Practical implementation of brain learning by neurons creation

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1. Introduction

Goal to create humanlike intelligent systems requires understanding of the human brain. As the brain is a complex system it is difficult to understand it as a whole. More achievable way is to understand main principles of brain functioning. When it is done, there could be different ways to implement those principles using most suitable resources.

One of the ways of understating principles of brain functioning is to distinguish individual mechanisms of neuron interaction and neuroplasticity and then make their most simple realizations and investigate their qualities and capabilities. That will allow to reconstruct intelligent system based on the principles that were discovered.

Brain learns new information by changing it’s neural structure or characteristics of certain neurons. One of that mechanisms is a "dendritic memory". It is ability to store gained knowledge using branched system of dendritic spines that could be dynamically expanded and aligned. There is also another type of memory that is based on the creation of new neurons, which are created when needed.

Principles of "dendritic memory" are more of less understandable. Having system of connected neurons, which define basic reflexes, visual elements and other predefined information, brain can create new dendrites to remember some sequences of spikes of existing neurons. That allows to enhance basic reflexes and create new behaviors or sequences of actions that leads to desired states.

There is also second mechanism – creating new neurons. I assume that without creating new neurons it’s not possible to create advanced behaviors, which contains basic behaviors as their parts.

To make proper investigation of both mentioned kinds of neuroplasticity they should be researched separately. In this work I will show implementation of memory based on new neurons creation.

2. Sample brain description

2.1 Environment description

Brain perceives one of two signals – 0 or 1, and tries to suggest what signal will be next. Every time after guess brain gets next input signal and can use it as a feedback to align it's structure.

So, here is possible samples of right guesses:

111 -> 1

101010 -> 1

11011011-> 0

Brain that will be modelled has such structure:

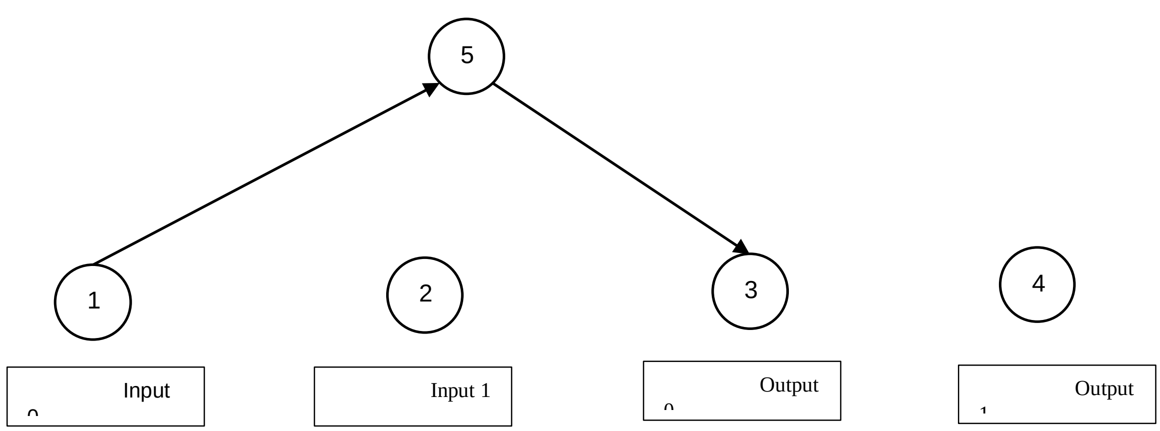
Two input neurons and two output neurons. Environment could activate one of the input neurons at a time. When signal goes from input neurons to output neurons there could be three situations: first output gets larger signal, second output gets larger signal, both outputs get equal signals. Output that gets maximal output signal is preferred output.

2.2 Neurons structure samples

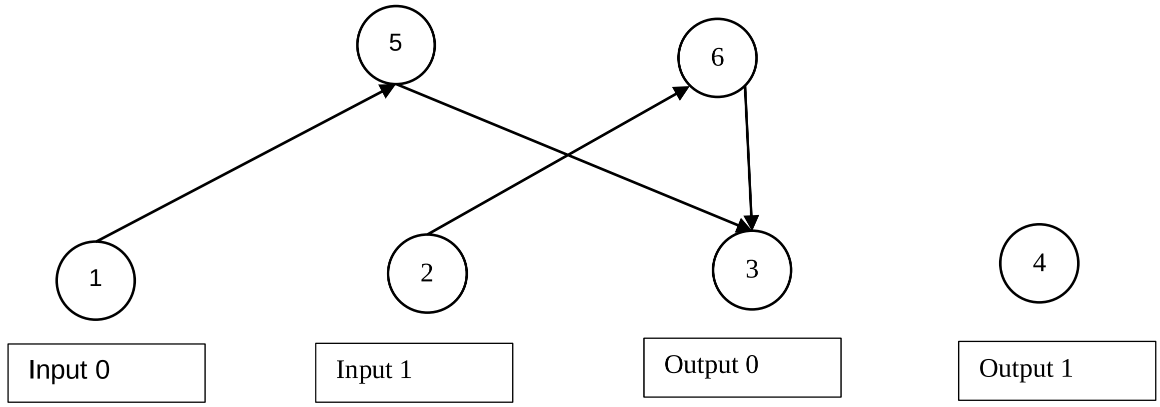
As it was mentioned earlier, we will review model where we can create neuron only with axon, and no dendritic tree.

