Echoes to Action: The Bat Superior Colliculus

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THIRTY YEARS OF SYSTEMS RESEARCH EXCELLENCE

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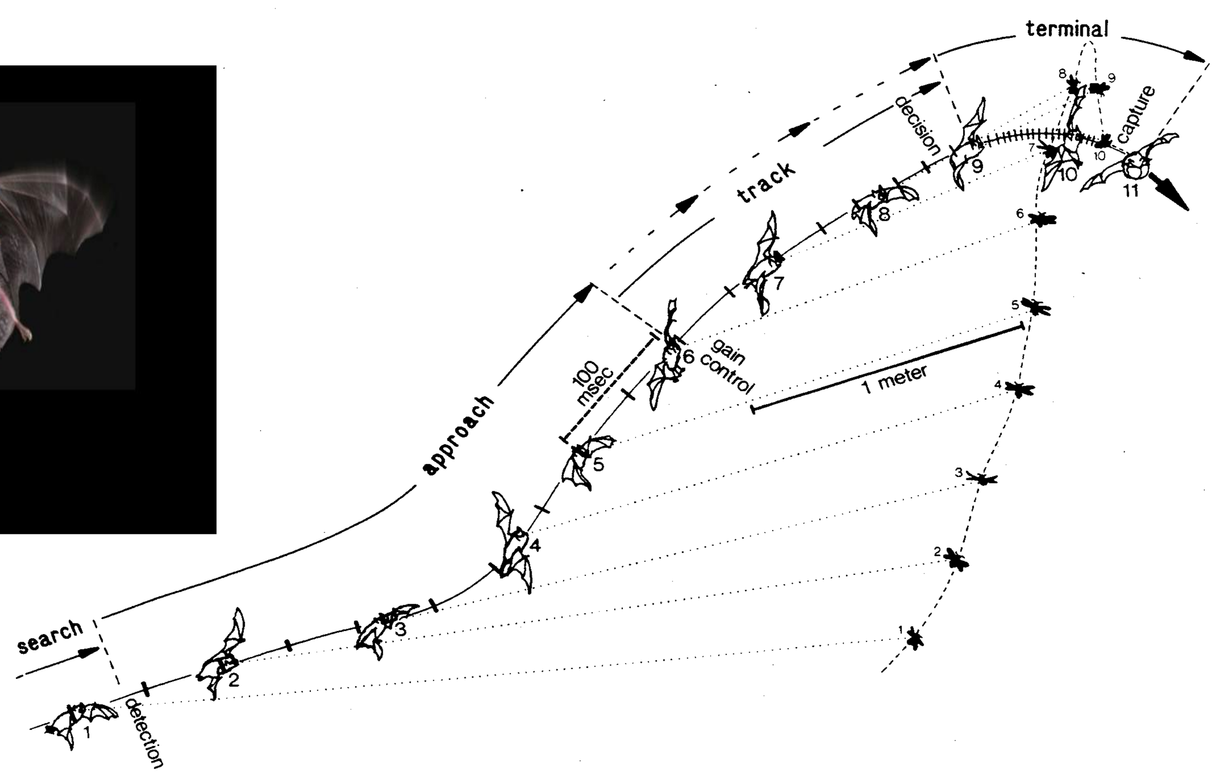
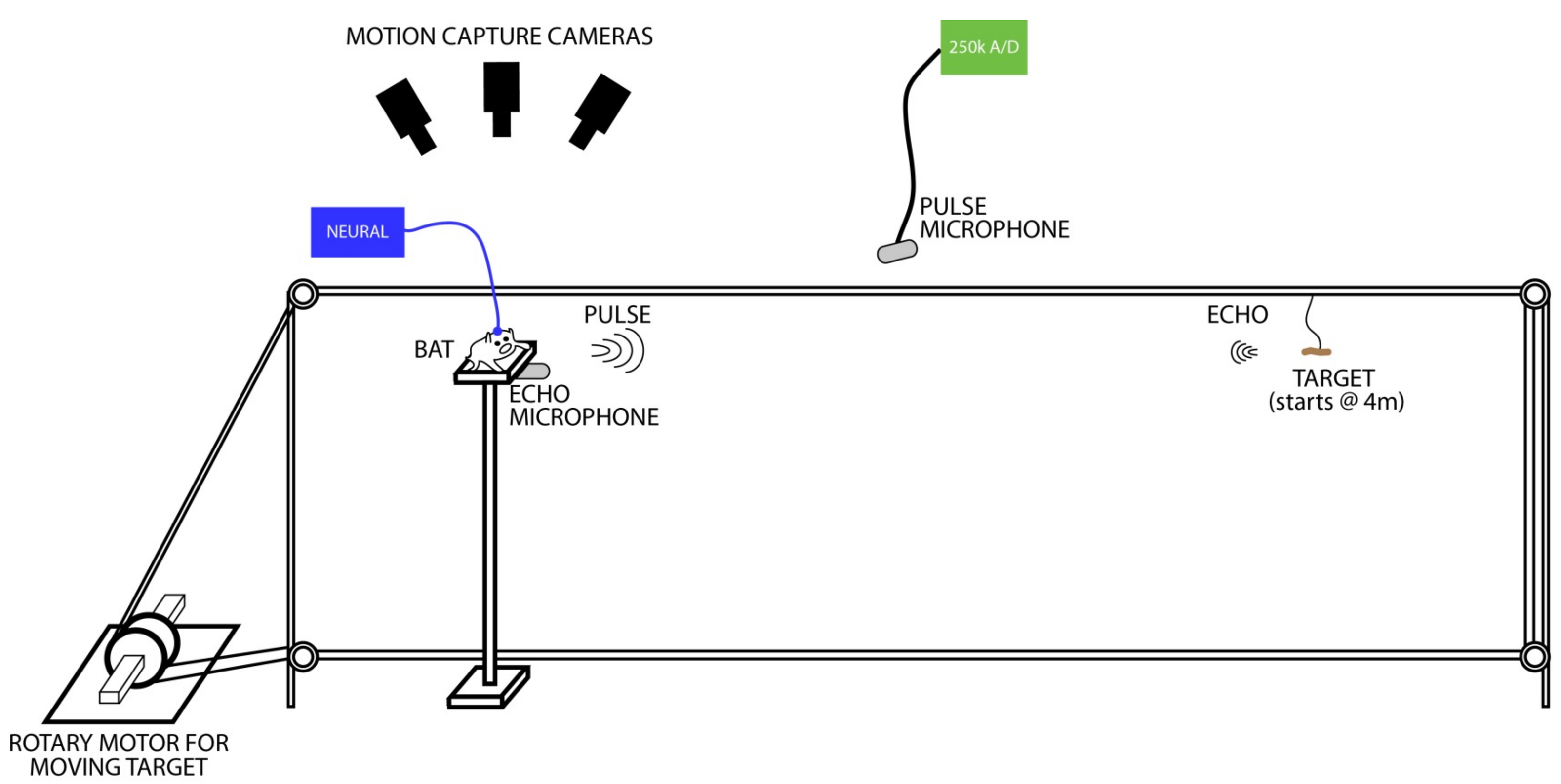
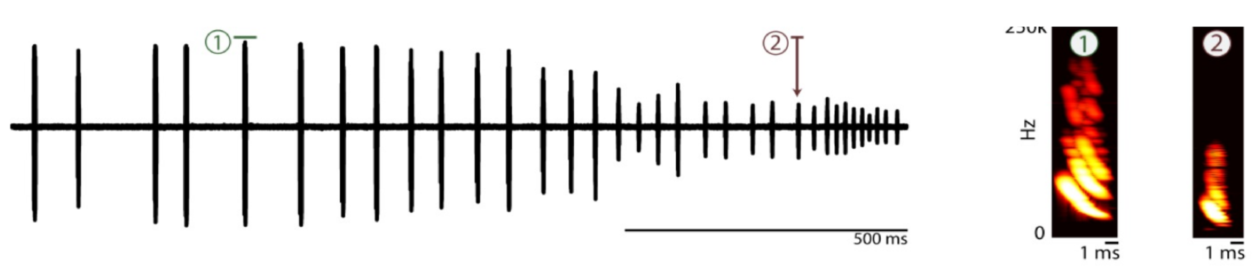
The Horiuchi and Moss laboratories have long collaborated on behavioral, neurophysiological, and neural modeling of the echolocating bat. In recent work, we investigate the brain area known as the “superior colliculus” which is involved in orienting behavior (e.g., head and eye movements), but known to be involved in generating echolocation calls in the bat.



