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Cognitive Interaction Technology

Neuromorphic Behaving Systems

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A Neuromorphic VLSI Implementation of a Simplified Electrosensory System in a Weakly Electric Fish

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Motivation

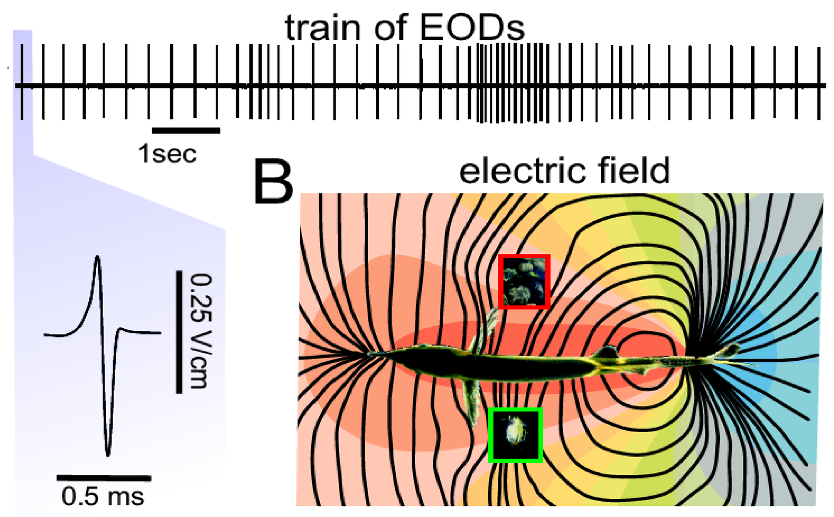
The weakly electric *Mormyrid* fish senses its environment through active electrolocation for navigation and object detection. We present a modeling study of the sensory system of this fish, with the aim of gaining insight into the role of different neuronal populations as well as developing novel computational approaches for efficient, real-time near-range sensing devices.

Mormyrid – the Weakly Electric Fish

The *Mormyrid* senses its neigbouring environment by generating electric field around itself through a tail organ. This field is generated in the form of short electrical pulses as a train of Electric Organ Discharge (EOD).

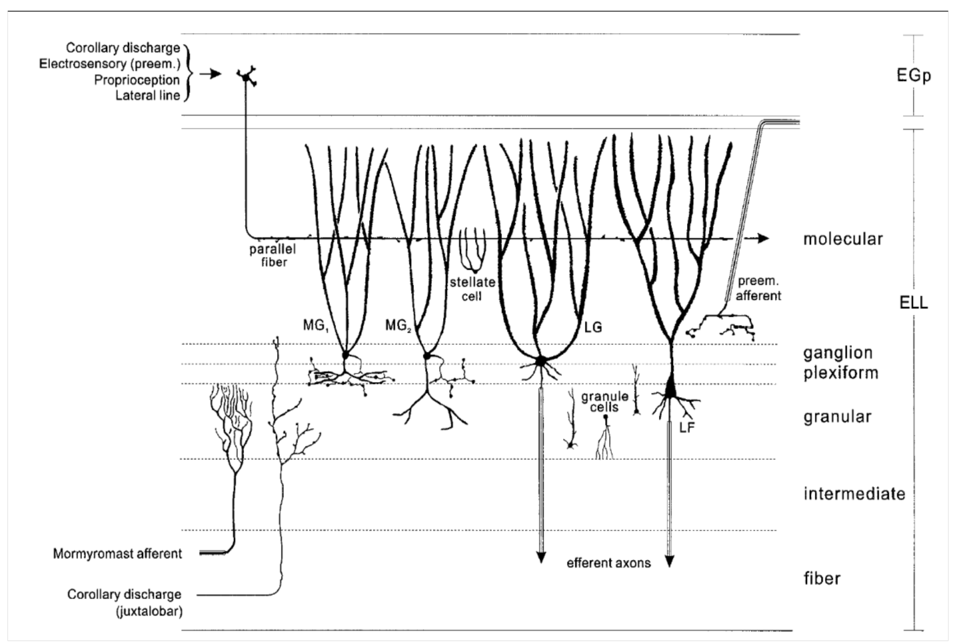
In the absence of field distortion, at 'basal' EOD, the electroreceptor afferents (first layer that feeds spikes to Electrosensory Lateral Line Lobe, ELL) emit 1 ~ 4 spikes.

The presence of an object affects the afferent spiking latencies as well as spikes/EOD.



Biological Basis of Electrosensory Lobe

The afferent fibres innervate the granular (Gr) layer (exc. and inh. cells). The exc. cells project to the large fusiform (Lf) cells. The local GABAergic interneurons, medium ganglions (Mg), inhibit the Lfs. The corollary discharge feedback (Electric Organ Corollary Discharge, EOCD) acts as gating and modulating input for Mg and Lf discharge [1].



