Marsupially-Aided Robotic Snake Exploration and Navigation of Cluttered Environments

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Problem

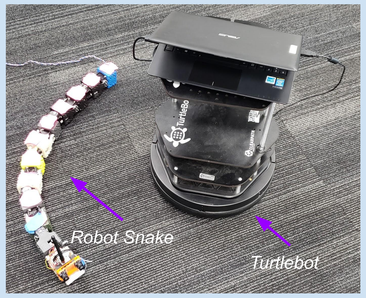
Use of mobile robots in exploration and search of disaster zones entails a variety of challenging terrain that must be traversed. A single platform is ill-suited to efficiently address all locomotive situations.

Marsupial robotics mimic marsupial relationships found in nature by pairing different platforms to exploit their **complementary strengths and weaknesses**. We pair a Turtlebot and robot snake to cooperatively explore and navigate complex obstacle scenarios. The snake robot is advantaged with a **narrow footprint** while the Turtlebot is endowed with greater **carrying capacity**, **processing power** and **faster traversal** of clear terrain.

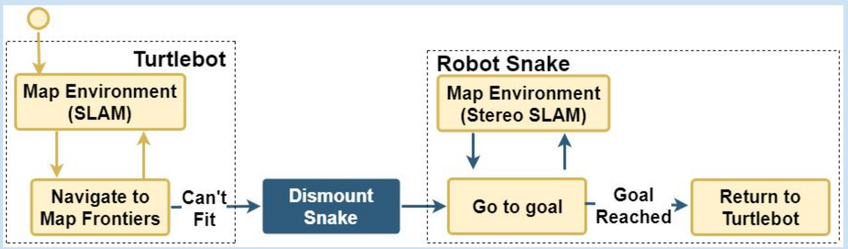
[1] Example of Disaster Zone

Marsupial Robotic System

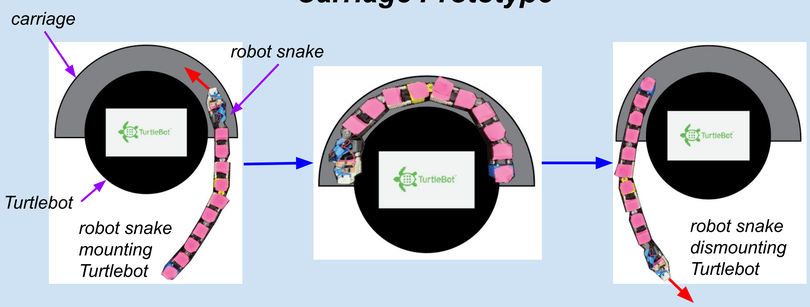
- Turtlebot transports robot snake in carriage
- Turtlebot explores and maps environment until reaching a gap that it can't traverse
- Robot snake dismounts to explore and map beyond the gap



Cooperative Robot Architecture



Carriage Prototype



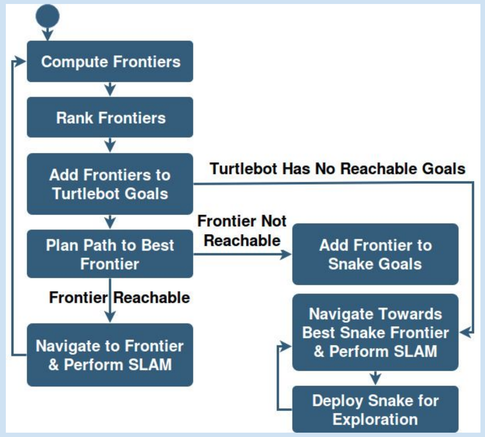
Prototype Turtlebot carriage designed for smooth mounting, transporting, and dismounting of robot snake.