Vocalization Behavior:

Spatial perception by echolocation involves the dynamic interplay between auditory information processing and adaptive motor control (Griffin, 1958). An important component of this adaptive system is the timing of echolocation signals, which the bat adjusts, not only with respect to object distance, but also in the context of perceptual demands and planning. Specifically, the big brown bat, *Eptesicus fuscus*, produces stable groups of echolocation signals, flanked by longer pulse intervals, when it performs challenging spatio-temporal tasks, such as figure-ground segregation and target trajectory uncertainty.





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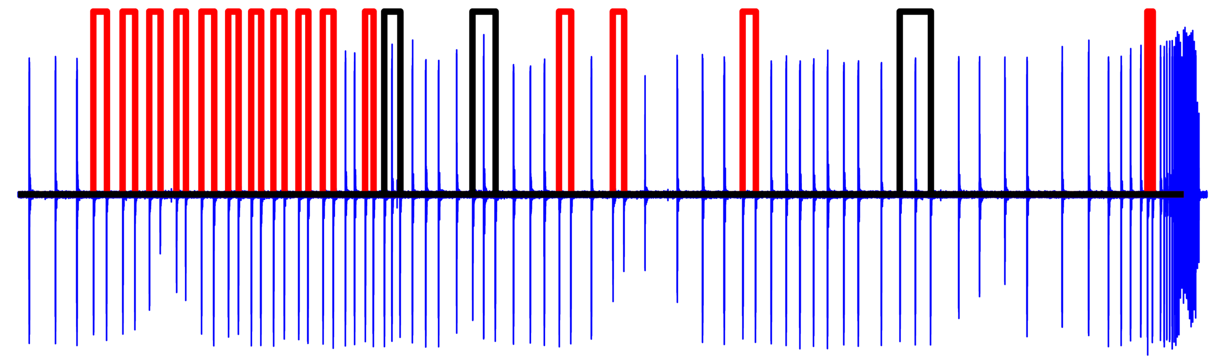
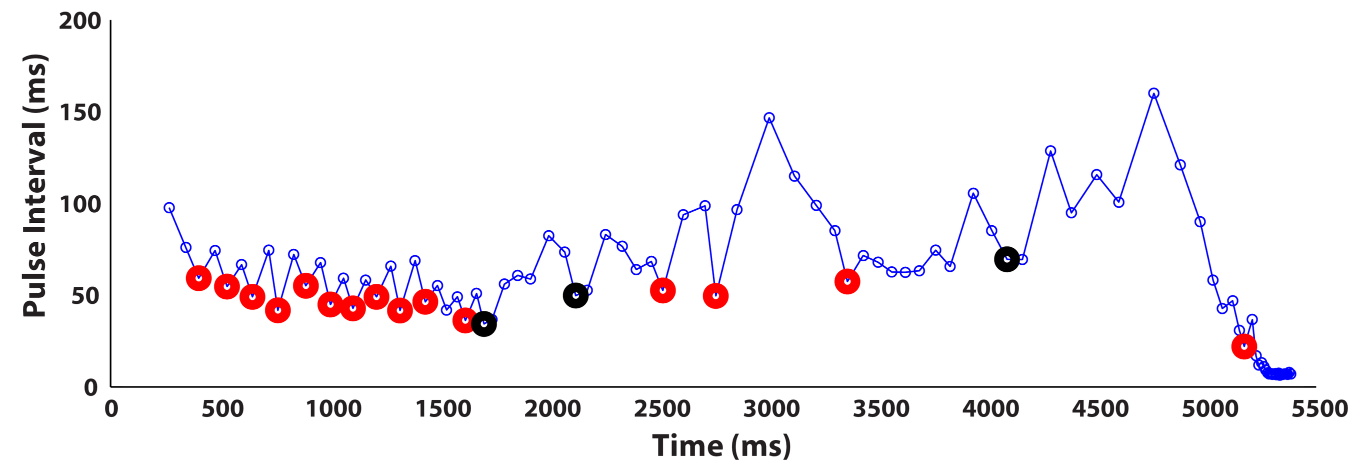
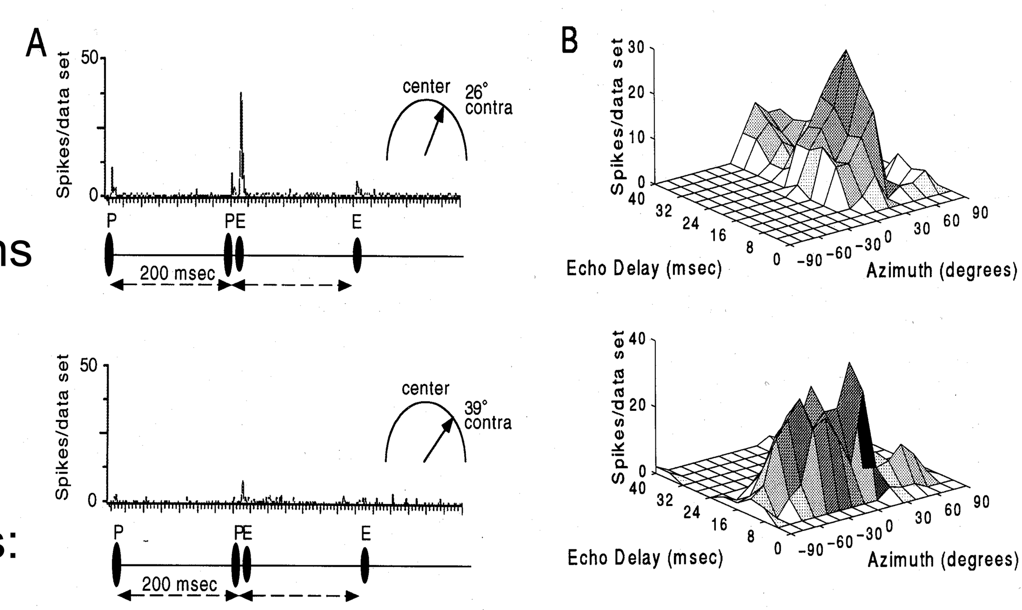


