My primary research goal is to improve the state-of-the-art abstractions and tools for modelling, programming and guaranteeing the behavior of robotic systems. To approach this broad goal, I focus on *minimality:* what tasks can be completed by robots with limited sensing, actuation, and computational capabilities? By exploring the "lower bounds" of robot power, we can gain a better understanding of the fundamental informational requirements of robot tasks. We are also forced to more carefully define what robotic *tasks* are, and how to define tasks in a platform-invariant way. I also explore how these questions relate to the robot *design process* itself: better abstractions can enhance human creative capacity. I have several ongoing research projects along these themes.

Robust nondeterministic mobile robots through simple boundary interactions: With my advisor Dr. Steve LaValle, I am examining "bouncing robots": robots which move forward in straight lines until colliding with an environment boundary, at which point they can rotate in place and move forward again. We also consider nondeterministic error in the rotation, since robots rarely rotate or translate perfectly. We have developed an algorithm for synthesizing simple controllers which cause the robot's path to converge to a stable limit cycle on a specified sequence of edges in polygonal environments (or determine that no such controller exists). Our results provide guarantees on how precise the robot control and actuation needs to be in order to cause the robot to "patrol" a space on a repeatable path. I have presented results from this work at the 2017 Midwest Robotics Workshop, IROS 2017, and the 2018 Dynamics Days conference. We are now using these results as building blocks for more complex tasks, such as navigation, localization and coverage, and formalizing task specifications. We are working toward algorithmically determining if a given mobile robot (with a specific sensor and actuator configuration) is capable of completing a given task in a given environment. Such results can help inform automated robot design and verification tools.

Robust nondeterministic self-assembly through simple robot-robot interactions: From my physics background, I have a strong interest in materials which achieve useful global structure or dynamics with minimal information processing, through local structures and coarse global controls. Along this line, I am mentoring a team of undergraduates researching minimal sensing and actuation strategies for collective directed rotation, translation, and eventually collective manipulation. We use off-the-shelf motorized "weaselballs," and augment them with assemblies that can alter their dynamics (through weight and friction), house simple sensors, and attach and detach from each other. Results on assembly dynamics have been presented by the team of undergraduates at the 2018 UIUC Undergraduate Engineering Research Fair, and we are now working toward synthesis of local rules for collective manipulation of robot assemblies and objects.

A high-level compositional movement design tool: I am also developing a project called *Improv*, a high-level programming language for describing and controlling robot motion, in collaboration with Dr. Amy LaViers, Dr. Mattox Beckman, and undergraduate Chase Gladish. This tool includes a simple live-coding interface for ROS (Robot Operating System), the prevailing control architecture in robotics. While ROS is a powerful open-source toolset and is immeasurably valuable to the community, the user interface can be quite inefficient (and intimidating for newcomers to programming and robotics). *Improv* helps fill this gap, and takes guidance from the movement analysis and dance communities to create a principled language for designing robotic movement. I will be presenting this work at the 2018 ACM International Conference on Movement Computing, and soon will run a user study to test *Improv*'s user experience.

Future work: My future goals are to continue exploring formal guarantees on robot behavior, apply these results to robotic software tools (especially interactive design tools) and use hardware experiments to verify the theory. I also plan to extend my work on robot-environment interaction and robot-robot interaction in 2D environments to aerial robots in 3D. Much of my research is in collaboration with undergraduates, and continuing to mentor students is one of the aspects of an academic career that I look forward to the most.