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# Obstacle Avoidance and Boundary Following Behavior of the Echolocating Bat


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# Outline

- Motivation and goals
- ‘Open space’ algorithm
- Experimental flight room
- Data analysis
- Comparison of observed bat behavior to:
  - ‘Open space’ predicted trajectories
  - Time-delayed boundary curvature

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# Motivation & Goals

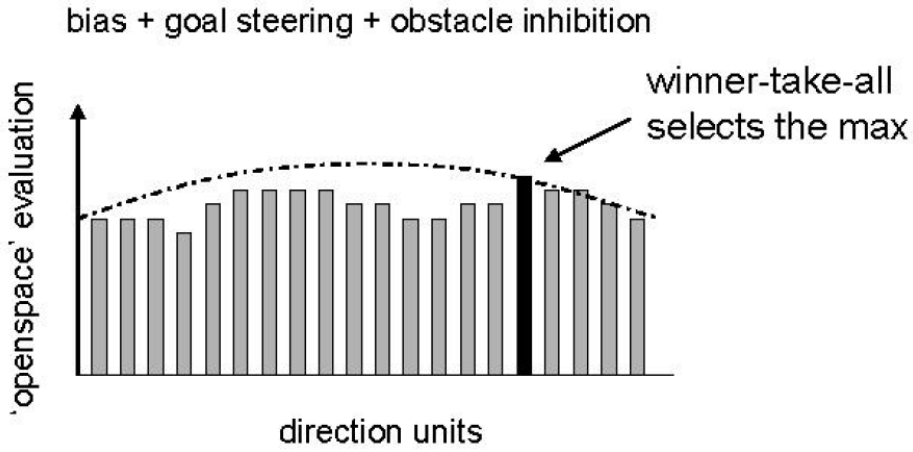
- **<u>Motivations</u>:**
  - Bats are experts in negotiating complex environments while in pursuit of prey.
  - Bats use an active sensing system: echolocation.
  - Previous work has elucidated strategies and sensorimotor feedback laws (Ghose *et al.* 2006, Reddy 2007).

- **<u>Applications</u> to robotics**

- **<u>Goals</u>: Understand sensorimotor feedback in**
  - Obstacle avoidance
  - Boundary following

