Attitude Control optimization of a Virtual Telescope for X-ray observations

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Outline

- Mission
- Orbit design
- Satellites’ dynamics
- Designing Guidance, Navigation and Control (GNC)
- Mission’s phases design
- Optimization phase
- Conclusion
Mission

Virtual Telescope for X-ray Observations

Attitude formation control with sub-arcsecond accuracy

Highly eccentric geostationary orbit

Approximately 1 hour observing the Crab Nebula
Orbit Design

- The orbits have the same parameters except the eccentricity
- Same period
- Collision avoided
GNC and Optimization

Objective function = Energy consumption and Error

- Initial conditions read by sensors, Ratio of error to energy
- Experiment phase
- Neural network
- Multi objective genetic algorithm
- Various initial conditions

Optimization phase

- Optimal parameters
- Desired Trajectory
- Controller
- Reaction Wheels
- Plant

GNC Plant System

- Extended Kalman filter
- plant
- Sensors
- Plant System

Training phase
Mission’s phases Design

- Phase 1:
  - The development phase
- Phase 2:
  - Scientific phase
- Phase 3:
  - Semi-open-loop formation phase

### Mission phases specifications

<table>
<thead>
<tr>
<th>Phase</th>
<th>Controller</th>
<th>Sensors and filter</th>
<th>Camera</th>
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<tbody>
<tr>
<td>Phase 1</td>
<td>Sliding mode/PD</td>
<td>On</td>
<td>Off</td>
</tr>
<tr>
<td>Phase 2</td>
<td>Sliding mode/PD</td>
<td>On</td>
<td>On</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Anti gravity gradient</td>
<td>Off</td>
<td>off</td>
</tr>
</tbody>
</table>
Phase 1: Development phase

Objective function = Energy consumption and Error in the last 30 seconds

- Initial conditions read by sensors, Ratio of error to energy
- Optimal parameters
- Desired Trajectory
- Optimal parameters
- Extended Kalman filter
- Controller
- Reaction Wheels
- Plant
- Sensors
- Plant System

- Neural network
- Experiment phase
- Multi objective genetic algorithm
- Various initial conditions
- Training phase
Phase 1: Development phase

Objective function = Energy consumption and Error in the last 30 seconds

- Initial conditions read by sensors, Ratio of error to energy
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- Optimal parameters
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- plant
- sensors
- Extended Kalman filter
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- Plant System
Neural network performance

PD Controller

Best Validation Performance is 0.069859 at epoch 921

SMC

Best Validation Performance is 0.0005864 at epoch 823
Results - Development phase

**PD Controller**

**SMC**
Phase 2: Scientific phase

Objective function = Energy consumption and Error

- **Ratio of error to energy**
- **Desired Trajectory**
- **Controller**
- **Extended Kalman filter**
- **Neural network**
- **Multi objective genetic algorithm**
- **Reaction Wheels**
- **Plant System**
- **GNC**
- **Optimal parameters**
- **Optimization phase**
- **Experiment phase**
- **Training phase**
- **Initial conditions**
Results - Scientific phase

PD Controller

SMC
average accumulated error (PD)=0.2219 deg

average accumulated error (SMC)=0.1738 deg
Results - Semi open loop formation
Conclusion - Future Work

• The controllers are robust against system uncertainty.

• To reach the desired sub-arcsecond accuracy, we need to introduce additional constraints and techniques, such as relative position, more sensors, image processing techniques, filtering techniques, and machine learning techniques.

• In the future work, the third angular velocity, which is the axis pointing at the Crab Nebula, will be set for better accuracy, and the energy consumption will be optimized for the whole system.

• In the current research, the PD controller and sliding mode controller give similar results. In the future, the nonlinearity of the system will increase by the relative position control coupled with the system and these controllers response will be examined.

• In the future work, reinforcement learning algorithms as controlling techniques will be implemented on the system, and the accuracy will be compared to the current controllers.
Questions/Comments?

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