At the beginning brain has only input and output neurons and no connections between them.

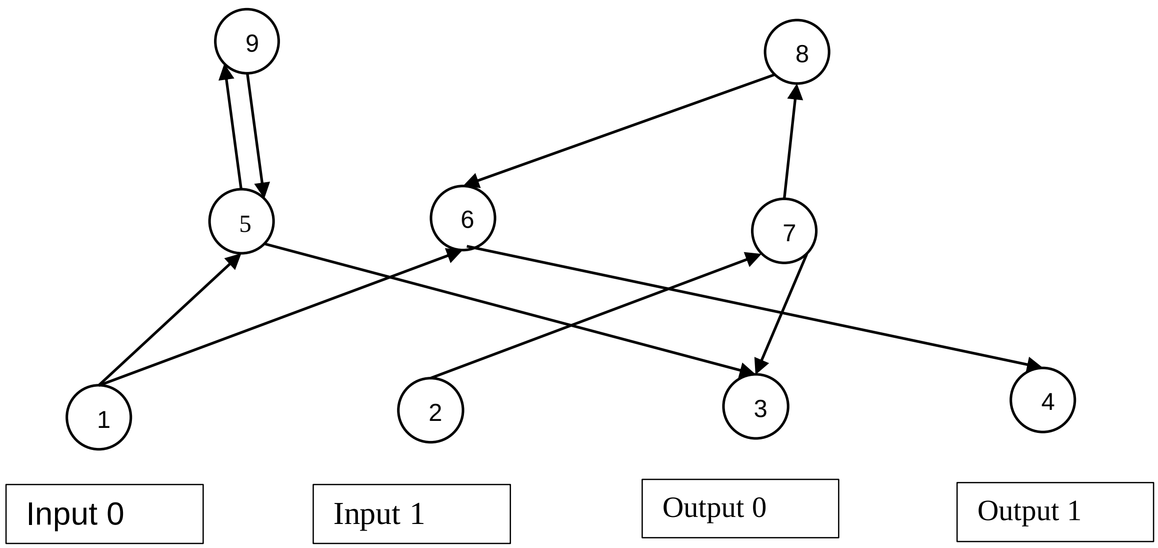
When brain have learned sequence 0..00 neural structure would be like this:



When brain have learned sequence 1010… structure would be this:



When brain have learned both sequences 0..00 and 1010… structure would be like this:



This example differs from previous with that here brain uses not only current input but also inputs from previous states.

Let’s say brain is now on a second position of sequence 1<u>0</u>1. Signal goes from neuron 1 to neuron 3 through neuron 5, and to neuron 4 through neuron 6. On this stage neuron 3 and 4 get equal signal.

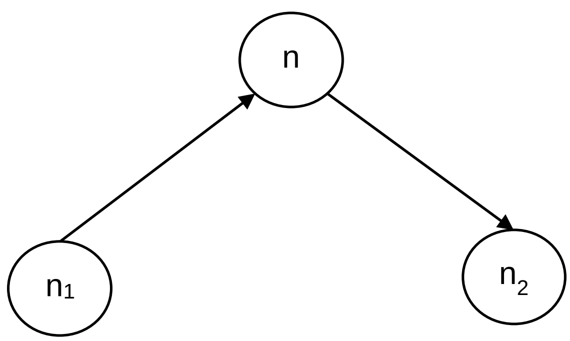
Also there are signal in neuron 7, as it gave right result in a previous moment. Signal from neuron 7 goes to neuron 6, and neuron 6 transfers signal to neuron 4. Therefore neuron 4 gets bigger signal and output 1 is chosen.

3. Brain functions and learning implementation

In previous section we saw examples of how neurons could store information. Here will be described application of the brain that builds such neuron structure while perceiving information.

