Simulating the Brain Criticality Hypothesis

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1 Idea

1.1 Goal

The goal of this project is to create a simulation of a brain in a state of criticality. I will be attempting to create a weak AGI. I plan to create a neural network (NN) with similar features to any other mammal's brain i.e:

- The NN will have a branching parameter of about 1.
- Each neuron will have roughly 120 connections.
- Each neuron will have an activation threshold.
- Neuron inhibitory and excitatory postsynaptic potentials will fade over time.

I will attempt to teach the NN simple tasks based around a simulated environment of an organism. My end goal is to create two machines running concurrently, one to simulate the environment, and one to simulate an organism living within the environment. The environment machine will provide inputs to the organism machine, and the organism machine will provide actions for the organism to take in the simulation.

2 Design

2.1 Overview

The NN will take the form of a directed graph. Each neuron will have about 120 receiving and transmitting connections to other neurons.

2.2 Neurons

Connections are the equivalent of synapses in the brain. Each connection has several attributes listed below:

1. Activation Threshold
2. Location

3. Connections

The functions of each attribute will be described in the following sections.

2.3 Activation Threshold

Neurons will activate when the excitation of the neuron exceeds the activation threshold.

2.4 Location

The location of a neuron is used to determine which neurons the a newly created neuron can connect to. The location will have three components: x, y, and z. The neurons that the source neuron can connect to will be based on the distance between the source and the target.

2.5 Connections

Connections are the equivalent of synapses in the brain. Each connection has several attributes listed below:

1. Source neuron
2. Target neuron
3. Weight

The functions of each attribute will be described in the following sections.

2.6 Transmitting

Upon activation, a neuron will send an activation to each of its forward connections with a signal strength based on the weight assigned to that connection. The signal strength will also be affected by the current simulation state (i.e. dehydration may cause weakened signals).

2.7 Receiving

Upon reception of a signal from a connection, a neuron will add the to its level of exicitation.

3 Neuroplasticity

3.1 Connection Strengthening

Connections will increase the magnitude of their connection strength according to the relative firing rate of the target neuron compared to the firing rate of the other target neurons from the same source neuron. Connections will 'share'

from a maximum signal strength from the source node.
Given a set of connections to target neurons from a source neuron, the strength of each connection will be calculated according to the following equation:

$$C_{if} = C_{i0} + \Delta C_i$$
$$\Delta C_i = k * \frac{F_n - \frac{1}{N}}{\sum_{n=0}^{N}(F_n)}$$

C_{if} = Final value of i-th connection weight
C_{i0} = Initial value of i-th connection weight
ΔC_i = The change in the i-th connection weight
F_i = The firing rate of the i-th neuron
N = The amount of outgoing connections to the source neuron

The maximum signal strength will be determined by averaging the all of the source neuron's target neuron's activation thresholds.

3.2 Connection Death

A connection will die when the target neuron dies.

3.3 Neuron Death

A source neuron death will occur when the firing rate of the source neuron becomes lower than a constant threshold. A source neuron can also die if the average magnitude of its connections is below a constant threshold.

3.4 Neuron Creation

Upon a neurons death, a new neuron will appear with new incoming and outgoing connections. Outgoing neurons will be created by searching for neurons within a constant distance according to each neuron's location.

4 Input/Output

4.1 Input

Input neurons will be special neurons that do not have any input connections. The values of the input neurons will be set by the organism simulator based on the simulation's state. Input neurons will not be affected by death and cannot be created. Forward connections that use an input neuron as a source, however, can die.

4.2 Output

Output neurons will be special neurons that do not have any output connections. The activation of output neurons affect the organism's actions within the simulation. These actions will affect the simulation's state. Output neurons will not (currently) be affected by death and cannot be created (currently). TBD: How will input neurons to the output neurons get refreshed (killed and re-created).

5 Motivating Intelligence

5.1 Self-Preservation

Self-preservation will be indirectly inherent to the rules of neuron survival. Neurons will get killed and replaced if they become inactive. If neurons are over-active, it will negatively affect the organism in the simulation and, in the long-term, negatively affect the individual neurons. Since active neurons are reinforced by their source neurons, active neurons will live longer than inactive neurons. Newly created neurons will compete with established neurons. Though indirect, active neurons will have more 'drive' to survive.

5.2 Comparing To Other NNs

In contrast to other common NNs, this NN does not directly change weights or biases to achieve a target output. This NN, instead, uses each neuron's self-preservation to attempt to achieve artificial general intelligence.

6 The Game

6.1 Objective

The objective of the game is to survive as long as possible.

6.2 Situation

The organism exists in a 2D space with food and water spread throughout the space.

6.3 Organism

The organism will have four legs, each with a defined extended length, a defined angle, and a grip. The legs will extend and can be used to grab the ground to maneuver around the space.

Leg Length The length of the legs will be bounded. The organism can extend and contract the legs to their minimum and maximum lengths.

Leg Angle The angle of the legs will be bounded. The organism can rotate the legs to their minimum and maximum angles.

Grip The grip will be how much the legs are 'gripping' the ground. When the grip is at its max level, its leg will remain planted and the organism can contract its leg to move it's body.

The organism will automatically eat food when it is within a defined distance to the food in its 2D space.

6.4 Organism Inputs

The organism will receive the following inputs:

1. 360 degrees of sight
2. Current leg positions
3. Current hunger
4. Current thirst

360 Degree Sight The organism will be able to 'see' by knowing exactly what is in sight at different angles. Its sight will also contain the distance of the item and what the item is (i.e. wall, water, food).

Current Leg Postitions The current leg extensions, angles, and grips.

Current Hunger The organisms need for food.

Current Thirst The organisms need for water.

6.5 Organism Outputs

The organism will output the following outputs:

1. Extend/Contract Legs
2. Rotate Legs
3. Grip/Ungrip legs

Extend/Contract Legs Allows the organism to control its leg extensions.

Rotate Legs ALlows the organism to rotate its legs.

Grip/Ungrip legs Allows the organism to control its grip on the ground.