inertial measurement unit (IMU), and lasers.



Project Description

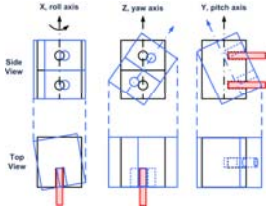
Multiple small satellites are more cost-effective to build and launch; more flexible in mission execution; and more robust than a single large satellite. Small satellites equipped with micro-navigation sensors such as a GPS receiver and an IMU provide position and orientation information for the satellites. In order to improve the orientation accuracy of the satellites, we introduce a laser alignment method, micro-navigation sensor uses two laser beams to align two satellites in the space. A micro-navigation sensor satellite with accurate navigation information will act as a reference satellite with known position and orientation. Two laser beams and the small divergence angle of the laser guarantee the consistency of the orientation relation between two aligned satellites. Therefore, an accurate orientation is maintained in the micro-navigation sensor network using lasers. The challenge is to target the photodiodes so the orientation information transfer can occur. We investigate the use of gimbals, solar panels, and advanced control theory to control two laser beams.

Components and Functions

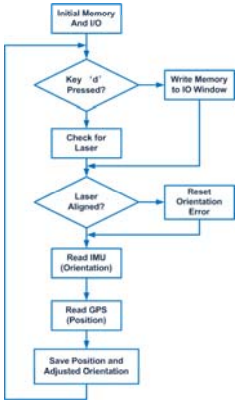
- GPS – Orbit Information
- IMU – Orientation Information
- Lasers – Orientation Transfer
- Photodiodes – Orientation Information Receiver
- Transceiver
- Microcontroller

μNav sensor and its components

Technical Approach and Innovations

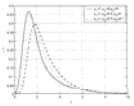


- Laser Alignment: A novel alignment technology will be developed using two laser beams.
  - Update orientation information.
  - Attitude coordination of multiple satellites.
  - Laser orientation information transfer analysis using epidemic model.
  - Optimal algorithm for multiple satellite orientation improvement
- Multi-sensor integration: Global Positioning System, MEMS Accelerometers, MEMS Gyroscopes, Laser Integration
- μNav Sensor Network: Sensors share the orientation information with the neighboring sensors via RF link.
- Targeting: Nonlinear Control for laser targeting
  - Deterministic Optimal Control
  - Statistical Control – LQG/MCV/RS Control
  - Discrete Event System and Satellite Automata
  - Hybrid Control
  - Control of Micro-Navigation Sensor Network



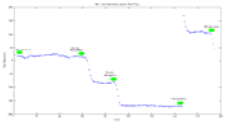
Societal Impact

- Exposure of Aerospace Projects
  (2 Grads, 5 Undergrads, best senior design project)
  - CanSat Senior Design (3 URG)
  - Multisatellite Control (2 Grads)
- New Spacecraft Systems Engineering course (17 students)
- Educating Underrepresented Groups (1 Undergrad.)

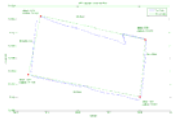


Major Accomplishments

- Fast Alignment method Using Rotation Vectors
- Nonlinear Control
  - Deterministic Optimal Control: Control-Affine Nonlinear System
  - Statistical Control: Cumulant HJB Equations
- Multi-sensor Integration

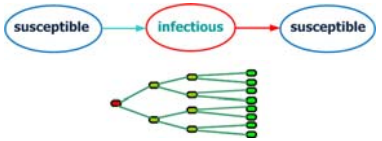


Orientation Test

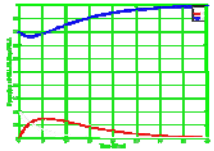


Position Test

- Orientation Information Transfer Analysis using Epidemic Model
  - We noted that the alignment process is similar to the epidemic disease dissemination process in the way that an infected individual can infect other susceptible individuals through the contact. Once a susceptible individual is infected, it becomes infectious and can infect other susceptible individuals via contact. Therefore, we use the concept of Susceptible–Infected–Susceptible (SIS) epidemic model to analyze the orientation information transfer process in satellite network. Simulations demonstrate the feasibility of analyzing the behavior of a satellite network using concepts of epidemic model.



SIS epidemic dissemination process



Confidence Level Transfer Simulation

Potential Other Applications

- UAV, UGV
- Robust navigation system for a walking person

Personal Navigation System

CSNAP
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