Object Tracking and Selective Attention in a Bat-Inspired Echolocation System

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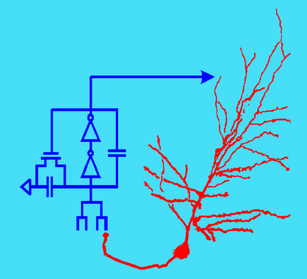
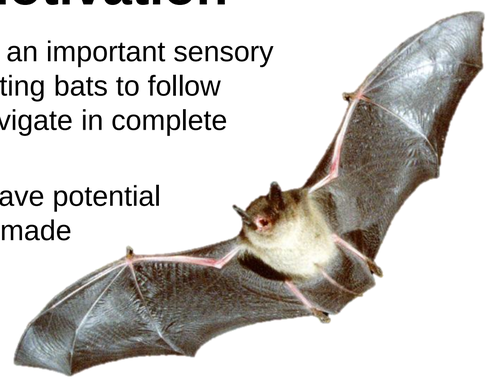


Motivation

- Air-coupled sonar is an important sensory system for echolocating bats to follow moving prey and navigate in complete darkness
- These capabilities have potential applications in man-made flying agents
- Current sonar technology cannot compete with a bat's echolocating abilities
- Typical air-coupled sonar devices used in mobile robotics cannot differentiate the angles of objects within their field of view



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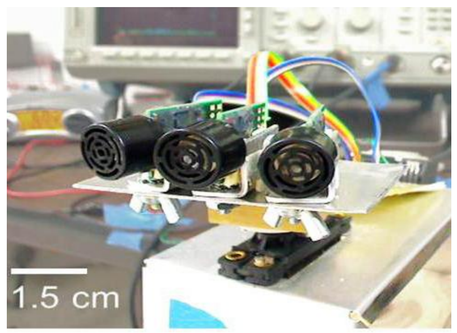
Objectives

- Demonstrate how air-coupled sonar, using a more biologically-inspired approach, can be used to determine the azimuth of an object
- Describe and implement practical applications of this ability (tracking and attentional system)

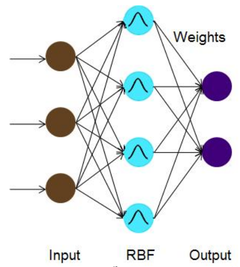
Setup



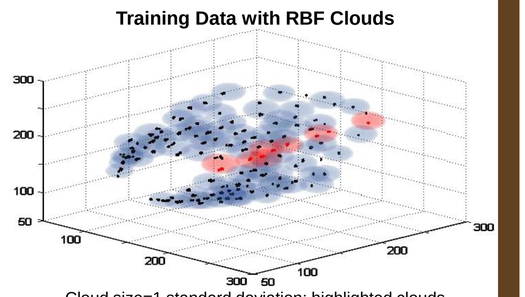
- 3 sonar transducers ("pingers")
- Each pinger can fire and receive ultrasonic pulses at 40 kHz
- Microphone sensitivity patterns allow amplitude data from each pinger to be compared to determine angle of target
- Sonar head is mounted on rotational servo that is computer-controlled

Training

A radial basis function (RBF) learning network was used to train the sonar.



$$f_r(x) = \lambda_0 + \sum_{i=1}^{n_r} \lambda_i \phi \left\| x - c_i \right\| \quad (1)$$



Cloud size=1 standard deviation; highlighted clouds (red) represent RBFs most strongly associated with one example angle.

