A neural circuit model for motor control in C.elegans

SE 367 Project
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Introduction

Motor control - information processing related activities that are carried out by the central nervous system to organize the musculoskeletal system.

Neural circuit - functional entity of interconnected neurons that is able to regulate its own activity.

Why C. elegans?

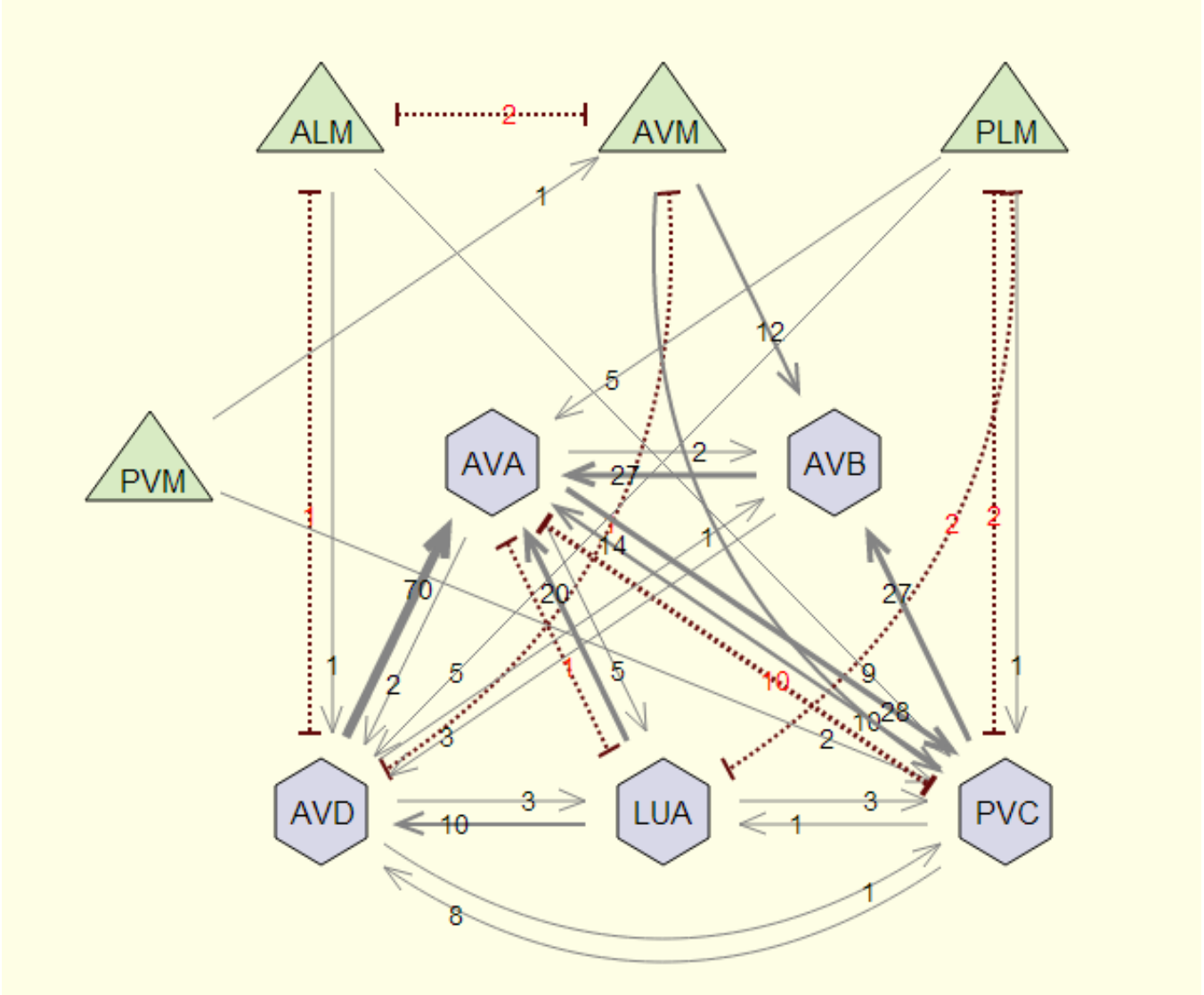
- Widely studied nervous system
- Relatively simple
- Reliable data easily available

Neural circuit for motor control in C.elegans

From the paper "*The structure of the nervous system of the nematode Caenorhabditis elegans*" by J. G. White et al it was found that -

- 18 neurons are involved in gentle touch stimulation
  - 6 sensory
  - 10 interneurons
  - 2 motor neurons
- Sensory neurons belong to the class ALM, AVM, PLM, PVM.
- Interneurons are from classes PVC, AVD, LUA, AVA, AVB.
- Two motor neurons are for anteior and prosterior touch.

