Cooperative Exploration of Unknown Environments Using a Robotic Snake-Turtlebot Leader-Follower Pair

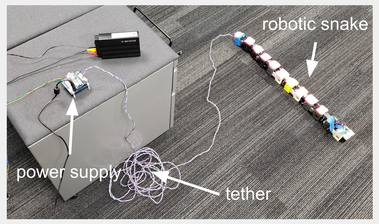
Alexander Faché, Sterling James, Kimberly Lie
PhD Mentor: Alex Chang, Faculty Advisor: Patricio Vela

ORS Opportunity Research Scholars' Program
School of Electrical and Computer Engineering
Georgia Institute of Technology

Problem

Evaluation/validation of novel robotic snake locomotive planning and exploration frameworks are limited by physical constraints (e.g. tethers, battery capacity, compute power.

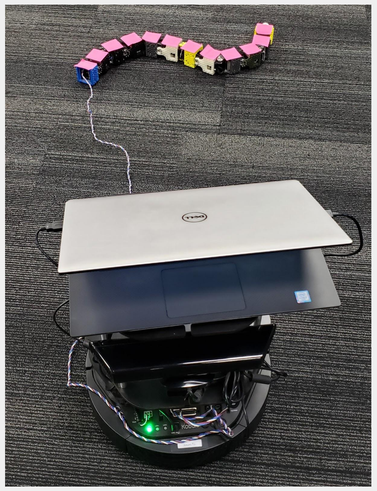
In research settings, experimental evaluation of snake-like robotic locomotion strategies can benefit tremendously from an ability to travel un-prohibited over large expanses of terrain. In order to realize such a capability, we adapt a Turtlebot to act as a 'follower' command center providing instructions, power, and computation.



Previous implementations prohibited free movement by snake-like robots.

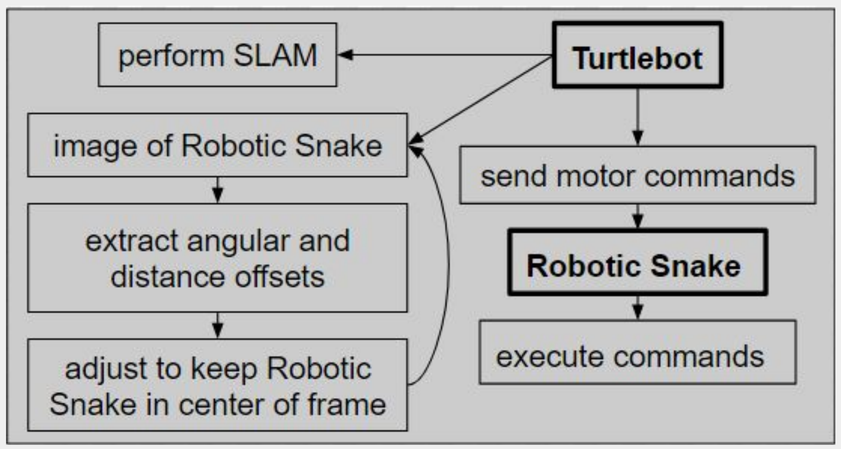
Leader-Follower Pair

- **Robotic Snake** (*leader*)
  - 10 Dynamixel motors
  - 3D-printed scales provide locomotive friction
  - *Tether* provides power and motor commands
- **Turtlebot** (*follower*)
  - Differential drive vehicle
  - *Robotic snake tracking*: Logitech C920 / Intel RealSense D435i cameras
  - Supplies power and commands to robotic snake



*Robotic snake (**top**) and Turtlebot (**bottom**)*

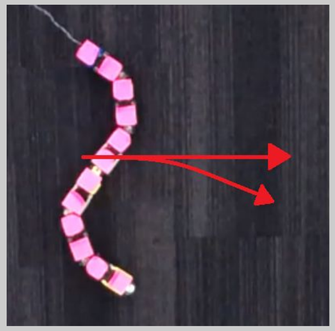
Leader-Follower Architecture



Robotic Snake Motion

- Robotic snake travels using different motion primitives

Sidewinding



- Robot ***translates laterally*** using a motion, mimicking bipedal motion
- Changes in the curvature of the 'average body' adjusts how straight the robotic snake travels
- Most locomotively efficient gait

