**Integrating Artificial Intelligence into Neural networks**

We ask how artificial intelligence (AI) systems can be integrated into an animal’s nervous system. Our goal is to open new avenues toward a fundamental understanding of both neural and AI networks.

Using AI to replace or augment neural circuits within an animal will allow us to explore the range of computational algorithms that AI employs to solve a behavioral task. We can then directly compare how biological and AI algorithms solve the same problems. Ultimately, we want to learn how artificial and biological networks interact with and adapt to each other to guide animal behavior.

Integrating AI networks with animal nervous systems to take over the function of a neural subcircuit is challenging. A key challenge is to determine the best self-guided learning algorithms and AI network architectures to rapidly learn from and interact with neural circuits in an animal. This proposal aims to address this challenge using a combination of cutting-edge AI, control theory methods (in collaboration with Professor Na Li in SEAS), and neurobiology.

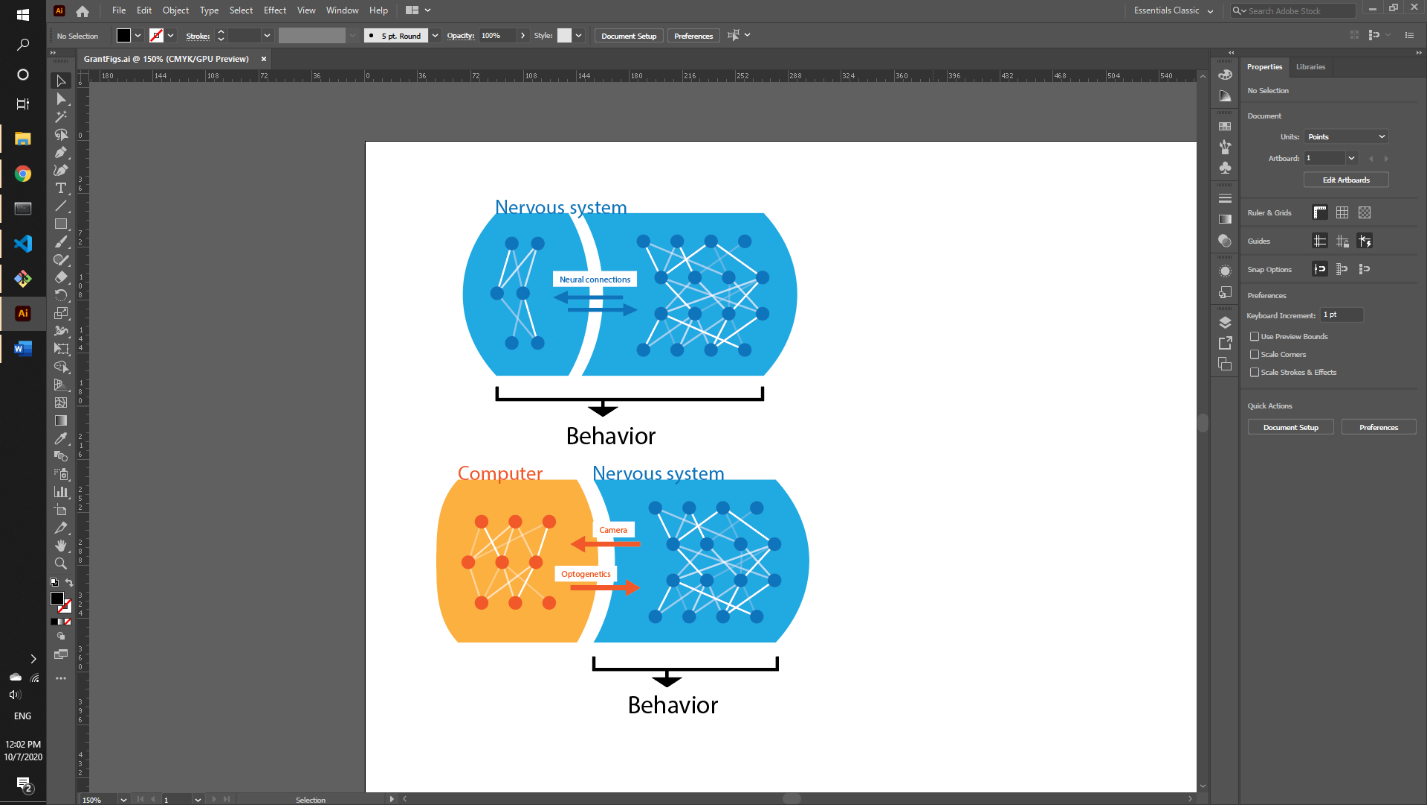
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**Approach** We will employ the soil dwelling nematode C. elegans to validate our ideas. *C. elegans* is highly amenable to genetic modification and optical manipulation. Additionally, its nervous system is extremely compact. It has just 300 neurons and 6000 synapses, yet can execute sophisticated search programs to locate bacteria or mates, associatively learn to avoid or pursue biochemical targets, and trigger stress-resistant long-lived states in dire conditions.

We will develop autonomous AI networks that communicate with the nervous system of the animal through optogenetics, in which animals are genetically modified so their neurons can be activated with light. We will design a closed-loop system in which artificial networks receive inputs from the animal in the form of images. Based on these images, the AI network will learn a spatiotemporal pattern of light to excite the nervous system of the animal. By doing so, the AI system can either learn to replace damaged subcircuits within the nervous system of the animal, or augment the nervous system to more efficiently drive animal behavior.

**(Top Left)** Nervous system of the animal **(top right)** where a subcircuit has been replaced by an AI network. **(Bottom Left)** Position of an animal as a function of time (time pseudo colored in blue) with an untrained AI network **(Bottom Right)** with a trained integrated AI network with a goal of making the animal move left (180 degrees)

Our preliminary work provides a proof-of-concept for our idea. We linked a simple computational agent to a key interneuron that can control C. elegans’ movement. After heavily preprocessing the agent’s input (images of the nematode) and a few minutes of real-time computer learning using a Q-table, our agent can direct the nematode solely through optogenetic links (Figure 2). We would next like to expand to more complex inputs, agents, and behaviors.

**Impact** We will achieve (i) a fundamental understanding of how AI and real neural networks adapt and work with each other, (ii) by comparing the algorithms the AI network converges to with that of the biological network, we will understand how these two networks compare when required to perform the same task, (iii) Determine whether algorithms learned from one animal can be implemented in another, (iv) in the long term, help repair damaged nervous systems. 