Title
Automated Mapping and Exploration

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Automated Mapping and Exploration

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Automated 3D Bathymetric Mapping and Efficient Exploration

Construct high resolution 3D maps of aquatic environments

- Accurate mapping of aquatic environments is important for both human activities and for marine scientists
- Mapping challenges – Navigational, sensor & dynamic modeling errors.

Application Areas

- Marine Environmental Biology
  - Obtain volume information to estimate biomass
  - Estimate biomass changes due to tidal flow and cycling
  - Obtain depth profile to select areas of interest (for further biological exploration)
- Marine Navigation
  - Plan safe paths for marine vessels
- Search
  - Locate objects of interest

Problem : Efficient Exploration for generation of high resolution 3D Bathymetric Maps

- Robotic boat
  - Equipped with a Global Positioning System (GPS), Inertial Measurement Unit (IMU) and a profiling sonar
  - Autonomous navigation capability
- Build a bathymetric map of a given water body
  - Classify portions of volume as unobstructed (water) or occupied (floor or obstacle)
- Explore the water body efficiently
  - Constraints on time, energy and boat dynamics
  - Path planning
  - Efficiency metrics
    - Uncertainty of the complete map vs. time
    - Explored volume vs. time

Proposed Solution: Priority Exploration of Regions with Higher Expected Information Gain

- Mapping Strategy
  - *3-D grid* based representation of the water volume
  - State of grid occupancy is represented using a probability distribution P(x) Є [0,1]
  - Integrate Sonar data into the map
- Exploration strategy
  - For each grid location x, compute the uncertainty in the knowledge about its occupancy. This will be the *maximum information gain* on exploring the location:

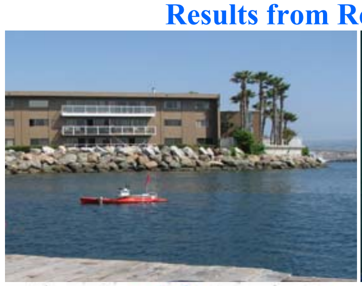
$$IG(x) = -p(x)\log p(x) - (1-p(x))\log(1-p(x))$$

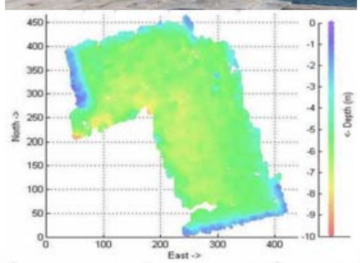
  - Determine unexplored frontiers *(i)* and compute the expected information gain on visiting and exploring them
  - Select frontier which maximize the cost function:

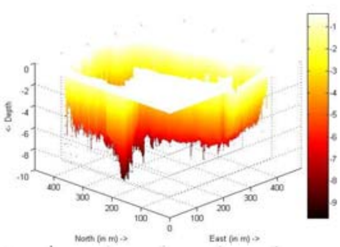
$$\arg\max_{i \in frontier} \{K_1 * IG_i + K_2 * f(\text{distance, time, } IG_{path})\}$$

  - Plan the most efficient path to frontier
  - Repeat until all areas are explored or {distance, time, energy} limit is reached

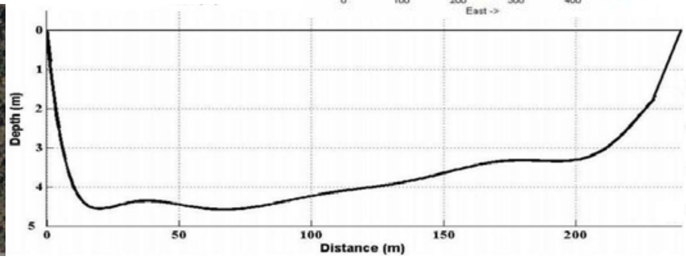
Results from Redondo Harbor

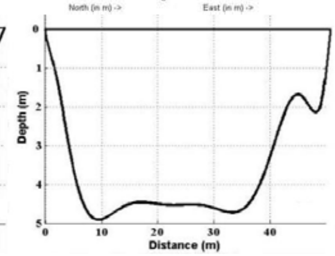


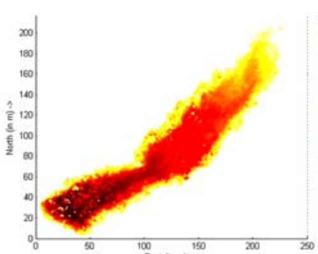


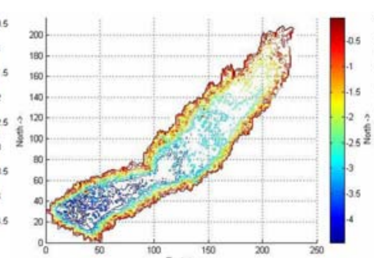


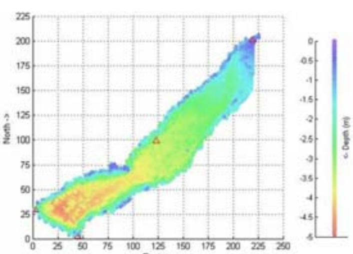
Results from James Reserve











Work in progress

- Evaluate the performance of exploration strategy
- Evaluate performance by adding additional degree of freedom (sonar scan angle)
- Adapt model for exploration using multiple robots
- Real time implementation on the robotic boat