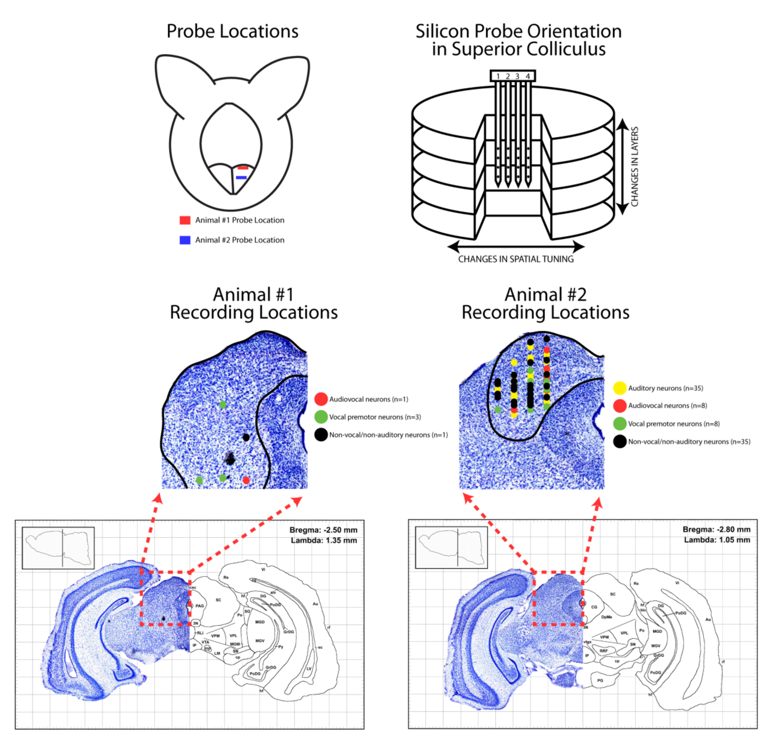


Echolocating bats dynamically modulate the temporal characteristics of their calls when they track approaching insects from a platform (above). In this task, they also produce sonar strobe groups (Kothari et al., 2014) (marked in red in the figure to the right), particularly when target trajectory is uncertain.

