Rooftop Assembly Inchworm Network & Swarm Tiling Optimization for Rooftop Maintenance

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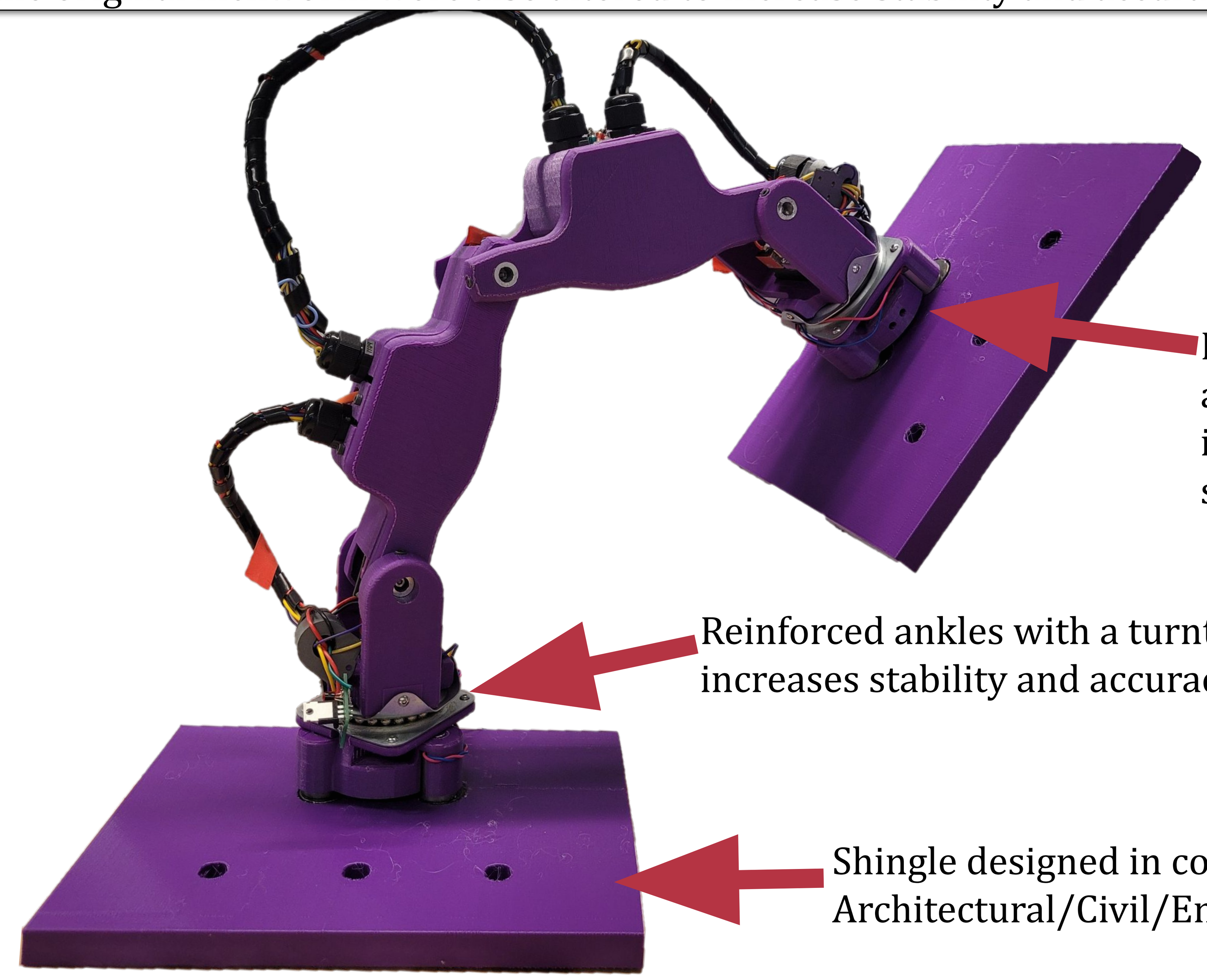
Abstract

Roofing is one of the most dangerous construction jobs, accounting for nearly 20% of total construction workplace fatalities in 2019 [1]. Autonomous robotic construction can increase worker safety and the overall workplace efficiency. However, these technologies are often designed for a single project and are not scalable. Therefore, we are applying an inchworm robot platform to shingle a roof with custom data shingles. Our system is a decentralized swarm of inchworm robots designed to collaboratively shingle roofs. These robots are able to communicate and collaborate by storing data within placed shingles. Overall, the use of a decentralized swarm that communicates through the environment will prevent single points of failures and increase reliability.

