A neural circuit model for motor control in C.elegans

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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.
- In this project a neural circuit model for motor control in case of gentle touch is prepared and studied. The study is based on a previous study by a japanese group lead by M. Sujuki. In that study they have also tried to develop a similar model for motor control in C elegans for gentle touch stimulation

WHY C.ELEGANS?

- **Nervous system**: The nervous system of C elegans have been studied very widely. It mainly consists of two parts – the somatic and the pharyngeal nervous system. These two mainly differ in their topologies and communicate with each other via a single pair of neurons called the RIP neurons
- **Simplicity**: The nervous system of C elegans is relatively very simple. Wile the Somatic nervous system consists of 282 neurons the Pharyngeal nervous system just contains 20 neurons. These neurons are connected by around 6400 synapses 900 gap junctions and 1500 neuro - muscular junctions.
- **Reliable data easily available**: The reliable data for these connections and their characteristics is also readily available on various sites like *"WORMATLAS"* and *"Database of Synaptic Connectivity of C. elegans for Computation"*

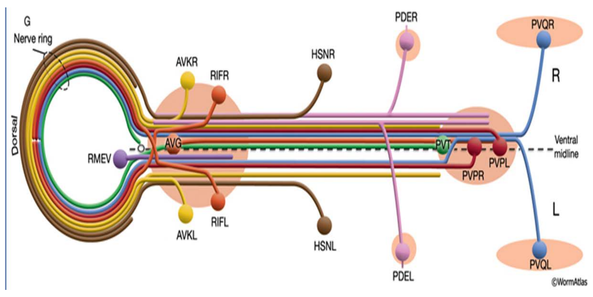


Fig: C.Elegans Nervous System

METHODS

From the paper *"The structure of the nervous system of the nematode Caenorhabditis elegans"* by J. G. White et al (1986) 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.

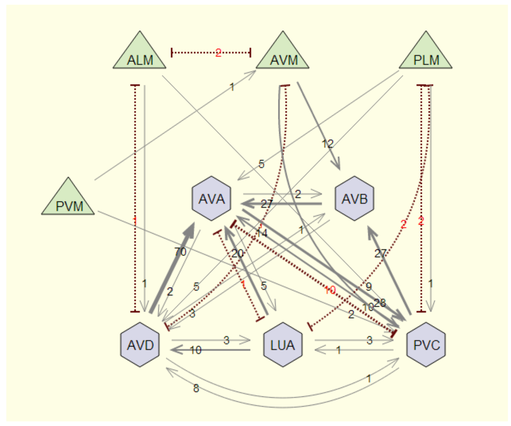
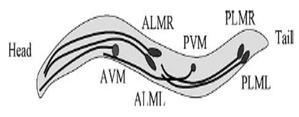


Fig: Neural Circuit Diagram

Considerations :

- Position
- Output range
- Sensitivity



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

Neuronal Characteristics

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

- 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 $g_{i,j} = g_{j,i}$

ALM	ALML(se) --> AVDR(in)	1	0
	ALML(se) --> AVM(se)	0	1
	ALML(se) --> PVCL(in)	4	0
	ALML(se) --> PVCR(in)	2	0
	ALMR(se) --> AVDR(in)	0	1
	ALMR(se) --> AVM(se)	0	1
	ALMR(se) --> PVCR(in)	3	0
AVA	AVAL(in) --> AVAR(in)	0	1
	AVAL(in) --> LUAL(in)	1	1
	AVAR(in) --> AVAL(in)	0	1
	AVAR(in) --> LUAR(in)	1	1
	AVAR(in) --> LUAR(in)	3	0
AVB	AVBL(in) --> AVBR(in)	0	2
	AVBR(in) --> AVBL(in)	0	2
AVD	AVDL(in) --> AVM(se)	0	1
	AVDL(in) --> LUAL(in)	1	0
	AVDR(in) --> ALMR(se)	0	1
	AVDR(in) --> LUAL(in)	2	0
AVM	AVM(se) --> ALML(se)	0	1
	AVM(se) --> ALMR(se)	0	1
	AVM(se) --> AVBL(in)	6	0
	AVM(se) --> AVBR(in)	6	0
	AVM(se) --> AVDL(in)	0	1
	AVM(se) --> PVCL(in)	4	0
	AVM(se) --> PVCR(in)	6	0
LUA	LUAL(in) --> AVAL(in)	5	1
	LUAL(in) --> AVAR(in)	5	0
	LUAL(in) --> AVDL(in)	4	0
	LUAL(in) --> AVDR(in)	2	0
	LUAR(in) --> AVAL(in)	3	0
	LUAR(in) --> AVAR(in)	7	0
	LUAR(in) --> AVDL(in)	1	0
	LUAR(in) --> AVDR(in)	3	0
	LUAR(in) --> PLMR(se)	0	1
	LUAR(in) --> PVCR(in)	3	0
PLM	PLMR(se) --> LUAR(in)	0	1
PVC	PVCL(in) --> AVAR(in)	2	0
	PVCL(in) --> AVBL(in)	11	0
	PVCL(in) --> AVBR(in)	12	0
	PVCL(in) --> AVDL(in)	0	0
	PVCL(in) --> AVDR(in)	2	0
	PVCL(in) --> PVCR(in)	2	1
	PVCR(in) --> AVAL(in)	1	0
	PVCR(in) --> AVAR(in)	3	0
	PVCR(in) --> AVBL(in)	5	0
	PVCR(in) --> AVBR(in)	6	0
	PVCR(in) --> AVDL(in)	2	0
	PVCR(in) --> AVDR(in)	1	0
	PVCR(in) --> LUAR(in)	1	1
	PVCR(in) --> PVCL(in)	1	1
PVM	no data	-	-