Collect amplitude data for a target at specified positions (input layer, above left; dots, above right)

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Scatter RBFs across input space. Adjust RBF centers and standard deviations to reflect data clusters and subspaces

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Multiply RBF outputs by weights and sum to produce angle outputs. Adjust weights using correct outputs

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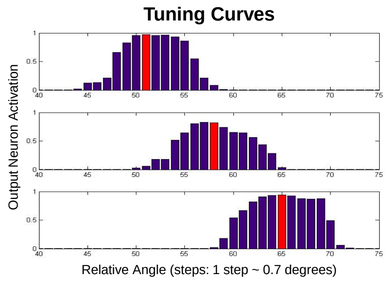
Use saved weights to determine azimuth of objects

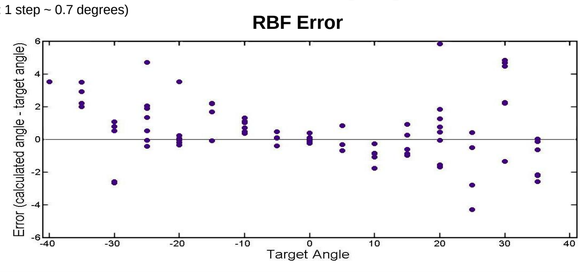
(1) x = input vector; $\Phi(v) = e^{-v^2/B^2}$; B = constant; λ_i = weights; c_i = RBF centers; n_r = number of centers from: Chen, Cowan, & Grant (1991). *IEEE Trans. Neural Networks 2*(2), 302-309.

System Performance



The angular sensitivity of three adjacent neurons is shown. The overlap of neurons shows where the system can estimate angles between the trained angles, which are highlighted in red.

Greater error toward the edges indicates higher resolution in the center.



Acknowledgments

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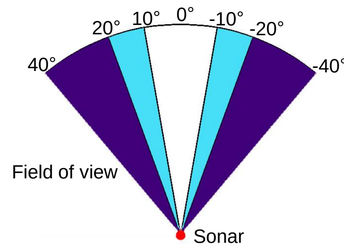
Tracking

The clarity in the center of the view and the ability to resolve angles brought about the design of a tracking algorithm in which the sonar reacts to the relative azimuth of the target.



- Stay in place, fire middle pinger
- Stay in place, fire pinger closest to target
- Move to target's last recorded position

Attention

An attentional system was created to guide the movement of the sonar to map and monitor the environment.

Compute angle estimate (output distribution) for each object in view

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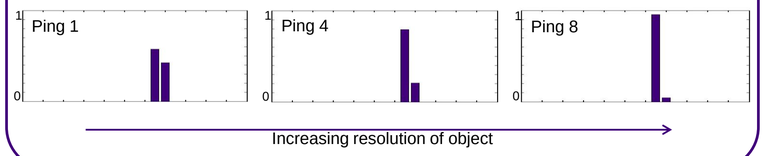
If an object has been seen before, multiply and renormalize its output distributions to achieve better resolution



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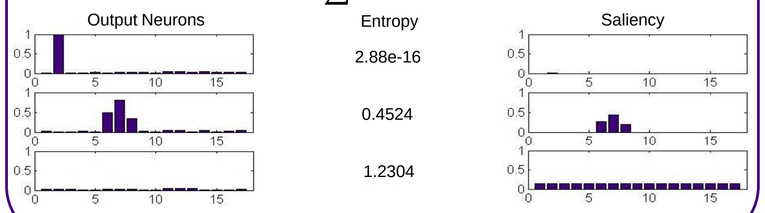
Determine saliency, or interest, of objects in view using entropy

$$Entropy = -\sum p(x) \log p(x) \quad (2) \qquad Saliency(x) = Entropy \times p(x)$$



(2) Renninger, Verghese, & Coughlan (2007). *J. Vision 7*(3):6, 1-17.

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Update saliency map with latest object-associated saliency; raise saliency of unobserved directions

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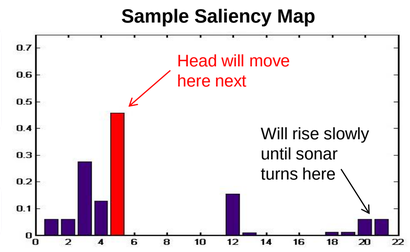
Move in the direction with the highest saliency



This attentional system was used to map out a room, but the framework can be used for other purposes, such as tracking multiple objects or locating empty space for navigation.