# Open Space Algorithm

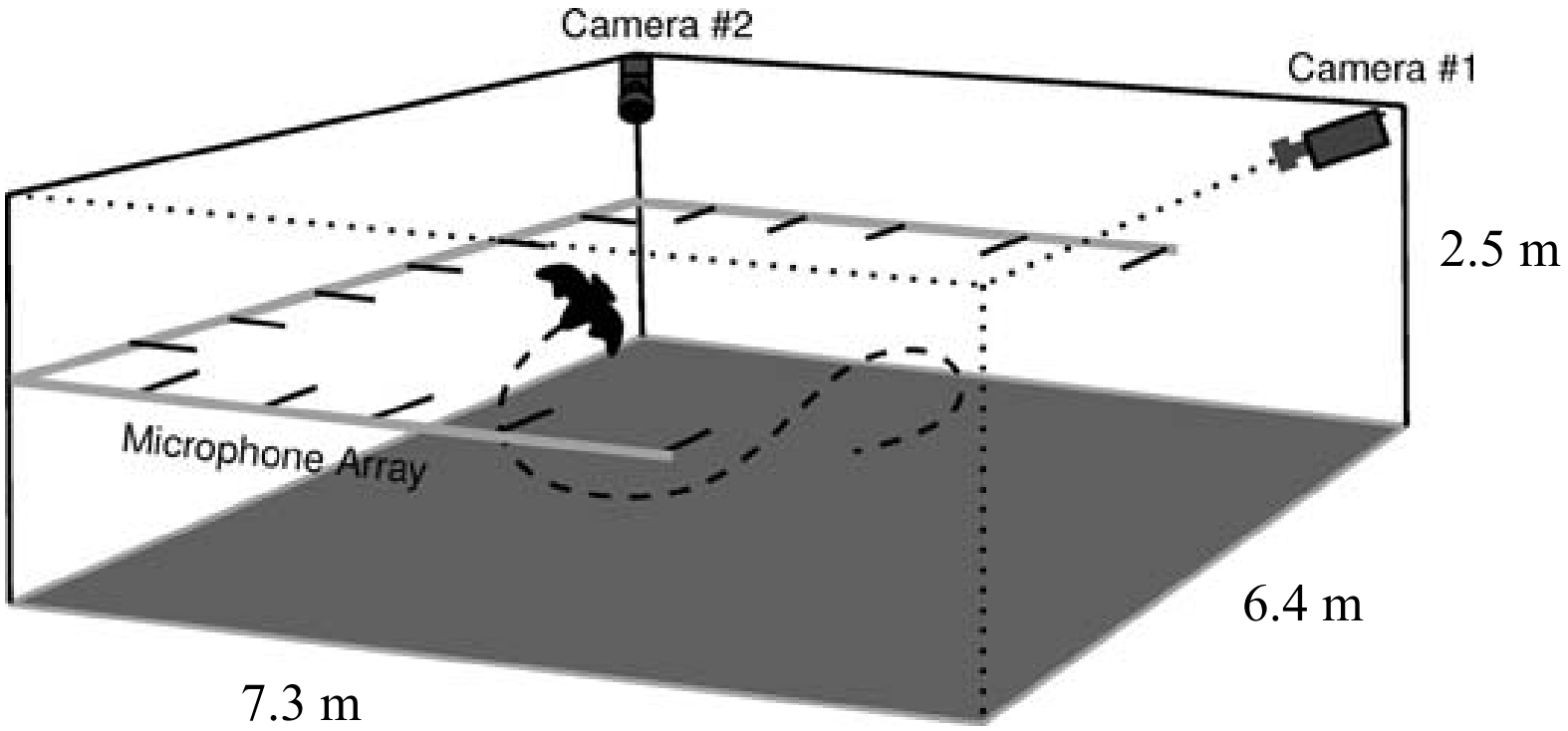
- Dr. Timothy K. Horiuchi (2006)
- Steering controlled by weighted directions
  - Goal Gaussian minus range-dependent obstacle Gaussian




(Horiuchi, 2006)

- Analog VLSI implementation using spiking neurons and winner-take-all circuit

# In The Flight Room




(Ghose *et al.*, 2006)

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# Obstacle Avoidance: Raw Video & Animation

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# Where is the bat “looking”?

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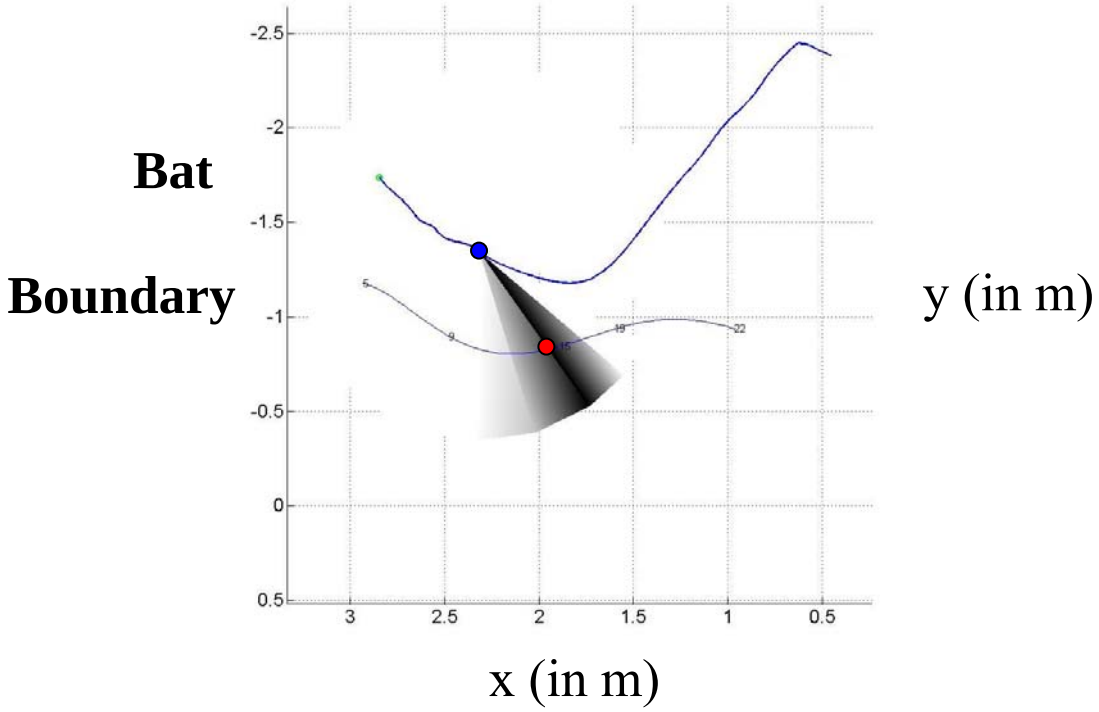
# Hypothesis Testing and Analysis

