Research Statement

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Desire

To secure a position as a postdoc, professor, an industrial or academic researcher or at an innovative start-up.

Education

PhD in Applied Math and Statistics, University of California, Santa Cruz, June 2009
MS in Computer Science, University of California, Santa Cruz, June 2008
BS in Computer Science, Carnegie Mellon University, May 2000

Capabilities and interests

My work lies at the intersection of control theory and theoretical computer science. As the field of robotics blossoms into a vibrant research area, the need for a unified set of algorithmic underpinnings is becoming increasingly apparent. My hope is that my strong computer science experience filtered through my graduate school shift into control theory ideally prepares me for such a position.

Some hallmarks of control for robotics include

- Non-linear dynamics are commonplace, rather than special cases (any wheeled vehicle with car steering or jointed robotic arm induces non-trivial non-linearities).
- Control is performed by computers. The time scale over which physical events in the world happens is slower than some characteristic processing time of a modern computer.
- Signals are discretized by level via some form of analog to digital conversion.
- Signals and actions are discretized in time, even if this is only in the form of a discrete approximation to a continuous framework we use to think of a given control system.

My practical research experience primarily deals with control of robotic swarms which communicate over wireless networks. Research in this area combines hallmarks and problems associated with general robotic control with some oddities specific to swarms and networks. Some of these are

- Algorithmic component of control becomes distributed, techniques such as those discussed in [3] become more important.
- Network topology is dynamically induced by robot states or positions.
- It often helps to think of swarm of robots as a mass of interacting particles, and then design a micro-scale physics for how pairs of robots interact that will yield the appropriate macro-scale swarm behavior.

Inspiration for swarming research come from systems in which many agents interacting with simple rules give rise to a global emergent behavior [5]. In some sense the task of designing control algorithms for swarms is the inverse problem to the common scientific task of predicting collective behavior from atomic rules of individual agents (for instance how the actions of individual neurons give rise to the behavior of the brain, how individual consumers interact to create macroeconomic behavior, how organisms give rise to ecosystems). Instead of seeking models that predict which global behaviors will arise from local rules, we seek to engineer local rules to give rise to desired global behaviors.

One might hope, therefore, that work in this area may help shed light on the related scientific problem of understanding complex interactions in multi-agent systems, and help better design the sorts of engineered systems like cities and networks that mirror the sprawling many-agent nature of the systems (populations, ecosystems, markets) with which they interact.

On a more immediate level, potential applications for such work include environmental monitoring, urban search and rescue, but could also be extended to related areas of ad-hoc networks and claytronics (the use of swarms of tiny robots to form granular programmable materials). The proposed NASA Terrestrial Planet Finder would use coordination among autonomous robotic spacecraft to create a virtual astronomical instrument.

Many of the established results in swarming rely on algorithms which make no guarantee that the network over which the robots communicate remains connected. At the same time, proofs of convergence often rely on the assumption that the network remains connected throughout the execution of the algorithm.

Many established algorithms (flocking, rendezvous, consensus on a measured value) rely on some form of distributed averaging, and therefore have a speed of convergence which depends on the second smallest eigenvalue of a variant of the Laplacian matrix [**?**] of the communication graph.

Research Experience

As a researcher at the University of California, Santa Cruz I performed a systematic study of distributed algorithms to maintain wireless network connectivity in swarms of mobile robots. My work consisted of three basic threads. The first of these [8, 11, 12] focused on developing discrete distributed spanning tree algorithms designed to be coupled with continuous control laws, such that the control laws were constrained to maintain the spanning tree induced by the discrete algorithm. The second [9, 10] revolved around a partial information approach to maintaining the graph Laplacian of a network induced by robot positions. Each robot would act, based on time-stamped out-of-date information disseminated from its neighbors, to keep the second smallest eigenvalue of the graph Laplacian above a threshold, while attempting to move in a direction close to the proposed motion of an underlying coordination algorithm. We proved that these individual robot actions, when coupled together, would collectively maintain the global constrained on the second smallest eigenvalue of the Laplacian of the inter-robot communication graph. The third thread [7] improved on coordination algorithms for a practical robotic spacecraft design developed at JPL [2, 4].