Spiking Response in ELL Layers

Network response to varying basal EOD (DC) and LEOD amplitudes:

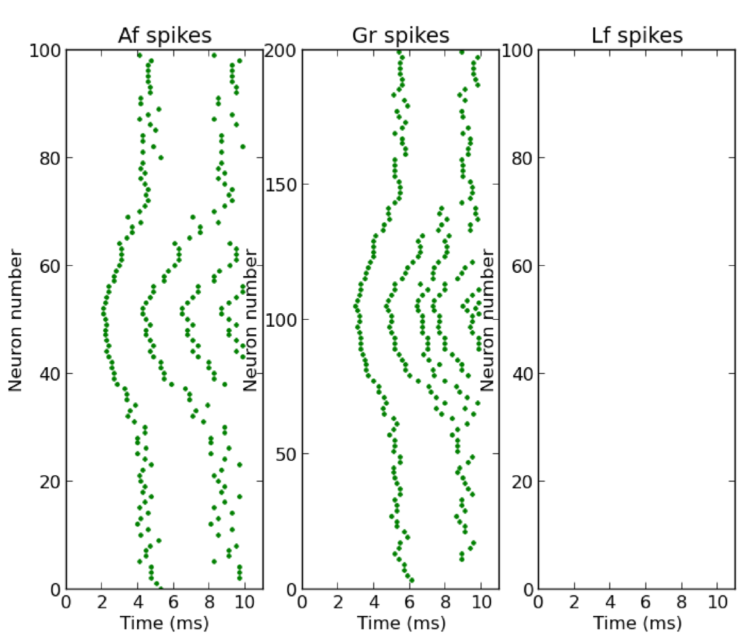
The visible jitter in spike time is due to the simulated mismatch among on-chip neurons.

CASE-I: For low DC and LEOD amplitude, Lfs fail to discharge.

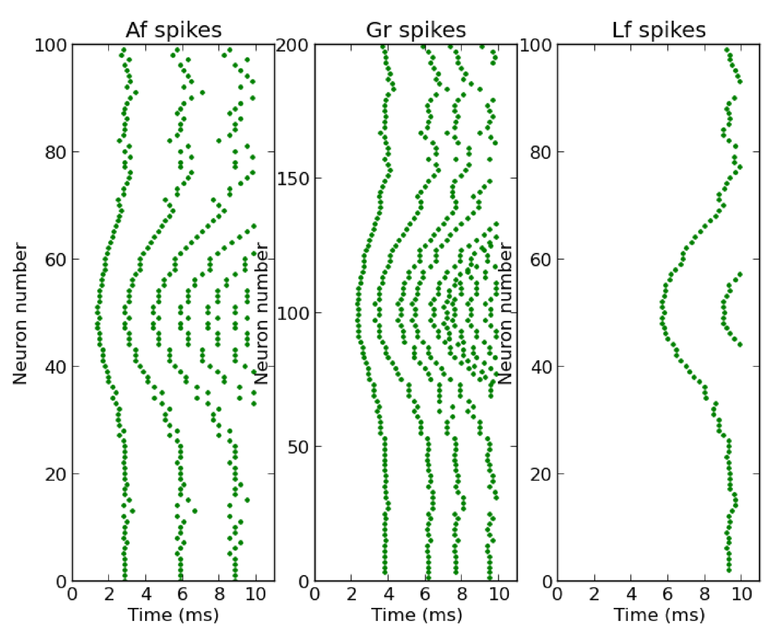
CASE-II: Without Mg inhibition, Lfs evoke spikes at DC (basal EOD) also.

CASE-III: As Mg inhibition and EOCD feedback is reinstated, Lfs spike in the stronger LEOD region.

