Statement of Purpose

Kyle Vedder *Ph.D. Applicant*

I plan to pursue a Ph.D. in Computer Science with a focus on Robotics to support my long term goal of building autonomous human-assistive robots that can robustly perform tasks in dynamic environments. In particular, my research interests include planning/scheduling, safe control in dynamic environments, manipulation, and building tools to make robot controllers robust.

My work in the Autonomous Mobile Robotics Lab at the University of Massachusetts Amherst with Professor Joydeep Biswas has allowed me to develop significant experience in both planning and control domains. One example of this is my work in realtime path planning in dynamic environments for individual agents. Finding paths for an agent efficiently is important in many domains, from robotic arms to courier robots, as these agents need to update their plans in realtime to conform to their rapidly changing environment in order to prevent collisions. This work focuses on augmenting roadmap based planners in domains where obstacle shapes are known offline, but positions are known online, by inserting "scaffolds" into the roadmap. These scaffolds, such as shown in Figure 1, and the associated insertion algorithm, are designed to add vertices near dynamic obstacles, where fine maneuvering is most needed, in order to provide a smoother and tighter path. This work provided me with a familiarity with the state-of-the-art for realtime path planning, spawned my interest in multiagent path planning, and taught me the importance of developing meaningful performance and quality measures when presenting results. This work was presented in the *PlanRob* workshop at *ICAPS 2017* [1] and presented as a poster at the *2017 Northeast Robotics Colloquium* [1].

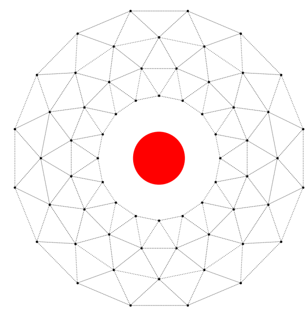

Figure 1: Scaffold Graph for augmenting roadmaps

Another example of prior research experience is my work in anytime multiagent path planning. Finding non-colliding paths for several agents efficiently is important in many multiagent domains, from warehouse automation systems to RoboCup Small Size League teams, as these teams of agents need to balance computation cost and plan execution time when traveling to their goals. This work presents the key insight that conflicts between agents in multi-agent plans often have geometrically local resolutions within a small repair window, even if such local resolutions are not globally optimal. Using this insight, we present a framework for anytime multiagent path planning which plans for each agent individually, and then repairs collisions locally in a bounded "window". While time permits, the window can be relaxed and a new, more optimal repair found, improving the overall solution quality. This work also presents a planner, Expanding A* (X*), which employs this anytime framework and introduces two novel concepts to speed up implementations on real systems: 1) a transformation to re-use the search tree of a previous repair window in a successive window 2) a lazy joint-space neighbor representation that allows for deferred enumeration. X* proves to be significantly faster than the state-of-the-art at generating first solutions, and competitive with the state-of-the-art for optimal solution generation. Figure 2 shows the "Normalized Runtime" (solution runtime / runtime to plan for each agent individually; designed to account for varying levels of implementation optimization) of X*, Conflict Based Search (CBS) [2] and M* [3], demonstrating X*'s statistically significant runtime performance improvements over the state-of-the-art for first solution time, and competitive performance with far tighter confidence intervals for full plan generation. As this was my first experience as first author on a paper, it provided me with the full research experience, from conceiving of the idea to performing a full literature search to writing the research paper. This paper also gave me the opportunity to employ the lessons learned from the roadmap scaffolding paper in the

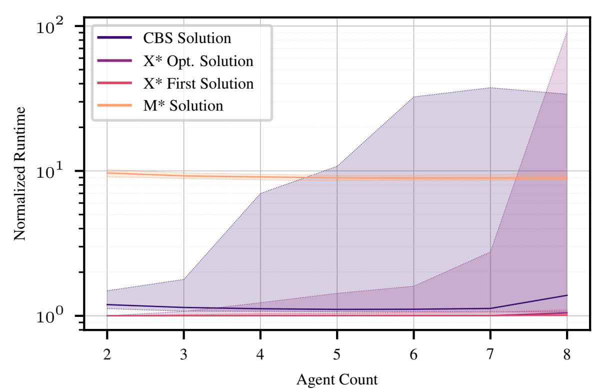

Figure 2: Normalized runtime of X* and state-of-the-art in RoboCup SSL random field configurations; 95% confidence intervals over 100 trials.

