Connor Spencer '22

Research with the Dartmouth Pauls Lab
Winter 2020

This winter, I worked with Professor Scott Pauls and his research group on the Dartmouth campus. The group is focused on the suprachiasmatic nucleus (SCN) – a group of approximately 20,000 oscillating neurons in the brain – and its role in controlling an organism's circadian rhythms. The behavior of these neurons is well-known when they all oscillate in phase with each other, as we get the regular circadian rhythms we are accustomed to. However, this is not always the case, and for a number of reasons they may become out of sync with each other. It is known that this produces disturbances to the SCN's rhythmic output, but the exact impact of this disturbance is unknown and is the current focus of the group.

I considered a number of possible lenses to examine this question through: using Kuramoto models to analyze the evolutionary impact of these disturbances, using a game theoretic framework to analyze each neuron and how their strategy changes over time, or a combination of these two approaches. I decided to follow the game theory approach, as I have always been interested by game theory but have never taken a course dedicated to exploring it. By following work outlined in previous game theory publications, I first developed a simulation engine in MATLAB that would simulate this synchronization game across networks of any size and topology, when given the rules of the game to play by. The outcome of these games depends mostly on the payoff functions – which look at the communicativity and phases of a player and one of its neighbors chosen at random, then assigns a payoff to that player based on those factors – but the topology of the network given can also influence these outcomes. Depending on these parameters, different strategies are favored in each game.

Although graduate student Elizabeth Tripp is currently looking more in-depth at these behaviors in situations where all players can interact with each other, I am using this model to both verify her calculations hold and expand on this and see what happens when other topologies are considered. I am continuing this work in the spring to fully explore this question and help establish some idea as to what could be happening in the SCN from a game theoretic perspective. I will also be working with Professor Pauls's group to submit a paper containing these results.

Overall, this was an amazing experience that I was really glad to be a part of. Not only did I get to explore a field I was interested in learning more about, but I also became invested in my research and began to think about other ways in which the same modeling framework can also be applied. I felt that my research built on my preexisting mathematical modeling experience and showed me how my interests in mathematics and computer science can be combined to formulate sophisticated mathematical models to answer questions in ways which we otherwise couldn't using more traditional techniques.