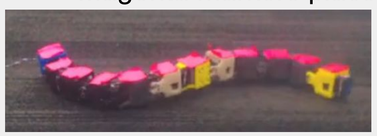
Turn-in-Place

- Two part gait cycle
  - Ends lift, body curls up
  - Ends drop, body straightens
- Accomplishes both ***clockwise*** and ***counterclockwise rotation***
- Minimal translation occurs

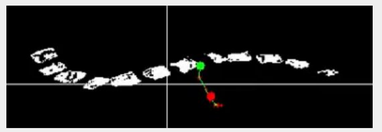
- Modulating parameters (e.g. amplitude, frequency) allows control of overall time-averaged gait motion

Turtlebot: Tracking / Planning

- Tracking of robotic snake
  - *Objective*: Keep robotic snake in center of Turtlebot camera frame and maintain a specified distance
  - Magenta markers placed on robotic snake



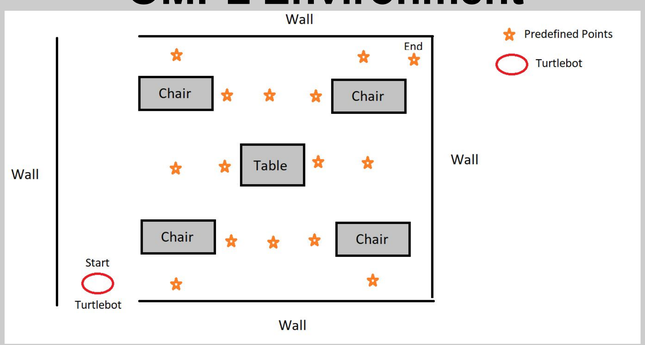
Robotic snake with magenta markers



Markers segmented from environment

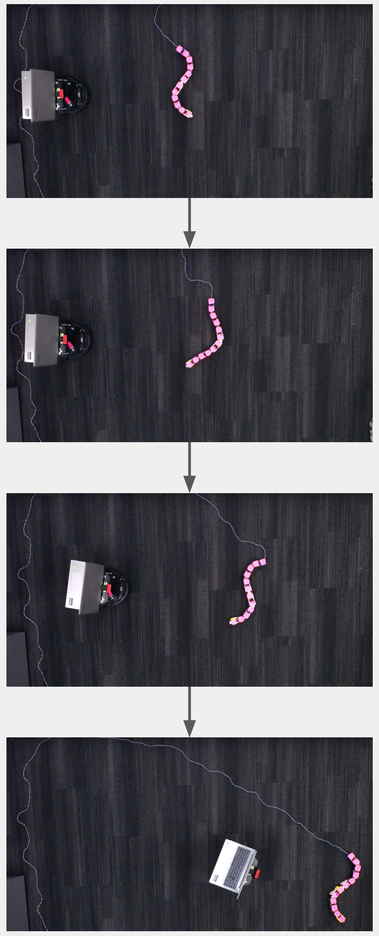
- Open Motion Planning Library (OMPL)
  - Used to plan paths for both Turtlebot and robotic snake between specified start and end positions

OMPL Environment



Leader-Follower Scenario

- Turtlebot tracks robotic snake that is executing sidewinding and turn-In-place motion primitives
  - Time proceeds from top-to-bottom



(1) *Initial position of Turtlebot and Robotic Snake.*

(2) *Robotic Snake is performing straight sidewinding with Turtlebot tracking.*

(3) *Continued command following and tracking.*

(4) *Final position.*

Conclusion

- Tracking system implemented: Turtlebot maintains robotic snake in center of view, following at specified distance
- Sidewinding motion controller implemented: Current robotic snake does not permit sufficient steering control

Future work

- Synthesize alternative sidewinding steering strategy
- Integrate tracking/following, planning, and gait control to accomplish Robotic Snake-Turtlebot leading/following

Georgia Tech School of Electrical and Computer Engineering
College of Engineering

Texas Instruments

NSF

IVALAB
Intelligent Vision and Automation Laboratory