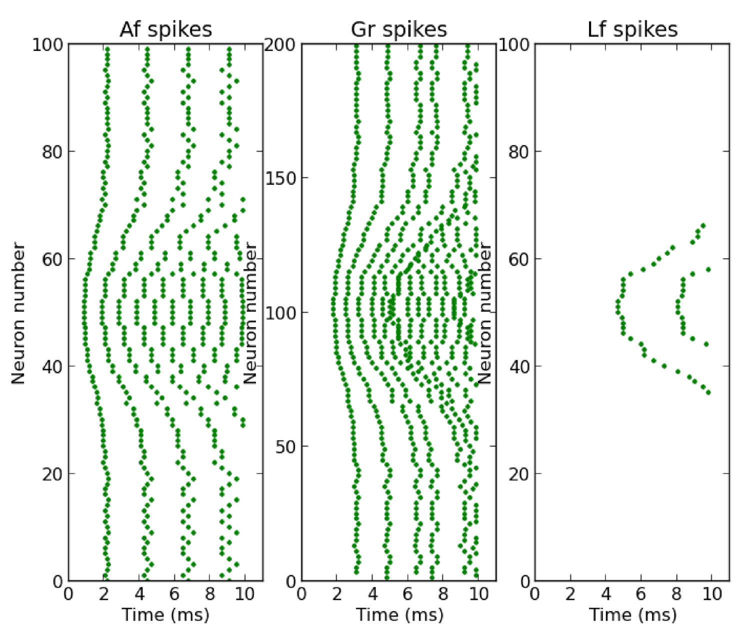
CASE - I



CASE - II

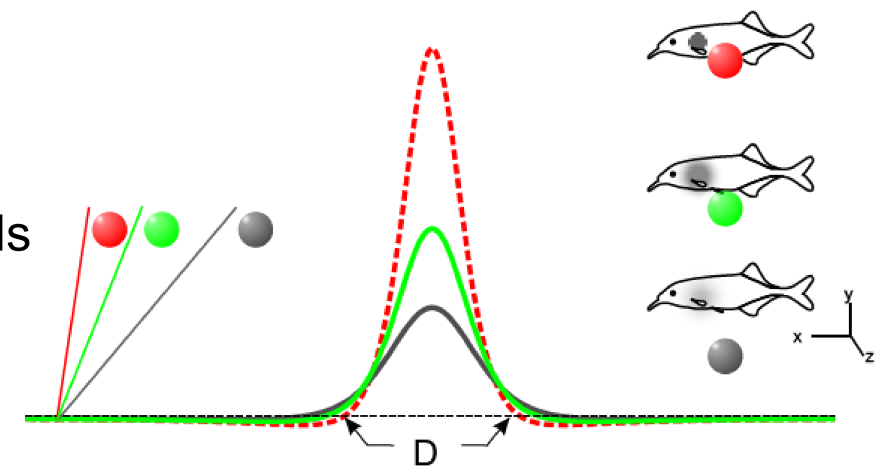


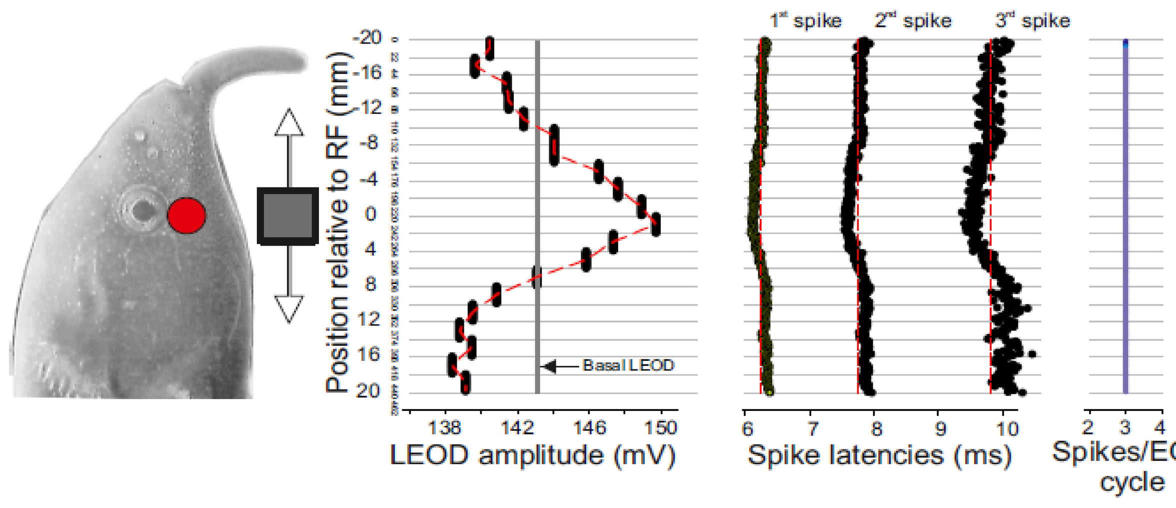
CASE - III



Electric Organ Discharge (EOD)

The electric image profile depends on the size and distance of the field distorting object. The amplitude of the modulated Local EOD (LEOD) depends upon the object proximity and the afferents' spiking output encodes the LEOD strength in latency [2].

