Persistent Ocean Monitoring with Underwater Gliders: towards accurate reconstruction of dynamic ocean processes

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Introduction: Persistent Ocean Monitoring

Path Planning for Continual Observation

- Collect a long time-series data set
- Generate a closed-loop, zig-zag path
- Optimize for repeatability
- Reward for visiting high-interest regions
- Penalty for navigating through areas of high magnitude currents
- Solved by use of Dijkstra's Algorithm

Optimize Spatiotemporal Sampling Resolution

- User-defined high-interest regions with associated relative importance given
- Sample areas of higher interest with greater resolution
- Optimize the vehicle velocity along the path
  - Closed-loop must be completed in a given time
  - Changes in velocity for a glider correspond to alterations of the dive and ascent pitch angles along the sawtooth trajectory
- Convex optimization problem

Problem Description: Resolve Multiple Dynamic Processes Occurring at Multiple Scales

Problem Statement

- Given
  - Area of interest with designated regions of high-interest (Qᵢ)
  - Relative importance of each region (pᵢ)
  - Historical data of ocean current magnitude and direction
  - Time budget for closed-loop path traversal
  - Range of velocities for the mobile sampling platform
- Goals
  - Compute a single, repeatable path that is continually traversed by a vehicle to generate a long time-series data set.
  - Optimize the velocity of the vehicle to alter the spatiotemporal sampling resolution throughout a region of interest.
  - Use collected data to resolve dynamic ocean processes occurring at multiple scales both spatially and temporally.

Proposed Solution: Persistent Ocean Monitoring with Underwater Gliders

A schematic example of a computed glider path. Regions of interest Qᵢ and associated user-defined importance pᵢ. The sawtooth pattern that the glider follows along each path segment j is shown with its relevant parameters labeled. The sawtooth pitch Φᵢ controls the sample density.

General overview of the experimental area. The mission domain Q is delineated by the white polygon. Regions Q₁, Q₂ and Q₃ are high interest regions (red, green and yellow polygons, resp.) The yellow lanes are the primary shipping lanes for Long Beach Harbor.

EXPERIMENTAL DATA AND PATH COST FOR THE IMPLEMENTATION OF THE REFERENCE PATH WITH STANDARD OPERATING GUIDELINES, REFERENCE PATH WITH VELOCITY CONTROL, AND THE COMPUTED PATH WITH VELOCITY CONTROL.

<table>
<thead>
<tr>
<th></th>
<th>Reference Path (Standard)</th>
<th>Reference Path with Velocity Control</th>
<th>Computed Path with Velocity Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prescribed Path Length (km)</td>
<td>97.3</td>
<td>97.3</td>
<td>99.2</td>
</tr>
<tr>
<td>Actual Distance Traveled (km)</td>
<td>93.3</td>
<td>4.58</td>
<td>105</td>
</tr>
<tr>
<td>Total Traversal Time (h:mm)</td>
<td>110 : 02</td>
<td>105</td>
<td>102</td>
</tr>
<tr>
<td>Navigation Score (km²)</td>
<td>70.35</td>
<td>13.35</td>
<td>86.06</td>
</tr>
<tr>
<td>H(W², λ)</td>
<td>-20, 280</td>
<td>-20, 280</td>
<td>-24, 638</td>
</tr>
</tbody>
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