Bat-Inspired Robot Navigation

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A Navigation Problem

Bats’ seemingly effortless navigation abilities have long fascinated scientists. We designed and implemented a system that enabled a robot to exhibit obstacle avoidance using echolocation.

Sonar System and Obstacle Detection

Information about an obstacle’s location lies in the differences between echoes in the left and right microphones:

- Figure depicts sonar system:
  - Speaker (like bat’s mouth) emits 40 kHz ultrasonic pulses
  - Two microphones (like bat’s ears) receive echoes off nearby objects
  - Echo is weaker in right microphone:
    - Directionality of microphone
    - Acoustical shadowing
    - Difference in distance

- MATLAB code filters signal envelope and detects peaks by:
  - Outgoing pulse creates first peak; successive peaks are from echoes
  - Amplitudes and times of echo peaks from each channel:
    - Determine obstacle location

- Interaural Level Difference (ILD) compares echo magnitudes in left and right microphones to determine angle:

  \[ ILD = 20 \log_{10} \left( \frac{ \text{Left Peak Amplitude}}{\text{Right Peak Amplitude}} \right) \]

  - 76% of trials estimated angle within ± 5°

Openspace Motion Planner

- In the MATLAB Openspace simulation, bat evaluates environment to develop best path to goal
- Evaluation function calculates the desirability of traveling in each possible direction based on the locations of the goal and obstacles
  - Additive Gaussian accounts for goal steering
  -Suppressive Gaussians account for each impeding obstacle
  - Winner-take-all selection chooses the direction with the maximum evaluation (red bar in figure)

System Overview

This figure details the flow of data in the real-time system. Once the Openspace evaluation function calculates the winner-take-all angle, a proportional controller adjusts the robot’s movement accordingly. Then the sonar system and obstacle detection code re-evaluate the environment to provide feedback.

Robot Performance

The robot displayed successful wander behavior through a variety of obstacle fields.

Conclusions and Future Work

Overall, the Openspace algorithm and sonar system worked together harmoniously, successfully navigating the robot through significant obstacle arrangements. Future developments would include incorporation of a GPS system to allow for world-coordinate feedback.

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References