- Obstacle Avoidance: Goodness of fit of the 'open space' model?
- Boundary Following: Bat follows time-delayed curvature of boundary?



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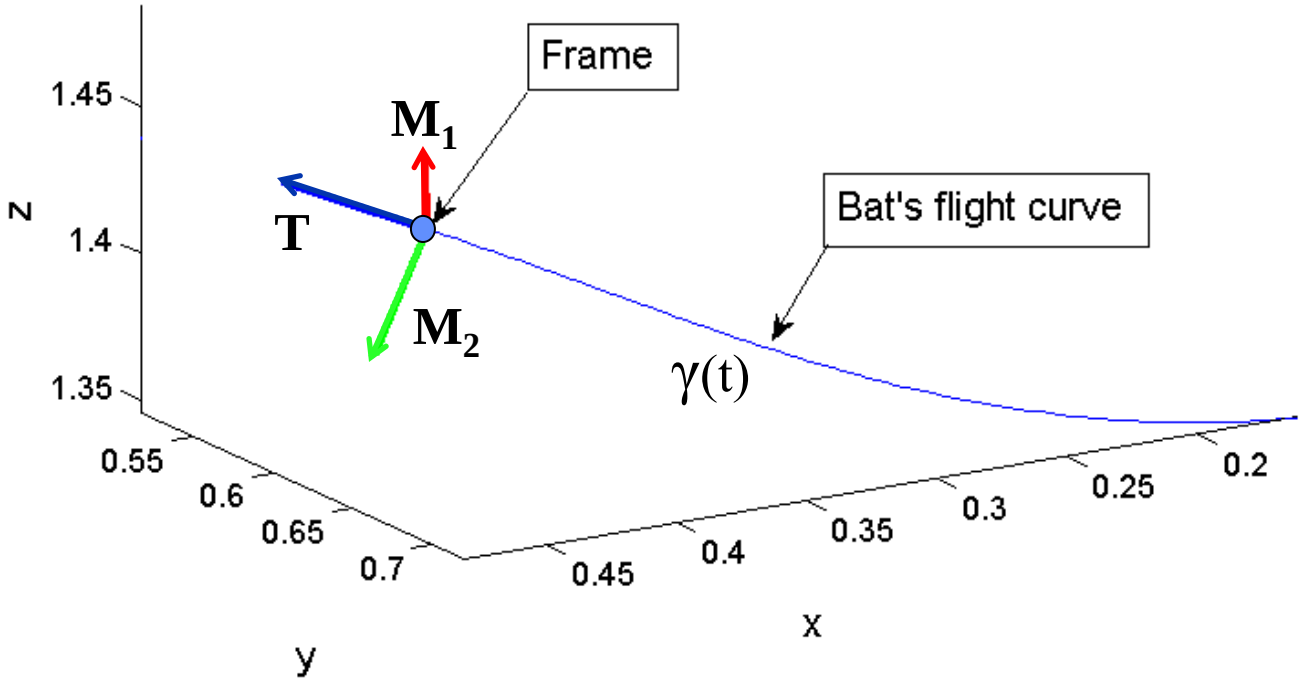
# Natural Frenet Frames: Sample Bat Frame