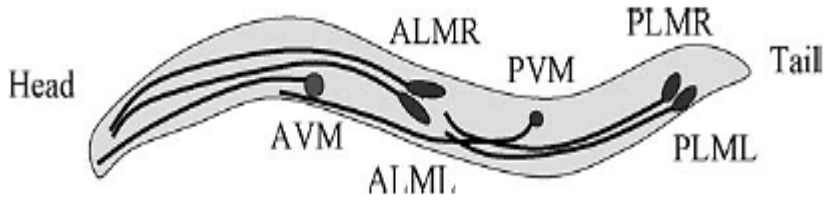
Neural circuit diagram



Modeling neurons

Considerations :

- Position
- Output range
- Sensitivity



Neuron characteristic

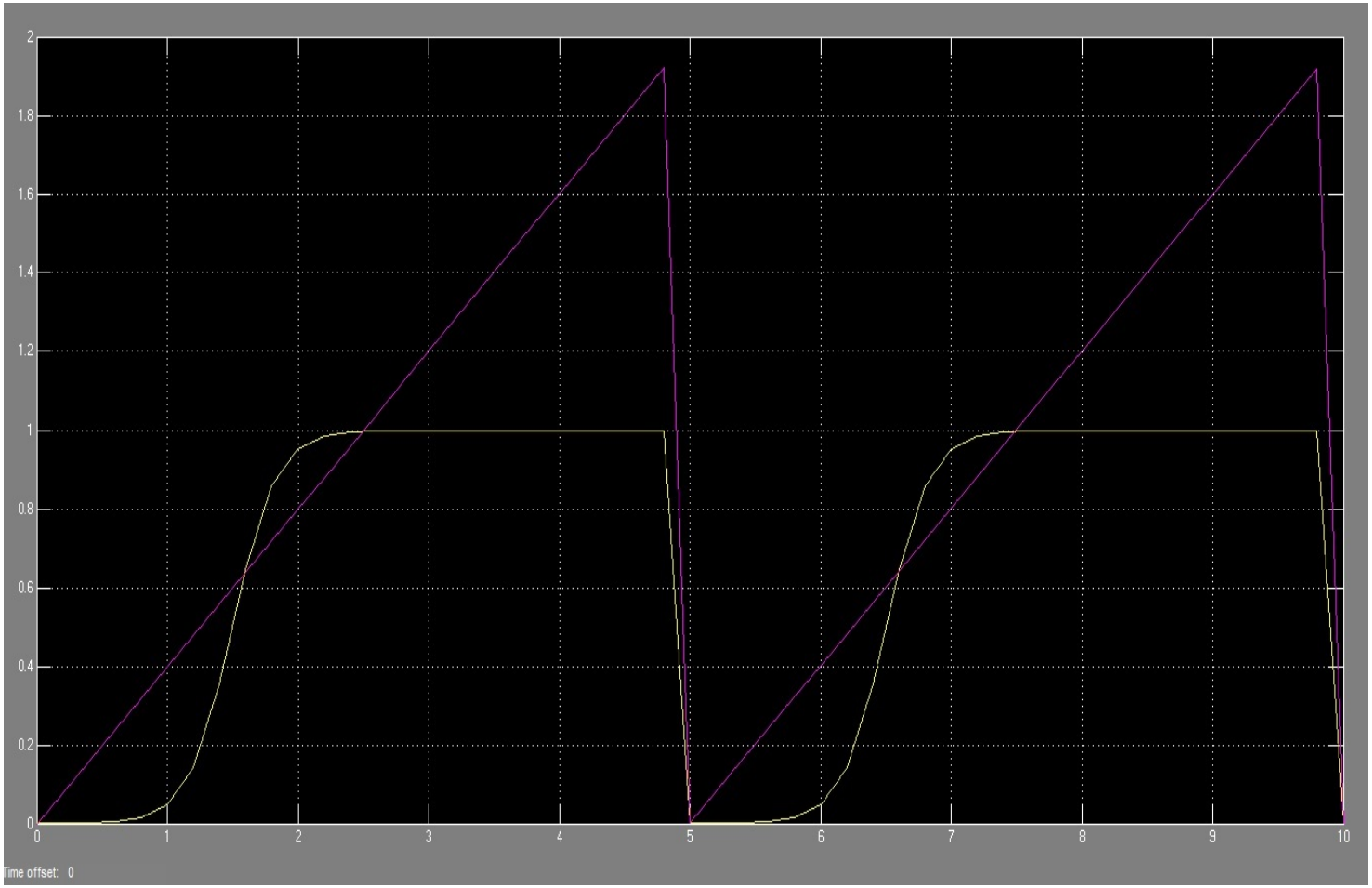
$$O_n = \frac{C_n}{1+\exp(-A_n(I_n - B_n))}$$

