**Reproducing the evolutionary path to human-level intelligence**

My research interests center on Artificial Intelligence (AI), an area that intersects my experiences in computer science and neurobiology. More specifically, my research attempts to understand and digitally reproduce the evolutionary path to human-level intelligence, with the longer-term goal of evolving an AI in a computer.

My undergraduate thesis project sought **to evolve an artificial brain for controlling the gait of a two-legged (biped) robot**, which has been a notoriously difficult problem in robotics research1. With guidance from a faculty research mentor, I developed an independent thesis project to determine whether a direct2 or indirect3 encoding from artificial DNA to the artificial brain was more conducive to evolving a controller for a walking biped robot. As part of this project, I learned how to analyze and extend previous research; how to design new experiments and test for errors; methods to create digital models of evolution; and how to gather, manage, and statistically analyze data. In addition to these technical and research skills, I also learned how to overcome unexpected problems, how to develop and test innovative solutions, and how to persevere when research does not go according to plan. At the conclusion of the project, I discovered that the directly encoded artificial brain model significantly outperformed the indirectly encoded artificial brain model when applied to evolve a stable controller for walking biped robots. Furthermore, my undergraduate thesis research suggested that indirectly encoded artificial brains must be self-adjusting (via feedback learning) in order to allow a biped robot to maintain balance while walking.

This undergraduate research experience confirmed my interest in evolved Artificial Intelligence, and motivated me to pursue graduate studies at Michigan State University (MSU). During my first year at MSU, I joined a research project studying collective animal behavior, which has important implications for understanding social intelligence and collective cognition in animals, and potential applications in the automated control of distributed systems4. Swarming behavior is one of the most striking examples of such collective animal behavior. These decades of research have produced numerous hypotheses about the selective benefits of swarming behavior, such as increased mating success or improved defense against predators5. However, due to the long generation times in swarming animals, studying the evolution of swarming behavior has often proven difficult6. To overcome this difficulty, I developed a computational model that simulates digital organisms with evolving behaviors to examine which of the proposed selective benefits favor the evolution of swarming7. Digital systems have previously been used to provide key insights into core evolutionary processes8, and several well-known studies have adopted digital systems as a method to study swarm behavior9. **With my computational model, I determined that the *confusion* *effect*, where swarming prey confuse and thereby reduce the attack efficiency of their predators, provides a sufficient (but not necessary) selective advantage to evolve and maintain swarming behavior in prey.**

Throughout this project, I further refined my research skills by learning how to design experiments to test biologically relevant hypotheses, collaborate in ongoing research projects, use a new artificial brain model developed in the lab, and learning about the responsible conduct of research. This graduate research project builds on the skills and experience I gained as an undergraduate working with evolving artificial brains, and I have made contributions to improving the artificial brain model in my current lab. I have had the opportunity to present my research at conferences and local meetings10-14, and this project resulted in a new method for testing hypotheses about the evolution of animal behavior7. As a result, data and methods from this project are being included in a grant proposal to the NSF this year.

**Intellectual Merit**

My previous research experiences have helped me develop essential skills for graduate research, including opportunities to construct hypotheses, design and execute experiments, analyze results, and publish outcomes. Beyond technical and research skills, I have developed a broad understanding of the evolutionary and neurobiological processes guiding the evolution of animal behavior.

**Broader Impacts**

The experience I gained in my previous research projects has enabled me to share my passion for science, evolution, and the field of Artificial Intelligence with the public. I have regularly participated in outreach efforts to educate the public about these topics via blog posts on NSF BEACON’s web site and my personal blog, museum events, and local science fairs. From the numerous presentations I have given about my work, I have developed the confidence to share and discuss my research with professionals in my field, and the ability to relate my research to other researcher’s work in a meaningful way. As a result, I have been able to establish numerous collaborations bridging computational research and biology, leading to yet more projects that will broaden our understanding of the evolution of animal behavior.

**References**

[1] Olson RS (2010). A step toward evolving biped walking behavior through indirect encoding. Undergraduate Thesis. In: University of Central Florida Burnett Honors College Library.

[2] Stanley KO, Miikkulainen R (2002). Evolving neural networks through augmenting topologies. *Evolutionary Computation* 10(2):99-127.

[3] Stanley KO, D’Ambrosio DB, Gauci J (2009). A Hypercube-based encoding for evolving large-scale neural networks. *Artificial Life* 15(2):185-212.

[4] Couzin ID (2009) Collective cognition in animal groups. *Trends in Cognitive Sciences* 13:35-43.

[5] Krause J, Ruxton GD (2002) Living in Groups. *Oxford University Press*, USA.

[6] Jeschke JM, Tollrian R (2007) Prey swarming: which predators become confused and why? *Animal Behaviour* 74:387-393.

[7] Olson RS, Hintze A, Dyer FC, Knoester DB, Adami C (2012) Predator confusion is sufficient to evolve swarming. *In review*. Preprint: http://arxiv.org/abs/1209.3330

[8] Lenski RE, Ofria C, Pennock RT, Adami C (2003) The evolutionary origin of complex features. *Nature* 423:139-144.

[9] Couzin ID, Krause J, Franks NR, Levin SA (2005) Effective leadership and decision-making in animal groups on the move. *Nature* 433:513-516.

[10] Oral presentation: "Predator confusion is sufficient to evolve swarming." SwarmFest, July 2012. Charlotte, NC.

[11] Oral presentation: "aBeeDa: A bottom-up approach to the evolution of swarming." BEACON Congress, July 2012. East Lansing, MI.

[12] Oral presentation: "Predator confusion is sufficient to evolve swarming." BEACON Seminar, October 2012. East Lansing, MI.

[13] Poster presentation: Olson, R., Adami, C., Dyer, F., Hintze, A. "A bottom-up approach to the evolution of swarming." ALife XIII, July 2012. East Lansing, MI.

[14] Poster presentation: Olson RS, Hintze A, Dyer FC, Knoester DB, Adami C. “High-performance computing enables the study of collective animal behavior.” MSU Cyberinfrastructure Day, October 2012. East Lansing, MI.