Research and Teaching Statement

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Research Interests

I am particularly interested in distributed decision-making in single- and multi-agent complex systems. Recently, I have shifted my focus to software verification in hybrid and stochastic cyber-physical systems. My goal is to combine work from these two areas for the verification of safety and liveness properties that emerge from distributed decentralized systems. In general, I combine theories from optimization, parallel computing, networks, non-linear dynamical systems, and formal logic to explain, design, or verify emergent system-level phenomena. I prefer problems that are multi-disciplinary or have solutions that can be applied in varied contexts. Consequently, my results have been published in peer-reviewed journals in fields as disparate as engineering [e.g., 4, 8] and behavioral ecology [e.g., 5, 7]. Here, I describe some of my prior research successes and some pending work of mine.

Biomimicry, Bio-inspiration, and Contributing to Behavioral Ecology

There is a convenient homomorphism between autonomous task-processing agents (e.g., autonomous vehicles) and solitary foraging animals. An agent (forager) faces a queue of tasks (prey) according to a merged Poisson process. Processing tasks (feeding) and searching are costly activities, but the agent must process tasks in order to accumulate value (calories) necessary for proliferation by the designer (natural selection). A good design chooses which encountered tasks to process and how long to process each task so as to maximize accumulated value in each agent runtime (lifetime). My prior work generalizes the intuitive analysis methods used in behavioral ecology to apply to a broad class of objective functions [2, 8] that describe similar task problems in engineering. I have also researched how this task problem is affected by search speed choice [4]. The insights I gained in these research directions allowed me to also publish results in behavioral ecology journals explaining laboratory impulsiveness [5] and sunk-cost effects in nature [7].

Distributed Systems: Cooperative Nash Equilibria, Multi-IFD, and Cyber-Physical Systems

Task-processing networks: I have also studied task-processing patterns in agent groups [3]. In one example [6], tasks arrive at agents on a graph; those agents can request processing assistance from their neighbors. Each neighbor must choose how often to answer assistance calls. Such systems occur with cooperative breeders, flexible manufacturing systems, and human organizations. To minimize communication and coordination constraints, I assume that agents optimize local objective functions that encode the cost and value of processing tasks. I give conditions on the network topology and on the utility functions that guarantee existence of a unique Nash equilibrium, and I prove the totally asynchronous convergence of distributed numerical algorithms to that equilibrium. For certain motifs exist in the network topology, the Nash equilibrium will have reduced cooperation willingness at loaded agents and increased cooperation willingness at their neighbors; so the competitive Nash equilibrium can be a collectively good solution.

Distributed resource allocation under constraints: I also study resource allocation models motivated by economic power dispatch and the emerging field of smart lighting [3]. For example, an array of autonomously controlled lights may be required to meet several illumination thresholds subject to an inseparable minimum power constraint across the array. Rather than using numerical dual-space methods on a centralized controller, I have showed that a generalized ideal free distribution (IFD) augmented with nutrient constraints can be used to solve the problem in a decentralized fashion much like a eusocial insect colony.

Software Verification in Cyber-physical Systems

My recent work uses formal methods from computer science and electrical engineering to verify safety properties in cyber-physical systems. One problem of particular interest is the Hoare-like verification of the safety of adaptive cruise control software on highways were there is limited vehicle-to-vehicle communication. Prior model-checking work is overly conservative and assumes vehicles are limited to emergency braking. Our work incorporates physical and software specifications to verify smooth maneuvers that guarantee safety [9, 10].

Teaching Interests

Facing an audience of millennials, classroom teachers compete for attention with new forms of interactive, highly available content. Staying relevant in this atmosphere is difficult as students see less incentive to physically attend classes that cover content that can be found on-line. Some universities have embraced self-paced e-Learning to appease these students and to free up research time for faculty. However, rather than competing directly with purely on-line schools, institutions can leverage faculty experience to create unique in-person offerings that are complemented by an engaging on-line presence. Along with the opportunity to do research with faculty, instructors can use inquiry-based teaching methods to augment traditional classroom learning with self-paced opportunities that prepare students for future research.

Open-Source Collaborative Course Content: Rather than using textbooks as the primary reference material in the courses I have taught, I have produced hundreds of pages of shorter documents[1] that are not only tailored for each course but provide multiple ways to engage the student. Each print-ready electronic document includes hyperlinks that: assist in navigation throughout the document, link to additional third-party sources of information that I have reviewed on the web, and link to other course documents. These fully searchable versions include professional-quality graphics that can be used by students in their formal reports. Because undergraduate students may have little experience writing technical reports, each document is written to serve as an example. Hence, they simultaneously guide a student through the classroom experience, provide her help finding additional technical resources, and serve as examples of language and format that she should use in her course submissions. Because the students know that these are living documents that I have contributed to, they are more likely to contact me about questions they have about the content. Moreover, I can easily make adjustments to the living documents based upon the responses I receive from the students. Students observe this editorial process directly as the Creative-Commons-licensed document source code is available from a distributed source code repository[2].