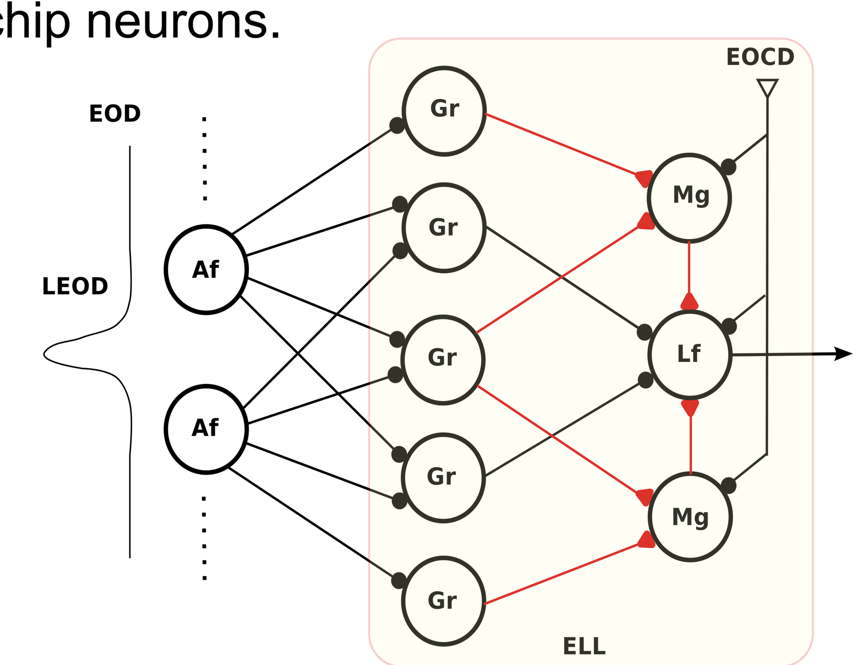




Electrosensory Lateral Line Lobe Model

During every EOD cycle, the LEOD evokes spikes in 100 electroreceptor Afs. The Gr layer within the ELL model comprises of 100 exc. and inh. cells each. The granular inhibition is routed via Mg cells and modulated by EOCD feedback. The neuron model is a leaky integrate-and-fire that also simulates the mismatch effects of on-chip neurons.

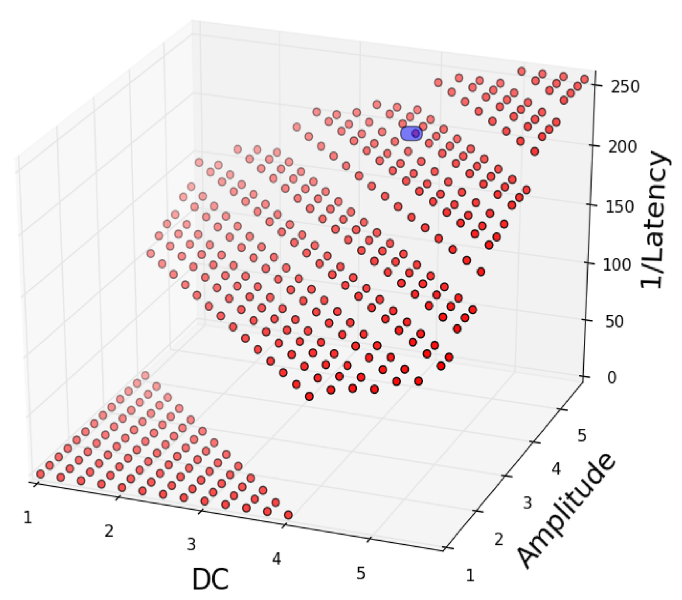
The granular inhibition (via Mg), prevents Lf discharge during the basal EOD cycle. The final Lf response is therefore in a central region of high image intensity (LEOD amplitude).



Lf Response as a Function of LEOD Input

Inverse latencies are plotted as a function of LEOD intensity parameters (amplitude and DC):

The plot depicts absence of Lf discharge at lower DC and LEOD amplitude. Above a certain level (stronger intensity) Lfs start discharging. Increasing inverse latencies indicate early firing, and reflects an encoding based on stronger image intensity (a nearby object).



Conclusions and Future Work

We studied and modeled the ELL circuit of a weakly electric fish. The architecture reproduces biological observations by producing a temporal code for object proximity by means of a spiking neural network. An implementation on a multichip Address Event Respresentation (AER) [3] based system is currently being investigated.

References

[1] Han et al., "Mormyrid Electrosensory Lobe in Vitro: Morphology of Cells and Circuits", *J. Comp. Neur.*, 404:359-374,1999.
[2] J. Engelmann et al., "Electric Imaging Through Active Electrolocation: Implication for the Analysis of Complex Scenes", *Biol. Cybern.*, 98:518-539, 2008.
[3] K. Boahen, "Point-to-Point Connectivity Between Neuromorphic Chips Using Address Events", *IEEE Trans. Circuits Syst. II*, vol. 47, no. 5, 2000.

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