Spiking neural networks to model Hydra nerve nets

Michael Ivanitsky, Connor Puritz

COLLEGE OF LITERATURE, SCIENCE, AND THE ARTS
UNIVERSITY OF MICHIGAN

Math 463
December 5, 2018

Table of Contents

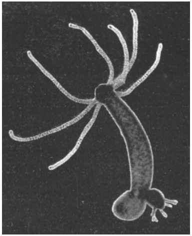
Slide Title

Definition

Introduce ANNs, why they suck for bio, introduce SNNs, mention why they're better.

Evolutionary History of H. vulgaris

- *Hydra* are small, freshwater hydrozoans (family Cnidaria)
- Believed to have originated around 60 Mya [3]
- Cnidarians first appeared around 580 Mya, haven't changed much since
- Ideal for studying development of common features across animals



Nerve Nets

- *Hydra* have diffuse nerve nets rather than a CNS
- Once mature, a constant density gradient of neurons is maintained [2]
-

Title 3

How we'll adapt the model for Hydra

Neuron Model

- Leaky integrate-and-fire model:

$$\frac{dV_m}{dt} = \frac{1}{C_m}\left(-\frac{(V_m - V_m^{eq})}{R_m} + I_{ext}\right)$$

- Computationally simpler than Hodgkin-Huxley
- Models neuron as RC circuit with leak term
- Doesn't explicitly specify spiking behavior or refractory period, but easy to implement using iterative ODE methods
- Possible implementation:

```
if V(t+1) > threshold:
   V(t)   <- spike
   V(t+1) <- hyperpolarize
if t < refractory period:
   V(t+1) <- hyperpolarize
```

UNIVERSITY OF MICHIGAN

Antagonistic Neural Circuits

- Assume each neuron of RP1 emits an inhibitory neurotransmitter E_{RP1} when spiking, and similarly for CB with E_{CB}. Using normalized concentrations, the model is:

$$\frac{dV_{RP1}}{dt} = \frac{1}{C_{RP1}}\left(-\frac{(V_{RP1} - V_{RP1}^{eq})}{R_{RP1}} + I_{ext}\left(1 - E_{CB}\right)\right)$$

$$\frac{dV_{CB}}{dt} = \frac{1}{C_{CB}}\left(-\frac{(V_{CB} - V_{CB}^{eq})}{R_{CB}} + I_{ext}\left(1 - E_{RP1}\right)\right)$$

$$\frac{dE_{RP1}}{dt} = d_{RP1}E_{RP1} \qquad \frac{dE_{CB}}{dt} = d_{CB}E_{CB}$$

Title 4

Maybe tensor stuff?

Title 5

It'd be cool to build this, gather real data, and test. Cool to adapt to larger and more complex organisms.

References

[1] Hydra imaging

[2] Hydra constant density

[3] Hydra origination date