BILKENT UNIVERSITY
Computer Engineering
CS 223 DIGITAL DESIGN

BRAIN:M

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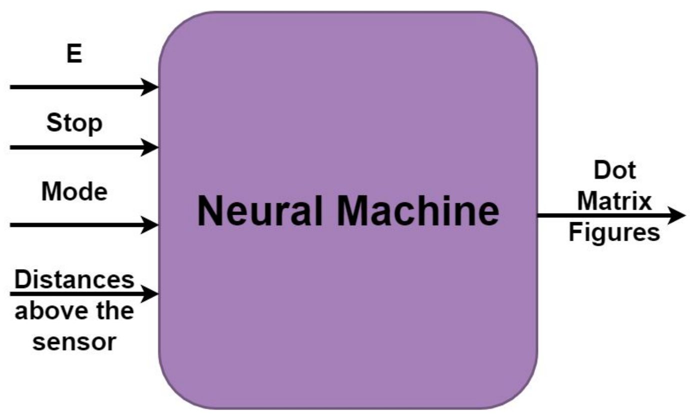
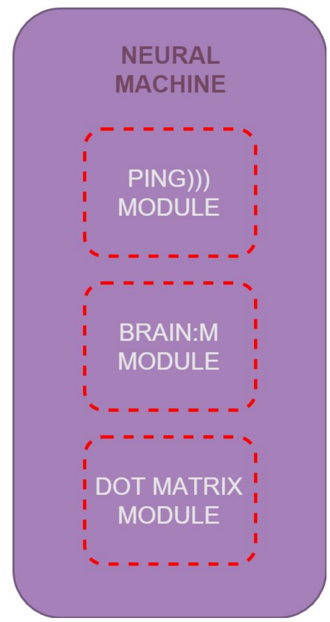
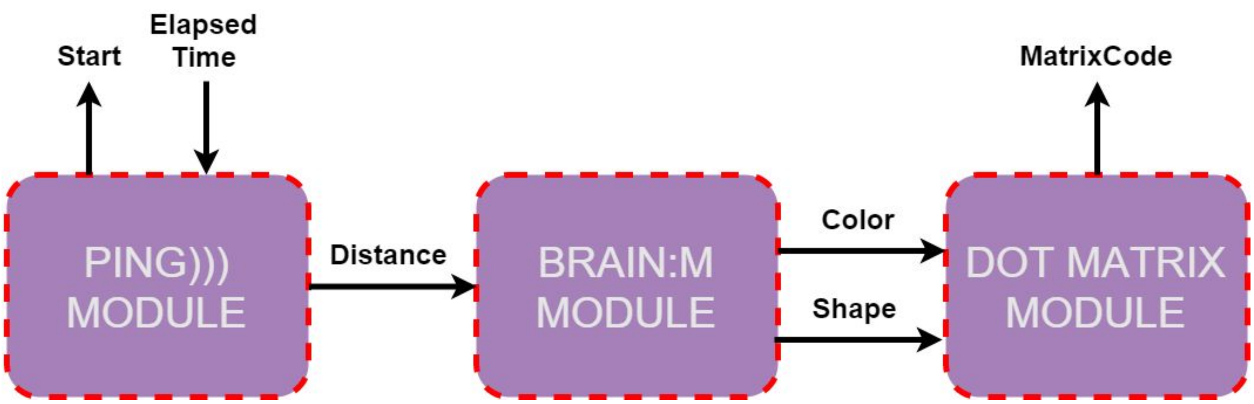
General Block Diagram

