As a fledgling robotics researcher, it amazes me to realize the changes that have swept the field in recent history - the increasing capabilities of hardware manufacturing, computational systems, and new sensors are transforming robots from academic curiousities and constrained factory tools to a real technology which will have impacts on many facets of our human experience. I feel incredibly lucky to be beginning my career now, and also feel compelled to structure my research around the development of robotics as a field in itself, by tackling fundamental questions about the nature and capability of robotic systems.

My primary research goal is to improve the state-of-the-art abstractions and tools for modelling, programming and making guarantees about the behavior of robotic systems. Specifically, I approach this broad goal through the lens of *minimality* - by exploring what tasks can be completed by robots with very limited sensing, actuation, and computational capabilities, we 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 very interested in the robot design process itself, and my research aims to enable human designers to think about and express robot designs at a higher level, enhancing human creative capacity and making these technologies more accessible.

I have several ongoing research projects toward these goals,

Bouncing robots: understanding mobile robots with simple boundary interactions

One project, with my advisor Dr. Steve LaValle, is continuing a line of work on understanding the information requirements of mobile robot tasks, such as navigation, localization, and coverage. We also are working to understand the relative power of different mobile robot models - for instance, can a mobile robot with an angular odometer and a contact sensor perform all the same tasks as a robot with a compass and contact sensor? This work contributes to our fundamental understanding of the capabilities of robots, and the resulting high-level abstractions can also be applied to algorithms for automated robot design and verification. This line of work is also useful for determining the *minimal* amount of information needed to complete a task, leading to more efficient robots.

Having fewer "moving parts" on a robot (whether actual moving parts, or sensors, or amount of computational state) can lead to more robust designs.

In particular, my line of work examines "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.

At IROS 2017, I presented a paper on such a robot which can sense and rotate itself to align at a controllable angle relative to the normal vector at an environment boundary. We have determined that under constant control (the same "bounce angle" at every collision), stable limit cycles exist in all convex polygons. Additionally, given a convex polygon, we are able to synthesize the range of control angles which result in such stable behavior. We are now using these stable cycles as a building block to perform more complex tasks such as navigation and coverage. We are also exploring visibility-based decompositions of more general polygonal environments, creating an information space representation of the environment which can be used to determine if a certain type of mobile robot (with a specific sensor and actuator configuration) is capable of completing a given task in a given environment.

Nondeterministic self-assembly and active materials

There is a large and recent interest in the materials, physics, and computational communities in "active materials," or "active matter," as well as in directed self-assembly: materials which, through local structure and interactions as well as coarse global control (such as applied external fields), naturally achieve some desired global structure and/or dynamics. Most of this work is on the nano and micro scale, but I am interested in finding macro-scale testbeds which simulate relevant dynamics at the small scale. Having such testbeds would allow researchers to focus on the high-level control and computational facets of this line of work, which is often hindered by difficulty of fabrication and observation of such systems.

My line of work in minimal robotics is an interesting lens with which to approach this application: we share many of the same modelling challenges, such as nondeterministic dynamics and sensing, and an emphasis on local and limited agent-to-agent interactions.

To this end, we are using weaselballs (off-the-shelf motorized balls) as our base “particle,” and modifying the balls by placing them in assemblies that can modify their dynamics (through weight and friction) as well as allow for the robots to attach and detach from each other and house simple sensors.

Improv, a high-level compositional movement design tool

I am also developing a project called *Improv*, in collaboration with Drs. Amy LaViers (UIUC Mechanical Science and Engineering Department) and Mattox Beckman (UIUC Computer Science Department, programming languages focus), 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. I am focusing on principled design of motion composition operators and motion transformations, taking guidance from the movement analysis and dance communities. I will be presenting this work at the 2018 ACM International Conference on Movement Computing. The next steps for this project are to run a user study which I have designed to test *Improv*’s usability compared to traditional ROS client libraries, and I hope to disseminate the results at a major robotics conference. While ROS is a very powerful system, and having a free and open source set of libraries immeasurably valuable to the community, the user interface leaves something to be desired, especially for newcomers to programming and robotics. *Improv* aims to fill this gap.

Chase - senior design

Future Work

Robot design space

Mentoring undergraduates

While different on the surface, all my projects share common motivating principles and applications: obtaining robust behavior and guarantees on task satisfiability from simple, local sensing and actuation. My work emphasizes physically-motivated theoretical models, integrated as much as possible with hardware and simulated experiments. Along with strong theory and experiments, I strongly believe we need to be principled with our development of our software tools - both to enable better, more accurate experimentation, but also to make the field accessible to as many different people as possible.

Robotics is a unique field in that it asks fundamental questions about the universe and affects mundane details of people’s everyday lives.