Using Laboratory Inquiry to Prove Rules by Exception: To investigate classroom scientific inquiry, I was granted a one-year graduate fellowship developing and implementing inquiry-based scientific instruction curriculum for fourth graders. Since then, my college-level teaching methods have been greatly influenced by the experimental scientific method. I work to strengthen students' understanding and appreciation of the abstract mathematical topics by highlighting how experimental deviations from theory follow from violations in model assumptions. When students assert that observed differences from theory are due to "noise" or "manufacturing variations," I work with them to execute an experiment to make these blunt statements precise. This process typically leads them to re-examine how few assumptions are necessary for many engineering methods and how easy it can be to find which assumptions are violated. By testing different hypotheses for why deviations occur, the students sometimes correct experimental errors and restore the expected results, and they often gain valuable insight into the scientific method itself. When it is not practical to provide a hands-on laboratory experience to every student about every topic, I provide simple first-principle-based simulation models to students that help them with their own out-of-class inquiry[3].

Learning by Creating: Although guided instruction is an important part of post-secondary education, I believe that engineering students greatly benefit from collaborating with their peers to create new solutions to unsolved problems. As described by Freuler et al. [1], I have spent several years on the instructional staff of a program for first-year engineering students that provides a cohesive year-long experience that introduces them to basic mechanical, electrical, and computer engineering tools and then requires teams to design, build, and present autonomous robots to complete novel tasks. This kind of tight organization between classroom instructors throughout the academic year is not practical for older students, and so I also served as a team leader in an extracurricular group that challenged these older students with more advanced design and build problems. In both cases, novel design challenges were valuable examples of real engineering and helped students gain exposure to topics that are not easily covered within the classroom.

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[1] Samples can be found on any of the course web page mirrors archived at http://www.tedpavlic.com/teaching/osu/.

[2] Mercurial source code repositories for course material available at http://hg.tedpavlic.com/.

[3] One example is the set of DC–DC boost converter simulation codes and results available at http://www.tedpavlic.com/teaching/osu/ece327/#lab_voltreg. This example was produced at the request of a student.

References

[1] Richard J. Freuler, Michael J. Hoffmann, Theodore P. Pavlic, James M. Beams, Jeffrey P. Radigan, Prabal K. Dutta, John T. Demel, and Erik D. Justen. Experiences with a comprehensive freshman hands-on course – designing, building, and testing small autonomous robots. In *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*, 2003.

[2] Theodore P. Pavlic. Optimal foraging theory revisited. Master's thesis, The Ohio State University, Columbus, OH, 2007. URL `http://www.ohiolink.edu/etd/view.cgi?acc_num=osu1181936683`.

[3] Theodore P. Pavlic. *Design and Analysis of Optimal Task-Processing Agents*. PhD thesis, The Ohio State University, Columbus, OH, August 2010. URL `http://rave.ohiolink.edu/etdc/view.cgi?acc_num=osu1281462093`.

[4] Theodore P. Pavlic and Kevin M. Passino. Foraging theory for autonomous vehicle speed choice. *Engineering Applications of Artificial Intelligence*, 22:482–489, 2009. doi:10.1016/j.engappai.2008.10.017.

[5] Theodore P. Pavlic and Kevin M. Passino. When rate maximization is impulsive. *Behavioral Ecology and Sociobiology*, 64(8):1255–1265, August 2010. doi:10.1007/s00265-010-0940-1.

[6] Theodore P. Pavlic and Kevin M. Passino. Cooperative task processing. *IEEE Transactions on Automatic Control*, 2010. Submitted.

[7] Theodore P. Pavlic and Kevin M. Passino. The sunk-cost effect as an optimal rate-maximizing behavior. *Acta Biotheoretica*, 59(1):53–66, 2011. doi:10.1007/s10441-010-9107-8.

[8] Theodore P. Pavlic and Kevin M. Passino. Generalizing foraging theory for analysis and design. *International Journal of Robotics Research [Special Issue on Stochasticity in Robotics and Bio-Systems Part 1]*, 30(5):505–523, April 2011. doi:10.1177/0278364910396551.

[9] Theodore P. Pavlic, Paolo A. G. Sivilotti, Alan D. Weide, and Bruce W. Weide. Comments on 'Adaptive cruise control: hybrid, distributed, and now formally verified'. Technical Report OSU-CISRC-7/11-TR22, The Ohio State University, 2011. URL `ftp://ftp.cse.ohio-state.edu/pub/tech-report/2011/TR22.pdf`.

[10] Theodore P. Pavlic, Paolo A. G. Sivilotti, Alan D. Weide, and Bruce W. Weide. Verification of smooth and close collision-free cruise control. In *Proceedings of the 2011 Symposium on Control and Modeling: Cyber-Physical Systems*, Urbana, Illinois, October 20–21, 2011. Poster abstract.