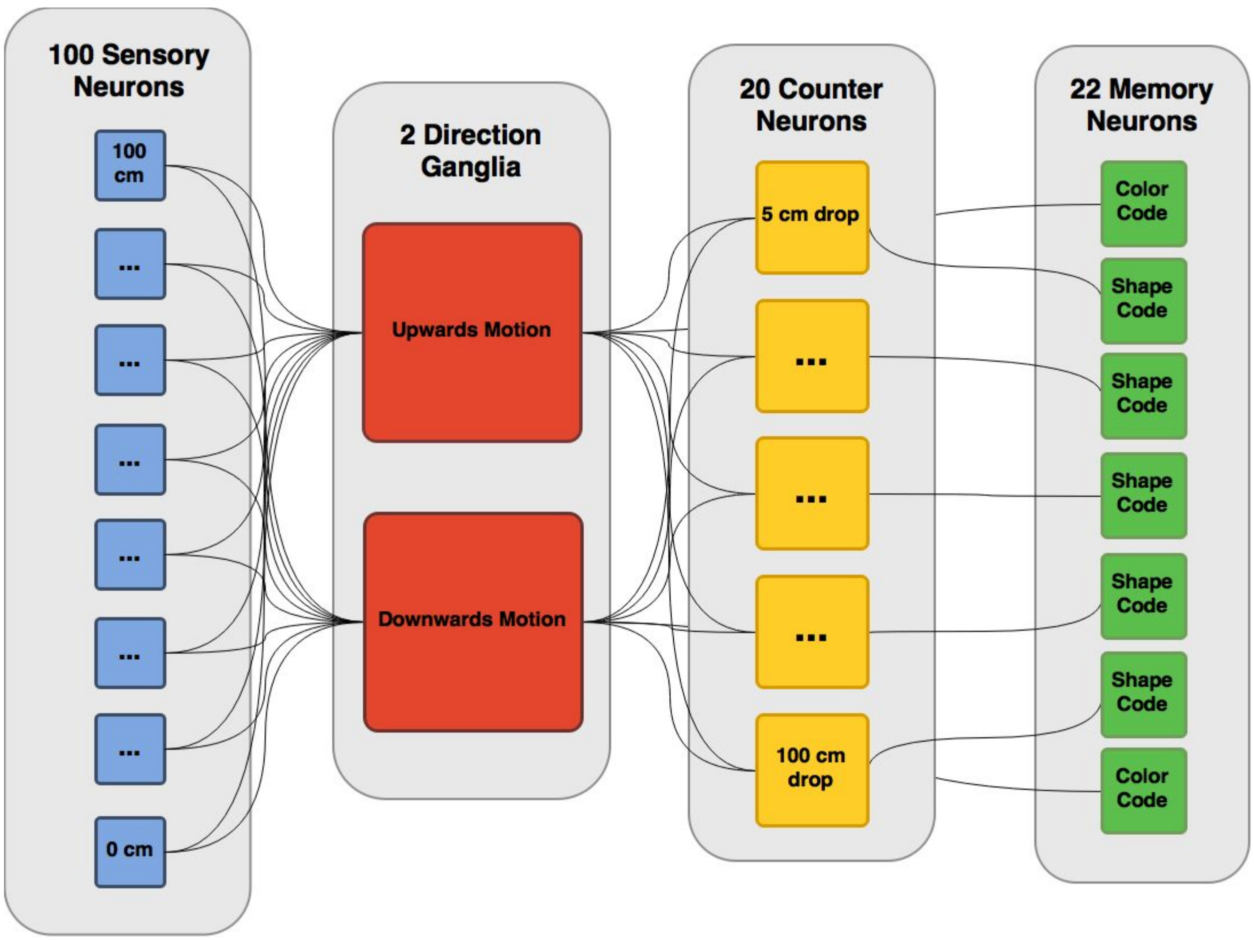




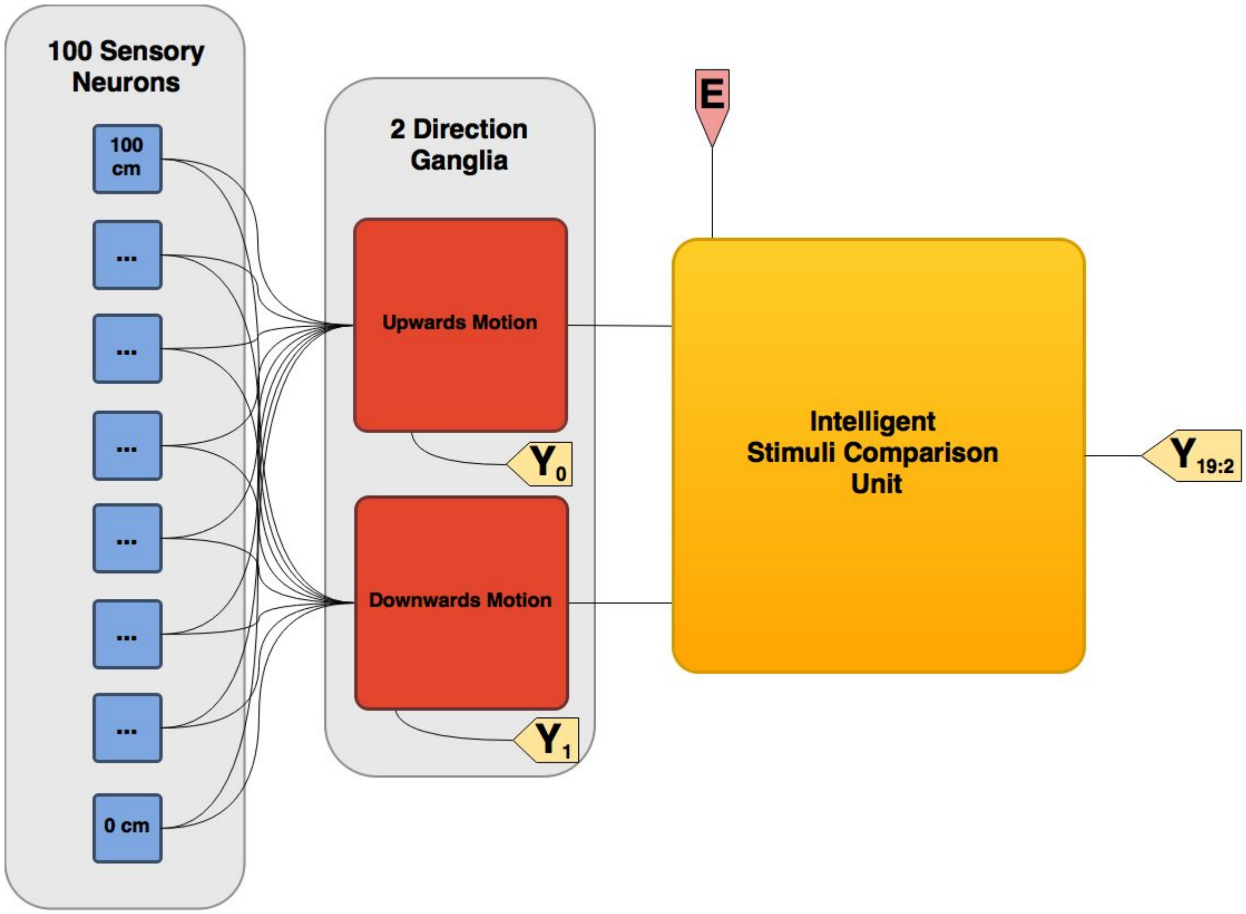


BRAIN:M Detailed Block Diagrams

Learning Mode



Demonstration Mode



Block Descriptions

PING))) Module

This block is the main part in which we gather the required distance information to work with in the BRAIN:M section. Mainly, this part sends a start signal to the sensor to start taking inputs by sending a pulse of high frequency sound, and listens to it. This PING))) controller will then get high input for the time being in which sound travels to and fro the object. This time length is divided by two to eliminate the first traveling time and then distance of the object is calculated using the elapsed time. Then this distance value is sent to the BRAIN:M module. This part will be coded in Verilog and some codes will be implemented collaboratively with Nashiha Ahmed's group which uses codes from http://4llamas.com/arr/code for the sensor as well. It will use the PING))) ultrasound module on the CS223 Beti board.

BRAIN:M Module

This section is the key part of the project as it involves the whole neural mechanism to learn from the distance of an object -whose data is gathered from the ultrasonic module- and output a shape with a certain color for the dot matrix. It also contains five different modules in itself. These are present to replicate the behavior of the sensory, motor neurons and interneurons. As the sensor is more like a visual element, most of the blocks are similar in function to the ones in the retina and visual cortex of an organic neural structure. All sections of this module will be implemented in Verilog written by ourselves and will use BASYS2 FPGA board.

Sensory Neuron

This is the first part of the sieving mechanism that categorizes and recognizes the distance values. First of all, a single sensory neuron takes the distance at a certain instance as an input and compares it to the threshold value that it holds. If the distance value is equal to its threshold then it would give a high output. Furthermore, we are going to use a hundred of these sensory neurons to correctly identify up to one centimeter difference of a maximum distance of one hundred centimeters. All of these outputs will then be sent to the direction ganglia to be evaluated according to their changes throughout a timespan.