An : inclination with output function

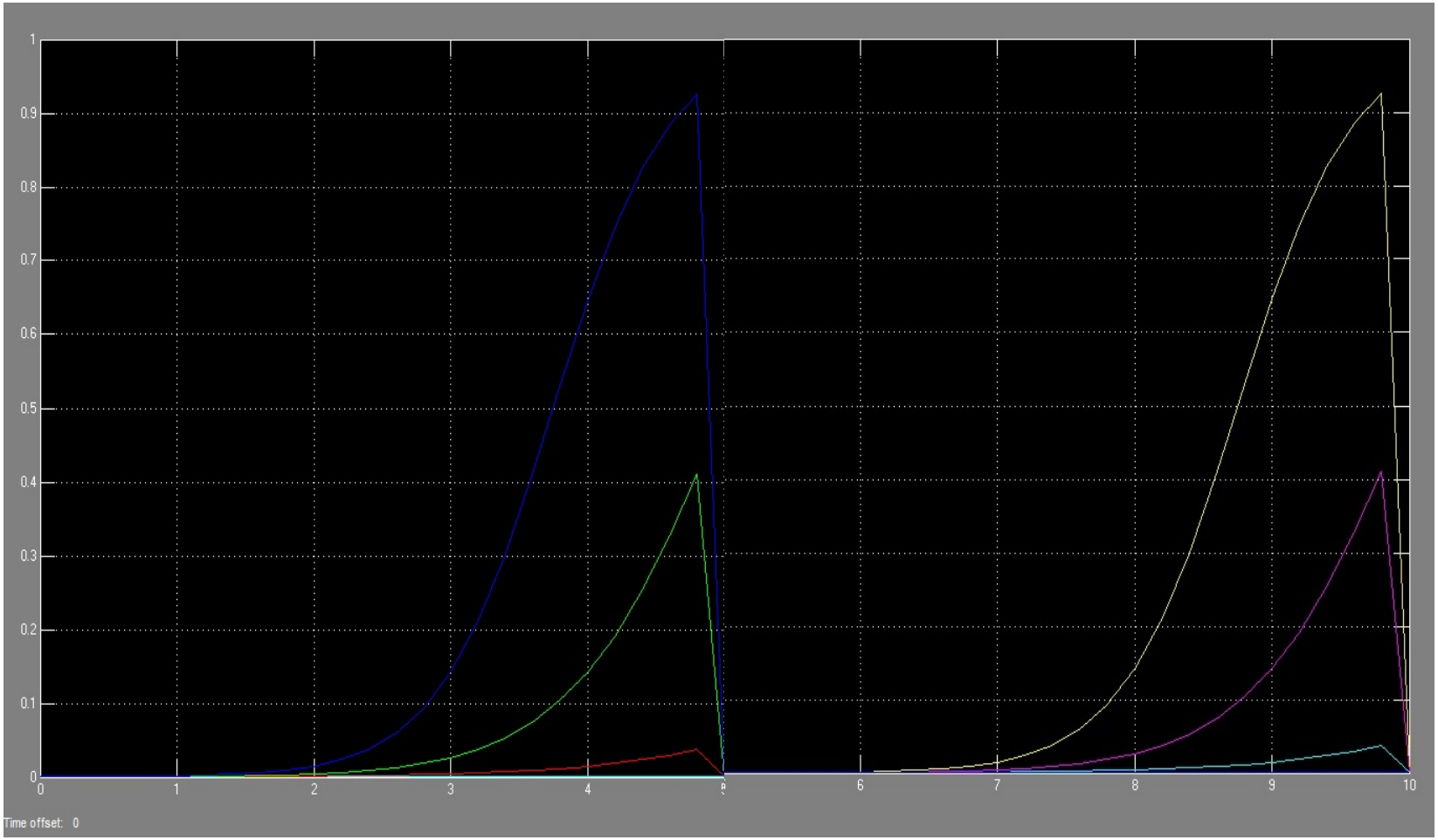
Bn : value of the stimulation input at which the output of the neuron takes a central value

Cn : stimulation reception sensitivity

Output Characteristic of a neuron model



Sensory Layer



Interneuron layer

- The output characteristics of interneurons are also expressed in the same way as sensory neurons
- The input I_n to the interneuron H_n is the sum of a value that multiplies the connection weight.
- $I_n = w_{a,n}I_a + w_{b,n}I_b + w_{c,n}I_c + g_{d,n}I_d + g_{e,n}I_e$
- Connection weight of synaptic junction is represented as $w_{i,j}$ whereas that for gap junction is depicted as $g_{i,j}$
- $w_{i,j} \neq w_{j,i}$ however $g_{i,j} = g_{j,i}$