Much of this theoretical work, in addition to validation through rigorous mathematical proof, was also demonstrated through the use of a custom simulation platform. I developed a graphical simulation and visualization platform [6] designed to simulate any robotic swarm algorithm developed under the framework proposed in [1]. This leads me to discuss further capabilities best introduced via discussion of my industrial experience.

Industrial Experience

Prior to starting graduate school, I spent 5 years in industry as a software engineer. I mostly focused on areas related to computer graphics and visual computing, in the process touching on CAD, GIS and visual simulation.

A start-up I worked for, CommonPoint Inc (`http://www.commonpointinc.com`), was recently bought by Bentley Systems. While there, I worked on view management, tessellation and collision detection systems, among other things.

Prior to that, I worked at the 3d scenegraph and virtual reality company Sense8. While there I helped to maintain and improve a mature 3d visualization and simulation package which primarily sold to academic virtual reality researchers.

During college I interned at Terrasim (`http://www.terrasim.com`), where I helped integrate 3d building models into geospatially accurate tessellated 3d scenes. I also interned at the Naval Center for Applied Research in Artificial Intelligence, writing support code for research in robotics and genetic algorithms.

References

[1] J. Cortés, S. Martínez, and F. Bullo. Robust rendezvous for mobile autonomous agents via proximity graphs in arbitrary dimensions. *IEEE Transactions on Automatic Control*, 51(8):1289–1298, 2006.

[2] C. D. Godsil and G. F. Royle. *Algebraic Graph Theory*, volume 207 of *Graduate Texts in Mathematics*. Springer, 2001.

[3] P. R. Lawson and J. A. Dooley. Technology plan for the terrestrial planet finder interferometer. Jet Propulsion Laboratory Publication 05-5, June 2005.

[4] N. A. Lynch. *Distributed Algorithms*. Morgan Kaufmann, 1997.

[5] S. R. Ploen, D. P. Scharf, F. Y. Hadaegh, and M. Bikdash. Initialization of distributed spacecraft formations. *Journal of the Astronautical Sciences*, 52(4), 2004.

[6] C. W. Reynolds. Flocks, herds, and schools: A distributed behavioral model. *Computer Graphics*, 21(4):25–34, 1987.

[7] M. D. Schuresko. CCLsim. a simulation environment for robotic networks, 2008. Electronically available at http://www.soe.ucsc.edu/˜mds/cclsim.

[8] M. D. Schuresko and J. Cortés. Correctness analysis and optimality bounds of multi-spacecraft formation initialization algorithms. In *IEEE Conf. on Decision and Control*, pages 5974–5979, San Diego, CA, December 2006.

[9] M. D. Schuresko and J. Cortés. Safe graph rearrangements for distributed connectivity of robotic networks. In *IEEE Conf. on Decision and Control*, pages 4602–4607, New Orleans, LA, 2007.

[10] M. D. Schuresko and J. Cortés. Distributed motion constraints for algebraic connectivity of robotic networks. In *IEEE Conf. on Decision and Control*, pages 5482–5487, Cancun, Mexico, December 2008.

[11] M. D. Schuresko and J. Cortés. Distributed motion constraints for algebraic connectivity of robotic networks. In *Journal of Intelligent and Robotic Systems*, 2009. To appear.

[12] M. D. Schuresko and J. Cortés. Distributed tree rearrangements for reachability and robust connectivity. In R. Majumdar and P. Tabuada, editors, *International Conference on Hybrid Systems: Computation and Control*, volume 5469 of *Lecture Notes in Computer Science*, pages ***–***, New York, 2009. Springer.

[13] M. D. Schuresko and J. Cortés. Distributed tree rearrangements for reachability and robust connectivity. *SIAM Journal on Control and Optimization*, 2009. Submitted.