Direction Ganglion

Direction ganglia will wait for a stop signal while getting inputs from the sensory neuron and determine the change in the distance measured by the sensor. It will have a special clock that has a cycle period of one second in order to evaluate change in distance in a systematic and efficient way. Whenever it spots a change in the same direction, it will increment its counter. After the stop signal is received it will output the incremented value and a random color to be associated with the direction of the movement. As there will be two ganglia in this module, one of them will be used to recognize downwards motions while the other one will recognize upwards motions. This will lead to using two different random colors chosen by the ganglia themselves to represent the direction of the motion.

Counter Neuron

This structure is very similar to sensory neurons. Counter neuron will take the several bits of count value in each ganglion and compare it to its own threshold value. However, compared to the sensory neuron, this time a displacement value will be held by the counter neuron, thus it will be able to decide the overall displacement of the motion -i.e. 5 cm drop or 60 cm increase. In addition, a random shape output such as a triangle or a circle will be assigned to this neuron to be used in the dot matrix part. There will be twenty counter neurons in this module, thus it can only learn descents or ascents of multiples of five up to a hundred.

Memory Neuron

This module will consist of registers only. It will either hold the shape code or the color code received from the counter neurons and direction ganglia. It will also hold the ascent and descent count in addition to the shape code. The sole purpose of the memory neurons is to hold the learned values for the Intelligent Stimuli Comparison Unit to compare them with a new distance.

Intelligent Stimuli Comparison Unit

This unit will use the formula of intelligence, which is also mentioned in the proposal, to compare the newly received values in the demonstration mode with the ones that were learned before that are stored in the memory neurons. It will also take into account the energy of the system, which is a separate input, and will recall the maximum possible learned displacement if the energy is high, and the minimum learned displacement similar to the new data if the energy is low. It will give the output shape of the recalled memory. For example, if we had thought the BRAIN:M to recognize 20 cm and 40 cm and both the upwards and downwards movements; then if we make the energy of the system high and show a 100 cm drop in the demonstration mode, it would recall the maximum output and find it inside the new value, thus, it would output two same shapes of 40 cm drop and a single shape of 20 cm with the color of downwards motion. If the energy is low, then it would recognize five 20 cm in it and output five identical shapes of 20 cm change.

Dot Matrix Module

This is the module in which the outputs of BRAIN:M are guided to the dot matrix device. This section will be written in Verilog by us and will use the Beti board’s 8*8 LED Dot Matrix and BASYS2 FPGA board. It will take the color code from the memory neurons of direction ganglia and the shape code from the memory neurons of counter neurons as inputs and combine them to produce the desired result which is then will be translated into the required style of code by the dot matrix device.

★ The only part of the project which is changed is the energy input to the system. This was a necessary change as otherwise the formula of intelligence would not have been integrated completely into the project.

Task Table

Block Name		Tasks Completed	Tasks Need to be Done
PING))) Module		• Research about PING))) sensor’s usage is done and several sources are found with the help of Nashiha Ahmed. • Significant effort is put into compiling and trying to work on the sensor, yet yielding unsuccesful results.	• It is needed to create the FSM diagram and code it in Verilog
BRAIN:M Module	Sensory Neuron	• HLSM is created. • Processor structure is formed. • Datapath elements of the processor are determined.	• FSM diagram will be implemented in the controller part of the processor. • Processor will be written in Verilog using both behavioral and structural styles.
	Direction Ganglion	• HLSM is created • Processor diagram is created with inputs and outputs.	• HLSM will be converted into Verilog code using behavioral and data-flow styles.
	Counter Neuron	• HLSM is created	• Verilog conversion and testing is required.
	Memory Neuron	• Required sequential circuit elements are determined.	• Only required task left for this module is writing the verilog code and connecting it to both the counter neurons and the intelligent stimuli comparison unit
	Intelligent Stimuli Comparison Unit	• HLSM is created but with small problematic areas.	• Implementation in Verilog will be done.
Dot Matrix Module		• Datasheet of the dot matrix is found and studied. • Also creating a random output code is obtained from Barış Poyraz.	• Creating the HLSM and trying to implement it in Verilog to get certain shapes.