3.1 Structure and definitions

- Every neuron is connected to two other neurons – cause neuron and result neuron.
- If neuron n1 is cause for neuron n, then neuron n is rule neuron for neuron n1. Signal goes from cause neuron to result neuron through rule neuron. Neuron could be cause, result or rule only relatively to some other neuron.
- Neuron has weight – it is number that characterize its influence.
- In a moment of time neuron could be active.
- In a moment of time neuron could be executed.



On a picture:

n – rule neuron for n_1.

n_1 – cause neuron for n.

n_2 – result neuron for n.

Neuron become executed if it is rule neuron for some active neuron.

Essence of neuron – neuron n (from n_1 to n_2) represents rule, which defines that if some neuron n_1 gave right result as executed in the previous moment or it is activated by current input, then in next moment n_2 will lead to correct output. If rule neuron leads to right output in current moment, then it will be active neuron in the next moment.

3.2 Algorithm

Designations:

I – set of input neurons.

O – set of output neurons.

A – set of active neurons.

Expression $n: n_1 \to n_2$ means: neuron n connects with dendrite to neuron n_1 and connects with axon to neuron n_2.

$weight_n$ - weight of neuron n.

1. Perceive input $n_I \in I$.

2. Let $A = \{n_I\}$.

3. Compute E – set of executed neurons for A.

4. Compute R – set of result neurons for E.

5. Compute $R_{i,i \in O, i \in R} \subset R, i \in R_i$, R_i – connected graph.

6. Compute all sets $E_{i,i \in O} \subset E, \forall \text{n} \in E_i: n: n_1 \to n_2,\ n_1 \in A, n_2 \in R_i$.

7. Compute preferred output: $n_p = \arg\max_{i \in O} \sum_{n \in E_i} weight_n$.

8. Perceive input $n_I \in I$. Let n_O- corresponding output for input n_I.

9. Make learning using n_I as feedback.

10. Let $A = \{n_I\} \cup E_{n_O}$.

11. Go to step 3.

3.3 Algorithm execution example.

Given brain structure than already knows 00… and 1010… sequences.

In this example brain perceive input "1" and return output "0". Then brain perceive input "0" and return output "1". Let $weight_n = 1$ for all neurons.

First iteration: input "1" -> output "0".

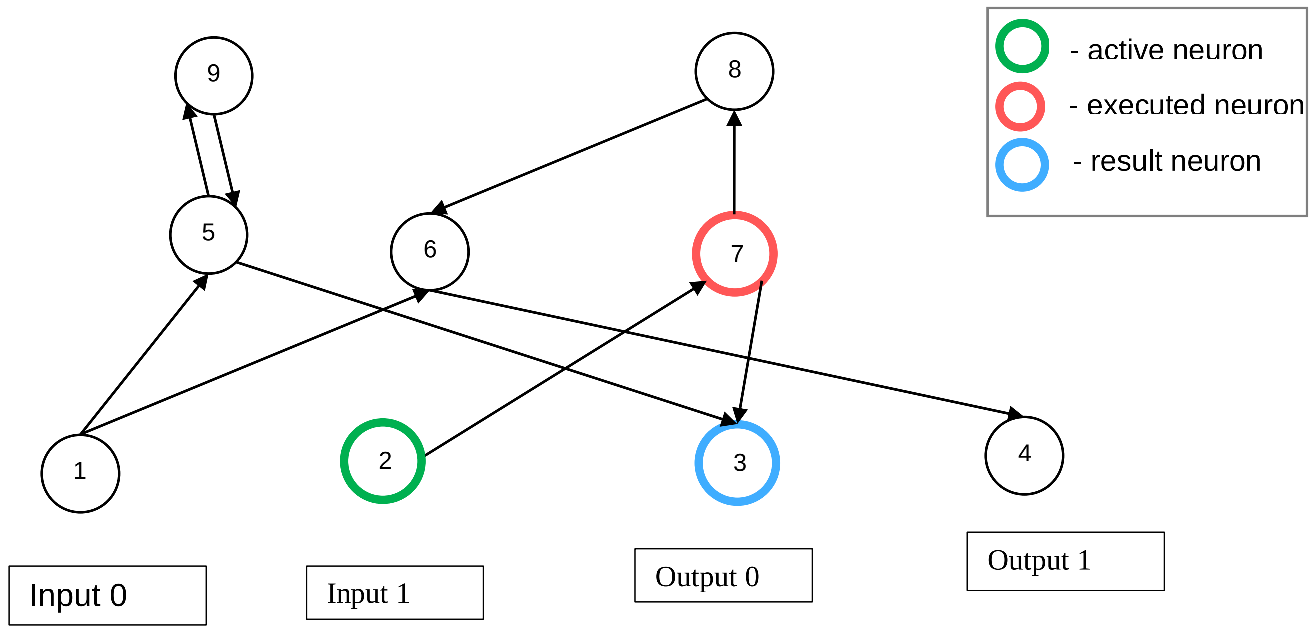
Perceived input $n_I = n_2$.