[1] https://www.army.mil/article/161663/army_corps_urban_search_and_rescue_program_responds_and_trains_around_the_world

Turtlebot Exploration

Turtlebot: Differential drive vehicle capable of:
(a) backward-forward motion and **(b)** in-place rotation

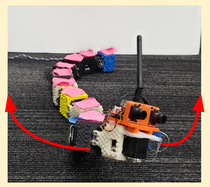
- Onboard sensing informs simultaneous localization and mapping (SLAM) used to explore, map and navigate
- Computed frontier centroids ranked by utility
- Centroids guide Turtlebot / snake exploration



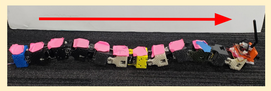
Robotic Snake Locomotion

Motion Primitives

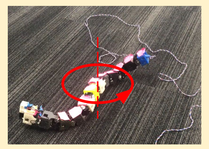
Head Scan
- Rear body is stationary
- Head lifts to scan local surroundings
- Wide field of view aids SLAM mapping



Rectilinear
- Traveling sine wave produces forward motion
- Body curvature along ground plane generates turning

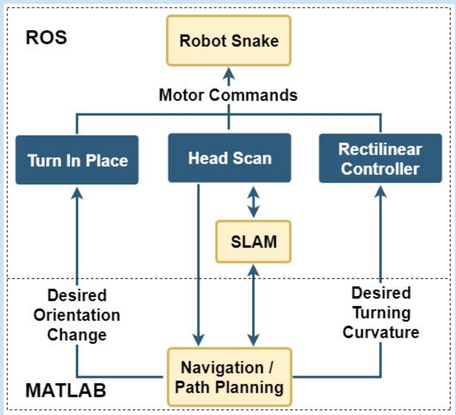


Turn-in-Place
- Produced by combining sinusoidal body waves
- Robot rotates in place

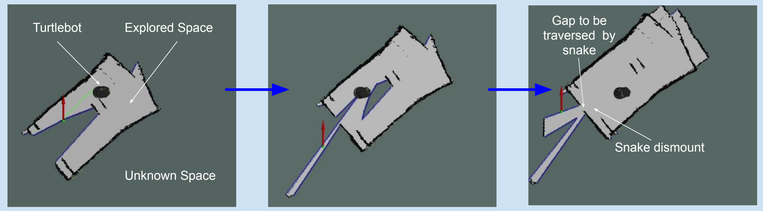


Controller Architecture

- Robot Operating System (ROS) controllers designed to command and manage each motion primitive (above)
- Navigation coordinator (MATLAB ROS node) commands individual controllers to accomplish "go-to-goal" tasks.

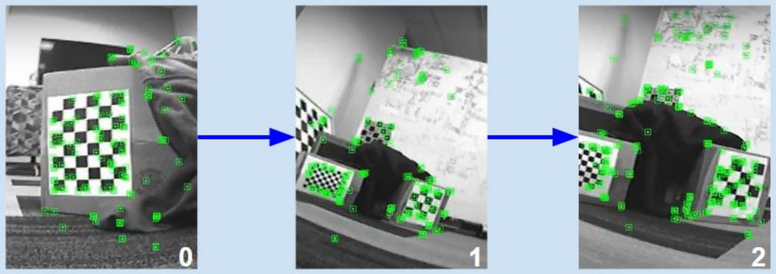


Obstacle-Strewn Scenario

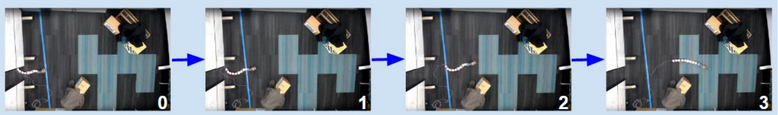


Turtlebot explores environment by navigating to frontier (blue lines) centroids (green dots) while performing SLAM.

Overhead view of Turtlebot exploration until reaching a dismount location for the robot snake.



Green squares are environmental features used to localize robot snake within the explored environment.



Robot snake travels through narrow gap and explores/maps environment beyond, using designed motion primitives.

Conclusion

- Turtlebot and robot snake cooperatively explore and map an initially unknown obstacle-strewn scenario

Future Goals
- Fuse maps independently explored by marsupial robots
- Integrate perception-based path planning into high-level robot snake navigation
- Design carriage mounting/dismounting motion primitives

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