PROJECT BRAIN:M PROPOSAL

Brilliantly Radical Artificially Intelligent Neural Machine

Mert İNAN | İmge GÖKALP /21402020 | 21402076 / CS223 Project/ Section: 1

DESCRIPTION

In this project, we are planning to create a digital brain that would use two different concepts of brain functions -mainly neural information propagation and high level cognition- to learn and recall a specific memory upon stimulus. Today's neural networks and brain simulations are very accurate, yet they either are not sufficient to show intelligent behavior, or lack neuronal basis. In order to tackle this problem, in this project, we are connecting both of these concepts together with a simplistic approach. Thus the project consists of three parts: First, neuronal evaluation of inputs; Second, creation of memory neurons from the evaluated outcomes of inputs; Lastly, intelligent decision-making from the given inputs using the formula of intelligence as proposed by Alex Wissner-Gross ($F = T \nabla S\tau$) on a matrix of memory neurons. In order to test whether the neural machine has learned or not, we will have two modes: First, in the **learning mode**, inputs will be stored in memory neurons after being sieved through the input neurons and each memory neuron will be assigned a random output; then in the **test mode**, when we give a specific input to the neural machine, it will show the output of the memory neuron that has the closest match to that one using the formula, (A great explanation video of the formula can be found here: https://www.ted.com/talks/alex_wissner_gross_a_new_equation_for_intelligence?language=en)

In the learning mode:

First of all, inputs will be gathered from the ultrasound sensor and evaluated according to the threshold level of a single neuron. One digital neuron unit will be assigned to a part of each sensory input. For example, a single neuron will search for a certain pattern in the ultrasound input, and another neuron will look for a different or continuing pattern in the same input. As a result, if the specific pattern on the neuron is matched with the input, it would give a high output. Then the outputs of these several neurons will be sent to another neuron -in neuroscience, it is called a ganglion- which will evaluate the overall pattern and decide on its own whether to give a high output or not. On the other hand, several different neurons corresponding to different sensors can also be inputs to a ganglion. This structure is very similar to that of finite state machines. This first neural mechanism will be used both in learn and test mode.

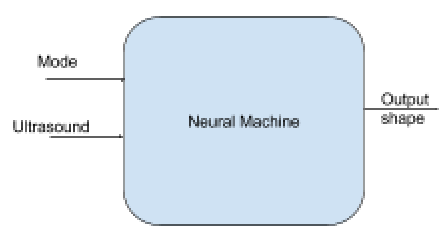
Following the outputs of the ganglion, new memory neurons will be created to store the several bits of input information, which can be done by using registers, and each memory neuron will have a random output assigned to them to show through the dot matrix. These memory neurons will receive input and hold them at the learning mode.

In the test mode:

When the test mode is on, an input will be shown to the ultrasound module, then it will go through the neural mechanism. When it exits the neural process, it will start to use the formula. The formula can be briefly described as, $S\tau$ represents a state in a matrix of several states that changes according to time. All of these states are the memory neurons. The overall $T \nabla S\tau$ statement will be the direction of the preferable memory neuron from the matrix that is assigned a coefficient according to its number of connections to different neurons. As a result, the input will be compared with each memory neuron and will be assigned a coefficient which will lead to the choosing of that memory location to show its outputs. Thus, the random output of that memory neuron will show at the dot matrix.

An example procedure:

The ultrasound system will be shown an approaching object -diminishing its distance towards the sensor- in the learning stage. At this point, each neuron -coded beforehand to give high output when the object passes from a certain point- that corresponds to certain instances of the movement will give high outputs. This outputs will be collected via ganglion and be held in a memory neuron. This memory neuron will have a random dot matrix output such as it would create a circle with a green color. After showing several inputs like this, such as an object going to the left, or right or backwards to the sensor, and creating several memory neurons corresponding to it with random shape outputs, the learning mode will be completed. In the test mode, when we show an object that is approaching, the neural machine, using the formula, will assign coefficients to the memory neurons according to their likeliness to the new test input by comparing them. As a result, the memory neuron with the biggest coefficient will be selected and its output will be shown on the dot matrix. A black-box representation of the neural machine is given below:



EQUIPMENTS

- BASYS2 Board
- CS 223 Beti Board
- Dot Matrix and Ultrasound I/O modules

DELIVERABLES OF THE PROJECT

We will submit a Progress Report, explaining what we’ve done until that point. Then we will submit a Final Project report which contains self documenting Verilog Code, external references and sources. Finally, we will present a demo of our project.