MULTI-OBJECTIVE OPTIMIZATION OF SPACECRAFT TRAJECTORIES FOR SMALL-BODY COVERAGE MISSIONS

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INTRODUCTION

- Small-body landing and topographical navigation operations require surface information.
- Topographical maps require images to be taken that meet a standard of “coverage.”
- For a given trajectory, the targeting sequence of images is a nontrivial optimization problem.
COVERAGE DEFINITION

• Emission angle: $\alpha$
• Incidence angle: $\beta$
• Spacecraft azimuth angle: $\gamma$
• Solar azimuth angle: $\delta$
### COVERAGE IMPLEMENTATION

**Super-Increasing List**

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<th>$...$</th>
<th>$ea_n$</th>
<th>$ia_1$</th>
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<th>$sca_1$</th>
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<td>$...$</td>
<td>$m+n$</td>
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<td>$m+n+q$</td>
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<tr>
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<td>$...$</td>
<td>$2^n$</td>
<td>$2^{n+1}$</td>
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<td>$2^{m+n+1}$</td>
<td>$...$</td>
<td>$2^{m+n+q}$</td>
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</tbody>
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NON-DOMINATED SORTING GENETIC ALGORITHM-2


• Multi-Objective Evolutionary Algorithm (MOEA)

• Non-Domination and the Non-Dominated Front
TEST PROBLEM

• Body of interest: Bennu
• 45° inclined trajectory initialized at 2 km from center of mass in the equatorial plane
• “Circular” initial velocity
• Timespan of 5 days with image opportunities every 5 minutes
• Objectives:
  • Maximize coverage
  • Minimize required change in rotation rate
MAXIMUM ACHIEVABLE COVERAGE
RESULTS

1750 generation
RESULTS

500 generation

1000 generation
RESULTS

Coverage: 24.2832%
Change in rotation rate: 58.8 degrees/s
RESULTS

1750 generation
CONCLUSION

• This implementation of NSGA-2 produced a set of non-dominated solutions that are able to recover 96.2% of the possibly covered area.

• This is intended as the inner-loop solver for a Multi-Objective Hybrid Optimal Control Algorithm where the outer-loop optimizes trajectories and the inner-loop optimizes observation schedules for those trajectories.
  • This would be a Hybrid Optimal Control architecture where both the inner and outer loops are multi-objective.
  • The optimized trajectories alter the bounded possibilities of the inner loop so as to provide the potential for greater coverage and lessened attitude control effort.