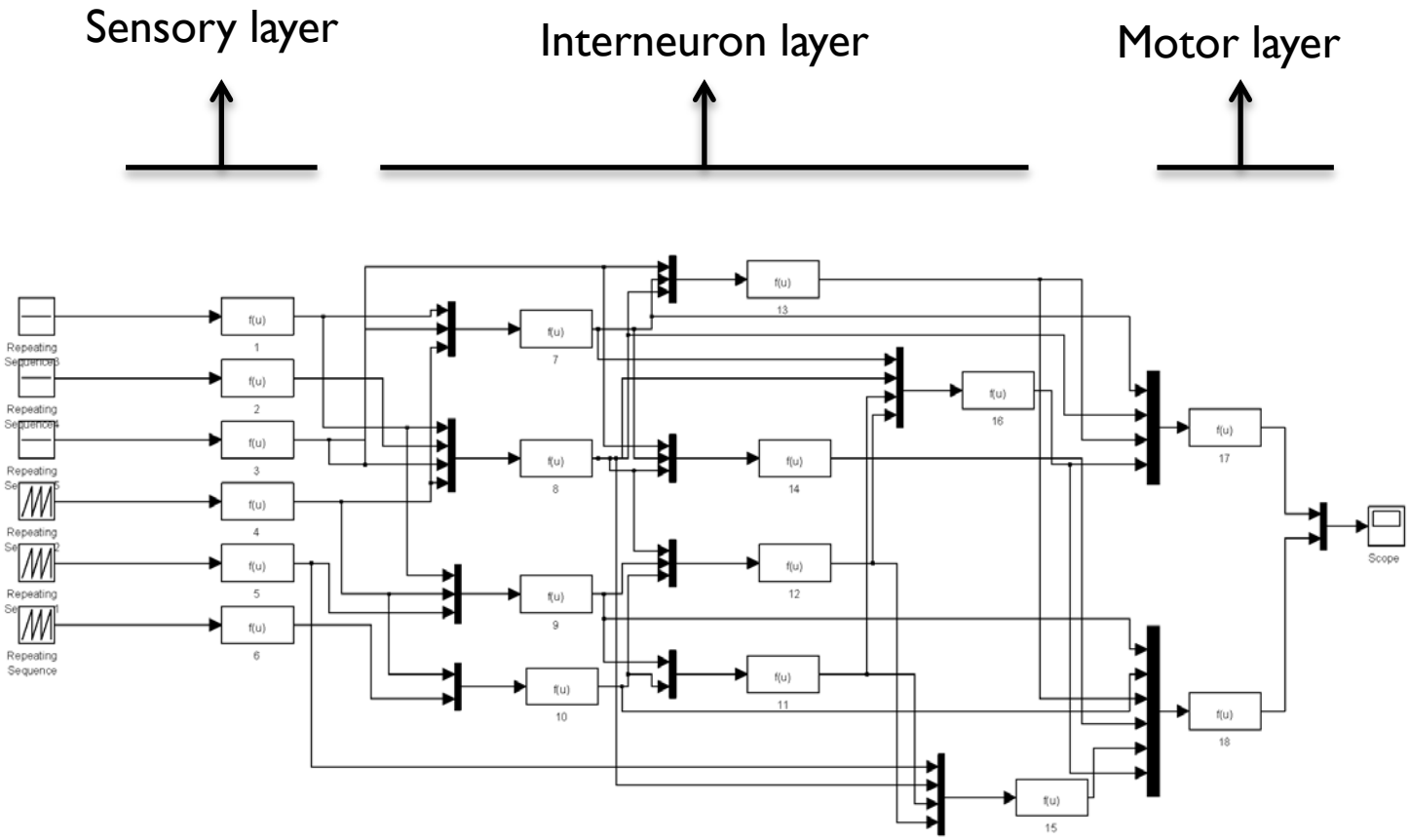
Motor neurons

- Characteristics of the two motor neurons are same as interneurons and fire as per the strength of stimulation

Weight of the synapses

- Assumption - Current in the axon is equally distributed to the synapses
- Weight of synapses from neuron n can be represented as $w_{n,i}$ = 1/(number of neurons with which neuron n forms synapse)
- Gap junction – synapses with equal wigthage in both directions, so Weight of gap junction = ½(Weight of synapse of a neuron)

Final Circuit



Work to be done

- Feedback loops need to be implemented
- Weight of synapses and gap junction is to be calculated

References :

[1] www.wormatlas.org/hermaphrodite/nervous/Neuroframeset

[2] Michiyo Suzuki et al, A model of motor control of nematode C.elegans with neuronal cicuits

[3] Piggot B.J et al, The Neural circuits and synaptic mechanisms underlying motor initiation in C.elegans.

[4] Sakai Y et al, Computational Algorithms and neuronal network models underlying decision processes.

THANK YOU !!