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 they can be defined in a platform-invariant way. I am also interested how these questions relate to the robot design process itself: better abstractions can enhance human creative capacity and make the design process easier. I have several ongoing research projects toward these goals.

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 turn perfectly or move perfectly straight. We have developed an algorithm for synthesizing simple controllers which (using only local measurements and state) cause the path of the robot 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 being able to determine 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 per "agent," 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 weaselballs (off-the-shelf motorized balls) as "particles," and modify them with add-on assemblies that can alter their dynamics (through weight and friction), house simple sensors, and allow the robots to 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 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*, in collaboration with Dr. Amy LaViers (UIUC MechSE), Dr. Mattox Beckman (UIUC CS), and undergraduate Chase Gladish, which is a high-level programming language for describing and controlling robot motion. This tool aims to be an easy-to-use 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 by taking guidance from the movement analysis and dance communities on how to create more principled languages of movement based on composition and transformation, enabling rapid prototyping of robot motion patterns. I will be presenting this work at the 2018 ACM International Conference on Movement Computing. My next step for this project is to run a user study to test *Improv*'s usability compared to other ROS client libraries.

Future work: While different on the surface, all my projects share common principles and applications: obtaining robust behavior and guarantees on robot task satisfiability from minimal, local sensing and actuation, and translating these results to robotic software tools. My work emphasizes physically-motivated theoretical models, integrated as much as possible with hardware and simulated experiments. All of my projects have been collaborative, with a strong emphasis on enabling undergraduate research. I find mentoring students rewarding, and one of the aspects of an academic career that I look forward to the most - as well as contributing to the development and formalization of the multi-faceted field of robotics.