Fig: Data for synaptic connectivity

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

RESULTS

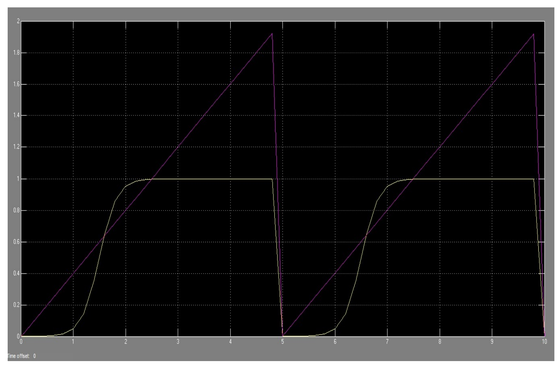


Fig: Output Characteristics of single neuron

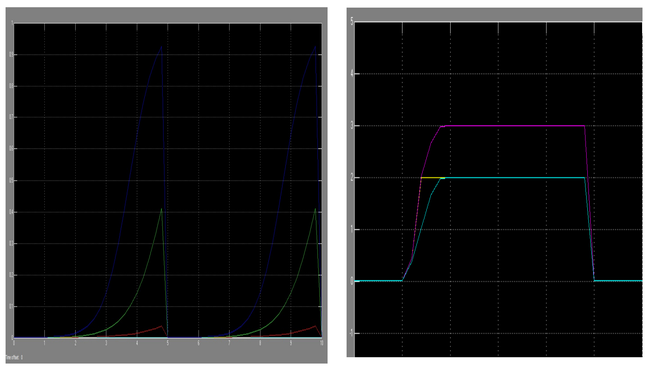


Fig: Output Characteristics of sensory layer and 6 sensory neuron coupled with 3 interneurons in anterior touch.

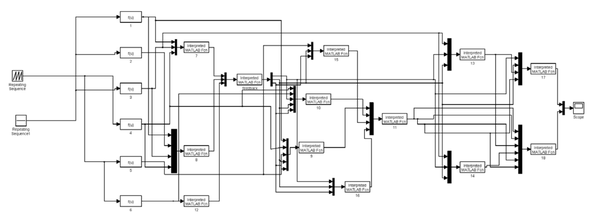


Fig: Final circuit

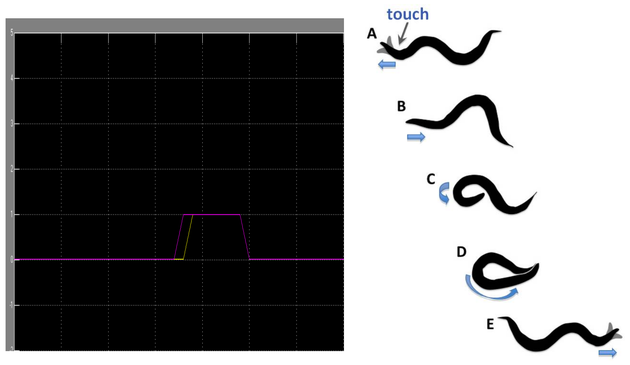


Fig: Final Response

CONCLUSIONS

- The model showed a stimulation in anterior motor neuron of the C elegans is followed by a simulation in the prosterior motor neuron which correctly depicts the response of the C elegan in gentle touch stimulation.
- Although the chemistry and genetics of cell have not been included in this model, but such an integral model might prove very useful in various types of cognitive and behavioural studies.

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