Improved State Estimation of a Resilient Spacecraft Executive

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20th August 2015
Autonomous vehicles for space exploration
Outline

• Background
• Objectives
• Experimental framework
• Results
• Discussion
• Future work
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Risk-aware Resilient Spacecraft Executive

- Navigate environment with resilience
- Handle uncertainty in unknown hazardous environments
- Observe environment and make risk-aware decisions
- Adapt to its own component failures

McGhan, Murray et al., 2015
(a) Risk-averse situation

Be risk-averse.

Let’s stay away from the cliff…

(b) Risk-taking situation

You are allowed to take greater risk now.

Let’s check out what’s down there…

McGhan, Murray et al., 2015
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Objectives

Real-time mapping and localization

Obstacle avoidance algorithm

Zaman, Slany et al., 2011
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Experimental framework

• Resilient Software Architecture (RSE)

• TurtleBot robot and simulation on Gazebo

• Robot Operating System (ROS)

• Hokuyo laser sensor

• GMMapping for laser-based Simultaneous Localization and Mapping

• Obstacle avoidance and path planning
Experimental framework

Gazebo

RViz

Riashat Islam (riislam@caltech.edu) Improved State Estimation
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Real-time dynamic mapping

Map of 12 Steele Lab – TurtleBot hardware with Hokuyo sensor without overhead tracking
Demo: Real-time dynamic mapping
Autonomous navigation with environment map

Green path showing navigation path from initial pose estimate to the goal state
Demo: Autonomous navigation with environment map
Local path planning and obstacle avoidance – Bug2 algorithm

Howie Choset et al., 2010
Path planning algorithm

Bug2 Pseudocode

1: $L_0 \leftarrow \text{init}; \ i \leftarrow 1$
2: \textbf{loop}
3: \quad \textbf{repeat} move on a straight line from $L_{i-1}$ to goal
4: \quad \textbf{until} goal is reached or obstacle is encountered at $H_i$
5: \quad \textbf{if} goal is reached \textbf{then} exit with success
6: \quad \textbf{repeat} follow boundary
7: \quad \textbf{until}
8: \quad \quad (a) goal is reached or
9: \quad \quad (b) $m$-line is re-encountered at $Q$ such that $Q \neq H_i$, $d(Q, \text{goal}) < d(H_i, \text{goal})$, and line $(Q, \text{goal})$ does not cross the current obstacle at $Q$ or
10: \quad \quad (c) $H_i$ is re-encountered
11: \quad \quad \textbf{if} goal is reached \textbf{then} exit with success
12: \quad \quad \textbf{else if} $H_i$ is re-encountered \textbf{then} exit with failure
13: \quad \quad \textbf{else} $L_i \leftarrow Q; \ i \leftarrow i + 1$

Howie Choset et al., 2010
Obstacle avoidance algorithm
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Discussion

• ROS Gmapping compatibility with TurtleBot and Hokuyo sensor

• Creating ROS package for integration in RSE

• Dynamic map updates with moving obstacles

• Real time map updates with obstacle avoidance algorithm
Summary

• Hokuyo laser scanner for real-time mapping with ROS

• Integrated mapping capability into RSE architecture

• Autonomous path navigation with generated map

• Integrated obstacle avoidance algorithm alongside path planner
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Future work

• Hokuyo laser calibration and more accurate maps
  
  - Use overhead tracking system to give better state data than odometry

• Using dynamic map updates to determine robot motion

• Fallback modes of operation

• Risk metrics into path planning and obstacle avoidance
Acknowledgements

Professor Richard Murray

Dr. Catharine McGhan

Dr. Michel Ingham (JPL)

Dr. Tara Estlin (JPL)

Keck Institute for Space Studies for grant in this project

Caltech SURF program
Thank You

Questions...?