Neurophysiology:



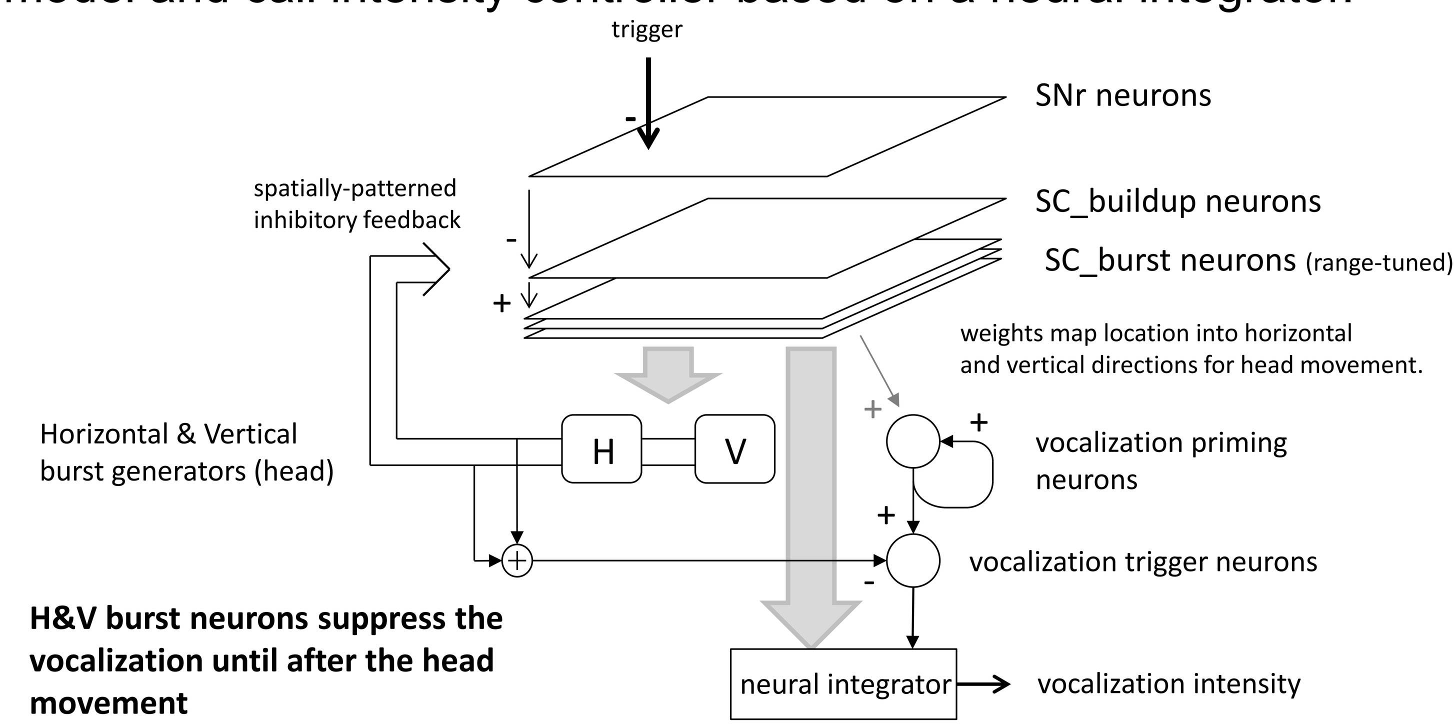
The midbrain superior colliculus (SC) of the echolocating bat shows functional specializations to support acoustic orientation by sonar. Auditory neurons in the bat SC show 3-D spatial response profiles: Echo delay tuning is tagged to the azimuth and elevation of a sound source (Valentine and Moss, 1997).

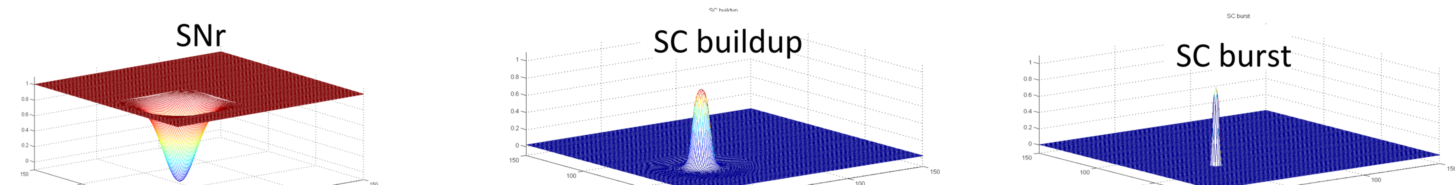


A 4x4 silicon probe was implanted in the SC of the echolocating bat (right). Wireless recordings were transmitted (TBSI) from the SC of the free-flying echolocating bat as it oriented in a large room. Extracellular potentials were acquired with a Plexon system, and spikes were sorted off-line. Echo scenes were reconstructed using a model based on 3-D video position data of the bat, its head aim, and the location of objects in the room. The echo model was then used to characterize auditory spatial responses in single and multiunit activity.