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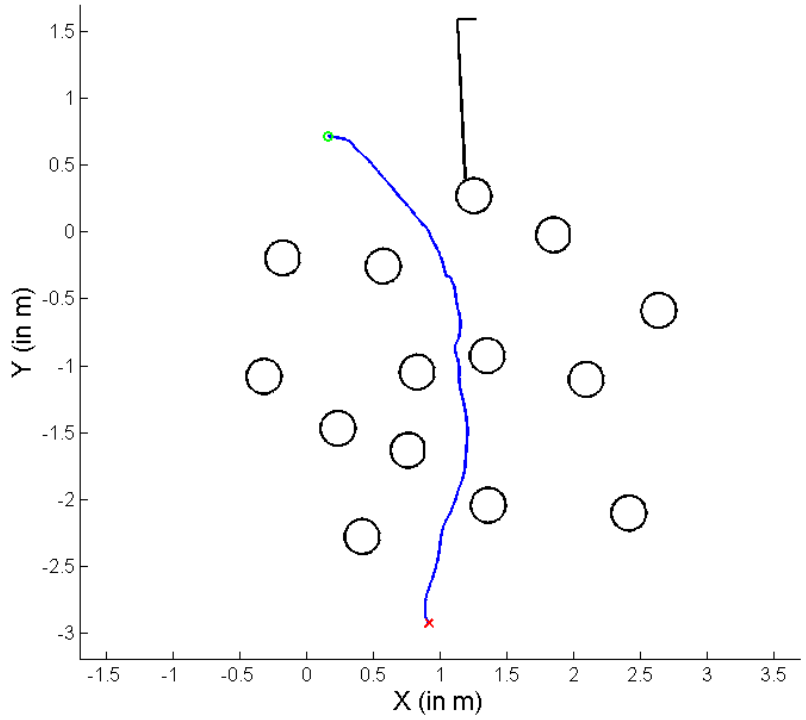
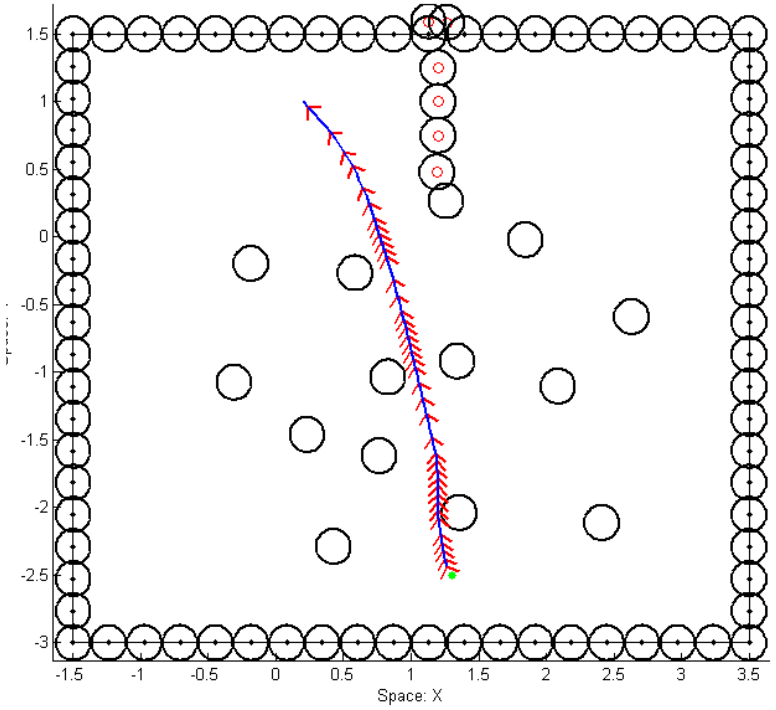
# Model of Obstacle Avoidance Behavior




