Lunar Satellite Attitude Determination System

SENIOR DESIGN
PROPOSAL PRESENTATION

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Background: Lunar Satellites

Manned (Orbital and suborbital) & Unmanned (Earth Orbit and Lunar Orbit)
Lunar Satellites include:

- **Clementine**—US Navy mission, orbited Moon, detected hydrogen at the poles
- **Luna 1**—first lunar flyby
- **Luna 2**—first lunar impact
- **Luna 3**—first images of lunar far side
- **Luna 9**—first soft landing on the Moon
- **Luna 10**—first lunar orbiter
- **Luna 16**—first unmanned lunar sample retrieval
- **Lunar Orbiter**—very successful series of lunar mapping spacecraft
- **Lunar Prospector**—confirmed detection of hydrogen at the lunar poles
- **SMART-1** ESA—Lunar Impact
- **Surveyor**—first USA soft lander
- **Chandrayaan 1**—first Indian Lunar mission
Background: Attitude Determination

- **Spacecraft**: A vehicle intended to be launched into space.
- **Attitude**: Orientation in space or transformation between a body frame and a reference frame.
- **Attitude determination**: Computing the spacecraft attitude from optical sensor measurements and ephemeris information. (Sun, Stars, Earth, Moon)

**WHY?**

**Torques (Disturbance)**

- Gravity gradient
- Solar radiation
- Atmospheric drag
- Magnetic torque
- Internal Forces
Closed loop (actuators controlled on board), Active (uses electricity or propellant).
Problem Formulation

- Customer wants to fly a simple, low-cost spacecraft near the Moon.
- A simple system to determine the attitude is needed.
- Design system, Build prototype, **Test prototype on Ground**.
- No magnetic field or GPS.
- Sun and/or Moon observations (not simultaneous)
- Coarse degree of accuracy needed
- Onboard Processing (real mission), External computer Processing (prototype).
Current Status of Art

- **Deterministic Method**
  - Measurements of two vectors in body frame
  - Know these vectors in the reference frame
  - Ephemeris, calculations (need to know position in orbit)
  - Find the rotation matrix, i.e. the attitude

- **Estimation Method**
  - Measurements of one vector in body frame
  - Recursive process
  - State estimation
  - Facilitated by gyros measurements

- **Example**
  LRO- Lunar Reconnaissance Orbiter
Current Status of Art

Current Systems’ main focus (Advantage)
- Null rotation rates to prevent data corruption

Achieved by
- Rate Sensors
- Sun Sensors
- Occasional Star tracker usage
- Reaction Wheels

Disadvantage
Sequential Estimation (Iterative), Required Algorithm (Complex)
Solution Approach

Impractical to use a real satellite. Hence the following:

- Earth Rotation (orbital motion)
- Servos or stepper motors (attitude motion)
- Box mounted on a tripod with a simple Sun or Moon optical sensor
- Control loop driving a servo to track the Sun or Moon.
Attitude Representation

Representation of attitude

- **Frame of reference**
  - Inertial frame
  - Orbit frame

- **Give orientation with respect to that frame**
  - Euler Angles
  - Quaternion

Tasks

LUNASAT Timeline

- Needs: 0
- Topic/Problem Formulation: Start 1, Duration 2
- Problem Solving/Alternative Designs: Start 2, Duration 2
- Best Design/Implementation Plan, Evaluation Plan: Start 3, Duration 4
- Solution Implementation/Problem Solving: Start 7, Duration 2
- Solution Implementation/Evaluation: Start 9, Duration 7
- Test/Evaluation: Start 16, Duration 2
- Final Report: Start 18, Duration 2
- Final Presentation: Start 19, Duration 2
Project Management

Danah – Project Manager.
- Checks up on individual tasks
  - Enforce timelines
  - Keeps track of meeting minutes
- Makes sure that all individual assignments are combined together appropriately.

Oluwayemisi – Lead Researcher.
- Research problem and constraints
  - Implement solution

Tolulope – Lead Developer.
- Simulation
- Code writing
Verification Plan and Deliverables

- **Lunar Satellite Attitude Determination System**
  - Input: Optical Sensors
  - Control Unit: Computer
  - Output: Visual

- **Demonstration Environment**
  - Gravity
  - Random Torques
Cost and Resources

- Total Cost < $1000
- Sensors
- Computer
- Box (Container)
- Less than 10 watts of power.
Conclusion

- Attitude determination and control = key component of satellite inspection and orbital rendezvous missions
- Simple Attitude determination System is needed.
- Prototype would be tested on ground
- Prototype would make use of Optical Sensors
- Finish Date: March 2010