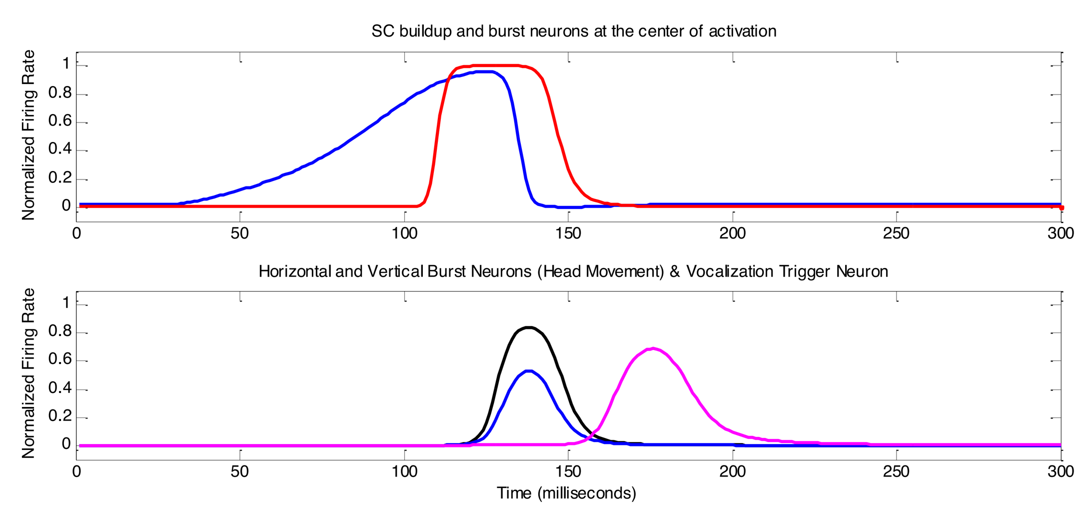
Modeling:

We hypothesize two important roles for the SC in echolocation behavior: 1) temporal coordination of head movements and sonar calls, and 2) control of overall call strength. We describe our bat SC model and call intensity controller based on a neural integrator.





Based on SC models for saccadic eye movements by Trappenberg, Arai, Keller, and others, we hypothesize a similar model for head movements and vocalization intensity control. In this 1-quadrant model, the SC burst neurons project in a position-specific mapping to the horizontal and vertical burst neurons (to control the direction) and a position/range-specific mapping to specify call strength.



When an object to be scrutinized is detected, the SNr neuron corresponding to the object direction is inhibited. This disinhibits the corresponding region of SC, allowing the buildup neurons to integrate up (upper panel, blue). When the buildup neurons reach a high threshold of activity, the local burst neurons (upper panel, red) fire, triggering the head movement via the H and V burst neurons (lower panel, black and blue) and activating the vocalization priming neurons (not shown). Once the suppression from the H and V neurons has subsided, the priming neurons activate the vocalization trigger (lower panel, magenta).

Griffin, D.R. (1958) *Listening in the Dark.* Yale University Press, New Haven.
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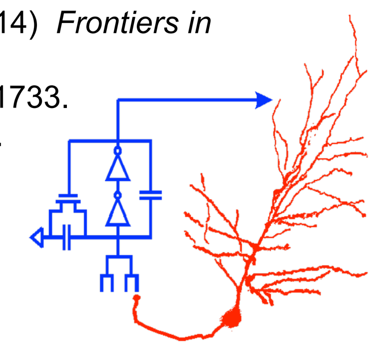
Trappenberg, T. P., et al., (2001) J. Cognitive Neurosci., 13:2, pp. 256-271.
Arai, K., et al., (1999) Neural Networks, 12, 1359-1375.



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