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Cameron Muhammad  
*Georgia Southern University, cmuhamm1@georgiasouthern.edu*

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Applying Spiking Neural Network Simulation to Neuromodulatory Autonomous Robot Control

Cameron Muhammad
Dr. Biswanath Samanta
Department of Mechanical Engineering

In this project, simulation of the brain based on an artificial spiking neuron model is used to create a self-learning algorithm based on the ROS platform. The spiking neuron simulation is used to demonstrate a neuromodulation program in which the reward seeking properties of dopamine, the risk-adverse effects of serotonin, and the attention focusing effects of the cholinergic and noradrenergic systems are applied to multiple mobile robotic platforms as they move autonomously throughout an environment. External stimuli are recorded by the program as spiking "events" that result in corresponding amounts of dopamine and serotonin influenced spiking patterns. These spiking patterns affect how the robots adapt to their surroundings depending on what type of "mood" is set in the internal programming. Also, alternate hardware platforms are analyzed to see how the neural model can be expanded to include cloud computing as a method of control.

Methods/Materials

- **Software**
  - **Neural Network Code**
    - The model consists of three groups of neurons - event neurons from sensory signals, neuromodulatory neurons and behavior state neurons. The first layer of neurons indicates the incidents happening in the real world environment for the robots. The neuromodulatory layer consists of AC/NE neurons, one dopaminergic neuron (DA), and one serotonergic neuron (S-HT). The last layer of four neurons indicates the four different behavioral outputs as states. Finally the "mood" of the robot (risk-taking, risk-adverse or distracted) was set beforehand.

- **Hardware**
  - **Turtlebot**
    - The "Turtlebot" is a combination of off-the-shelf products like the iCebio Kobuki robot base, ASUS laptop (on-board computation of parameters), Ubuntu Linux (ROS supported operating system), and the Microsoft Kinect (for motion sensing) to create a ROS compatible robotic platform capable of running in many different applications.

- **ROS**
  - The open-source Robot Operating System (ROS) is used as the software framework for the robots. ROS is a collection of publicly available tools and libraries that allow for the creation of reusable general purpose robot code that can be ported over to many different platforms.

**Future Plans**

- **Cloud Server**
  - Using the ROS software platform, the neuromodulator code will reside on a single networked server, reducing the amount of on-board computation that needs to be done by the robot(s).

- **SNN biological model**
  - A more biological realistic model of artificial neuron called the Izhikevich neuron will be adapted into the neuromodulator code for the spiking neural network simulation.

- **Larger swarms of robots of different models**
  - Tests so far have been done with only two robots at the most in one environment. Recording the neural activity of three or more robots in a single space would be a long-term goal. Also, the only robot type used in the lab so far has been of the "Turtlebot" type. The vast majority of the neuromodulated code base can be ported onto other ROS compatible robots to create heterogeneous swarms of various sizes.

**Graphical Overview of Neural Model**

**References**

- Krichmar, J. L., A neurobiotic platform to test the influence of neuromodulatory signaling on anxious and curious behavior, Frontiers in Neuroinformatics, vol. 7, article 1, 2013.
  - http://www.turtlebot.com/