$A = \{n_2\}$, $E = \{n_7\}$, $R = \{n_3\}$

$R_{n_3} = \{n_3\}$, $R_{n_4} = \emptyset$

$E_{n_3} = \{n_7\}$, $E_{n_4} = \emptyset$.

Preferred input $n_p = n_3$.



Second iteration: input "0" -> output "1".

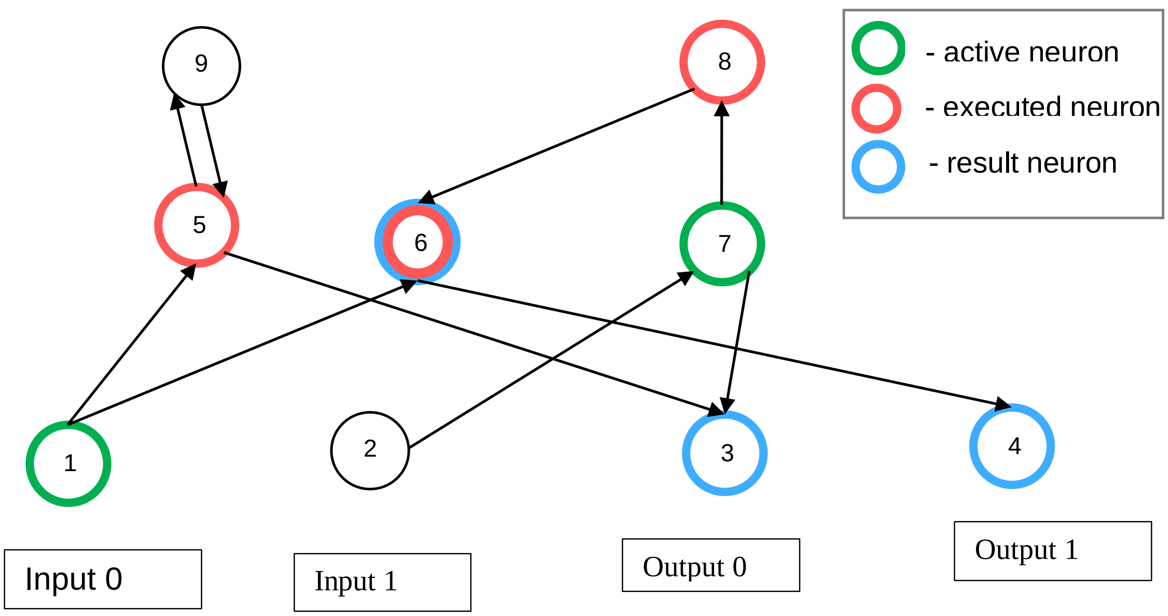
Perceived input $n_I = n_1$.

$A = \{n_1\} \cup E_{n_O} = \{n_1, n_7\}$, $E = \{n_5, n_6, n_8\}$, $R = \{n_3, n_4,\ n_6\}$,

$R_{n_3} = \{n_3\}$, $R_{n_4} = \{n_4, n_6\}$.

$E_{n_3} = \{n_5\}$, $E_{n_4} = \{n_6, n_8\}$.

Preferred input $n_p = n_4$.



3.4 Learning

Learning take place at step 9 and it consists of two parts:

- aligning weights,
- creating new neurons.

Aligning weights:

If $n_p = n_O$, then increase weights of neurons from E_{n_p}.

If $n_p \neq n_O$, then decrease weights of neurons from E_{n_p}.

Creating new neurons:

If $n_p \neq n_O$ then create new neurons that connect neurons from A to neurons from E_{n_O}.

Realization details:

At start there are only neurons n_1, n_2, n_3, n_4 with zero weights.

Neuron weight increases and decreases by 0.2. Minimal weight – 0, maximal – 1.

New neuron has weight 0.2.

New neurons connect only neurons that has equal “height”.

3.5 Results

Some samples of what brain can memorize:

- Any 1, 2, 3-length sequence
- "001" and "110" and "010"
- “1100”
- "01" and “1110”.

Example of how brain learns new sequences (spaces were pasted between different patterns, underscores were pasted where preferred outputs are equal):

```
Input:          00000 11111 010101010101 1101101101101101101101
Pref. output:    _000 0_111 1010_1010101 00_1001001001_01101101
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4. Conclusion

In this paper was implemented approach to build intelligent system based on creation of new neurons. Further research of this and other brain functioning principles could give us ability to create humanlike intelligent systems.

5. References:

1. https://github.com/olegvolovoda/DiscreteApproach - sources of program application.