Real bat flight path




Predicted flight path

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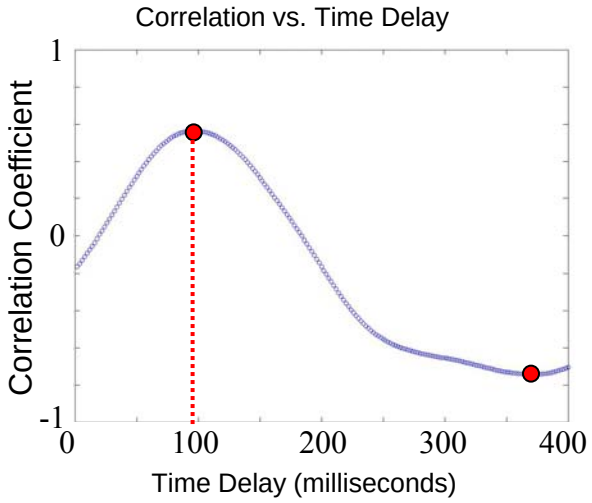
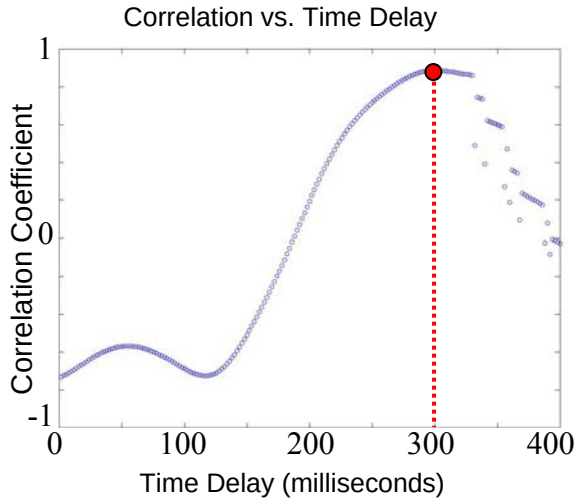
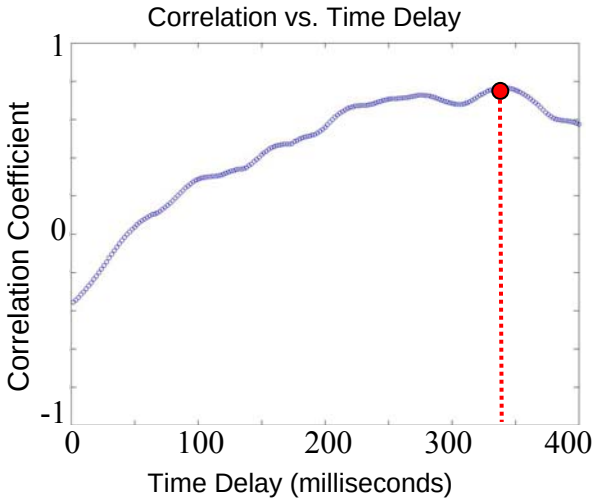
# Boundary Following




Max Positive
Correlation Coefficient: 0.5640
Time Delay: 98 ms
Number of Vocalizations: 29




Max Positive
Correlation Coefficient: 0.8856
Time Delay: 302 ms
Number of Vocalizations: 26




Max Positive
Correlation Coefficient: 0.7655
Time Delay: 340 ms
Number of Vocalizations: 38

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# Conclusion

- Initial results suggest:
  - ‘Open space’ algorithm is a viable model for bat’s obstacle avoidance behavior.
  - Bat’s flight path curvature is similar to time-delayed boundary curvature.
- However, these are only initial results.
- A more rigorous statistical examination is necessary.
- In future work, we hope to develop sensorimotor feedback laws describing observed behavior and implement them in a mobile robot.

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- Bats HP77, OR41 and HP76

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