[1] Paper available at `http://vedder.io/publications/ScaffoldsLaneVedderBiswasPlanRob2017.pdf`

evaluation of this work. This work is currently in submission to a conference and was presented as a poster at the *2018 Northeast Robotics Colloquium* and the *2018 Massachusetts Undergraduate Research Conference*[2].

Along with my research, I also work in the Autonomous Mobile Robotics Lab as a core developer on the lab's RoboCup Small Size League team, the UMass MinuteBots [4] [5]. I helped architect the control stack and implemented much of the core infrastructure from scratch. I also implemented and maintain much of the low-level control code, from the path planner to the control safety algorithms, giving me significant experience and an appreciation for the difficulty of building very fast and robust control systems. Performing this engineering work, debugging these systems, and tuning other systems such as the state estimator, the motion controller, and the high level planning system has impressed upon me the need for better verification tooling. In particular, I think that in order to reliably build robust, long-term autonomous systems, tooling needs to make these complex systems more explainable and easier to debug without requiring the programmer to write out onerous predicates that are themselves difficult to construct correctly.

Aside from research, I also have three semesters of experience working as a UCA (Undergraduate Course Assistant) in UMass Amherst's Programming Methodologies course. As a UCA, I was responsible for running discussion sections, holding office hours, answering questions on Piazza (a Q/A forum), and aiding in the design and grading of homework assignments. In particular, I was heavily involved in overhauling the structure of the discussion sections to be more engaging and better meet student needs. I chose to stop working as a UCA after three semesters in order to spend more of my time on research; however, I enjoyed the work of a UCA, particularly the teaching aspect of discussion sections, and I would love to have the opportunity to work as a TA in the future.

Outside of academia, I also have significant software engineering experience. I spent two summers as an intern at Unidesk, a startup now owned by Citrix, and two summers as a SWE intern at Google. At Unidesk, I first worked with the CTO on a robot for a trade show, and I then worked with their Windows kernel driver development team, building a testing framework for their Windows registry hive manipulation system. At Google, I first worked on a data processing pipeline to do anomaly detection over hundreds of terabytes of data, and I then worked on a training data sub-sampling system for ML training pipelines, designed to extract interesting subsets of data. These experiences gave me a taste of how to build complex systems in team environments, under deadline pressure, at scale.

I want to pursue a Ph.D. because I believe that is the best path to understanding and contributing to the state-of-the-art in robotics, necessary for my long term goals. In addition, I also want to pursue a Ph.D. because I deeply enjoy doing quality research. I take great satisfaction in presenting work that I know is valuable, and doing so in a convincing way. I know that research is not always glamorous; I've experienced paper rejections, strong critiques, and research projects that fizzled out. These moments, while trying, were also learning experiences and opportunities for me to try again; these experiences are what convinced me that I can stick it out, even through the low points of research.

My goal after a Ph.D. program is to work on autonomous human-assistive robots. My hope is that I can be part of the team that designs the robots which dramatically improve the quality of life of the elderly and disabled.

Although I am open to a variety of research topics, there are several professors at MIT whose prior work is appealing to me. In particular, I am interested in Professor Julie Shah's work on building robots to perform tasks alongside humans, Professor Leslie Kaelbling's work in building intelligent systems to perform human tasks, Professor Nick Roy's work in building robots to operate robustly under uncertainty and in human environments, and Professor Tomas Lozano-Perez's work in integrating planners together for manipulation.

References

[1] Spencer Lane, Kyle Vedder, and Joydeep Biswas. "Augmenting Planning Graphs in 2-Dimensional Dynamic Environments With Obstacle Scaffolds". In: *Proceedings of the 5th Workshop on Planning and Robotics (PlanRob)*. 2017, pp. 48–52.

[2] Guni Sharon et al. "Conflict-based search for optimal multi-agent pathfinding". In: *Artificial Intelligence* 219 (2015), pp. 40–66. ISSN: 0004-3702.

[3] G. Wagner. "Subdimensional Expansion: A Framework for Computationally Tractable Multirobot Path Planning". PhD thesis. The Robotics Institute Carnegie Mellon University, 2015.

[4] Kyle Vedder et al. *UMass MinuteBots 2017 Team Description Paper*. 2017.

[5] Kyle Vedder et al. *UMass MinuteBots 2018 Team Description Paper*. 2018.

[2] Pre-publication available at `https://arxiv.org/abs/1811.12598`