[5]

Contribution

We developed a distributed swarm algorithm that allows inchworms to collaboratively shingle a roof. To show collaboration, we developed multiple simulators that can execute the algorithm and use different shingling parameters such as shingling pattern and the number of inchworms. We designed a end effector using permanent electromagnets to interface with a flat side of a roof shingle. Several aspects of the mechanical design of the original inchworm were also altered to increase stability and accuracy.



Electromagnet end effectors allow for a controlled magnetic interface between the robot and shingles

Reinforced ankles with a turntable and a secondary support arm increases stability and accuracy

Shingle designed in cooperation with an Architectural/Civil/Environmental MQP team

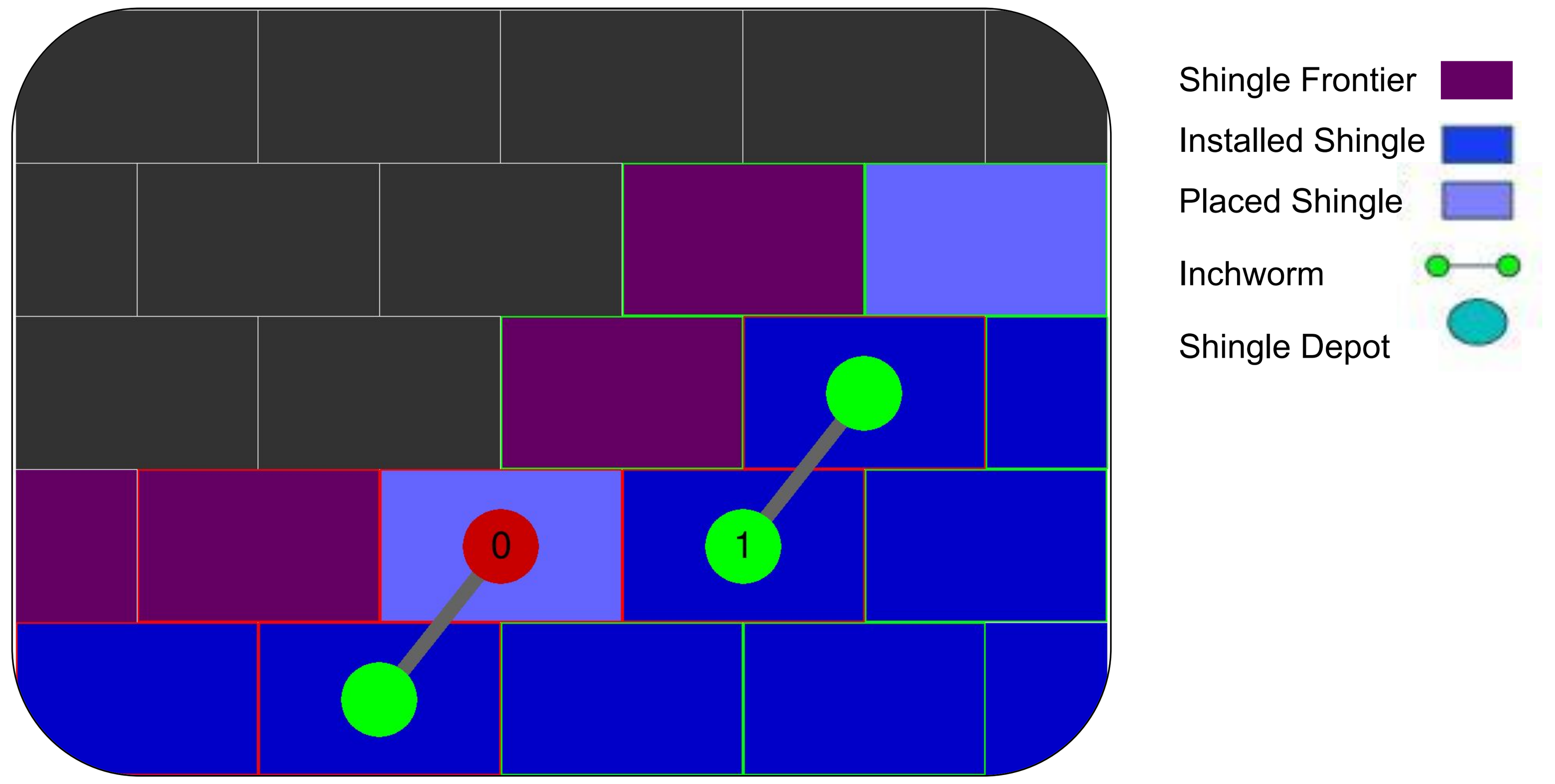
Process

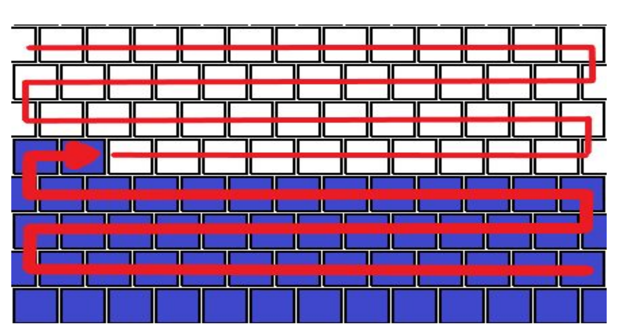
The team broke the project down into a physics simulation, an algorithm simulation and the physical robot. Each part was controlled using the Robot Operating System, ROS [2], and allows for interconnectivity between each section. The algorithm controls high-level functionality and decision-making. The physics simulation turns these high-level actions into motion profiles. The physical robot executes these motions to perform the actions in reality.

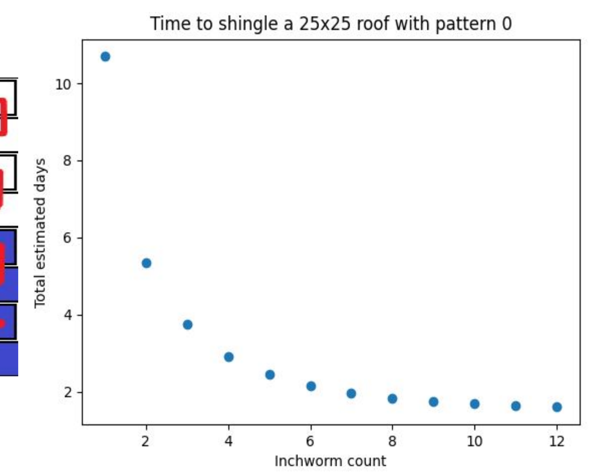
Shingling Algorithm

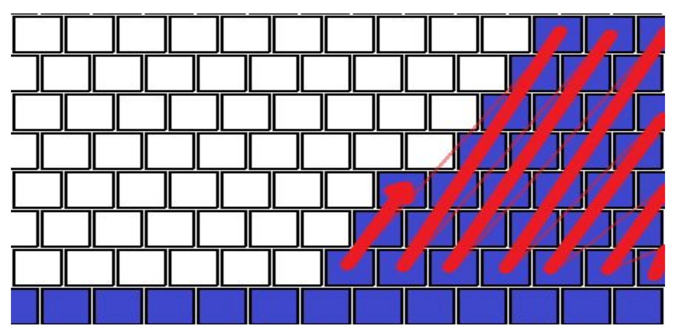
The algorithm tested two different shingling patterns: Boustrophedon (left), Diagonal (right)

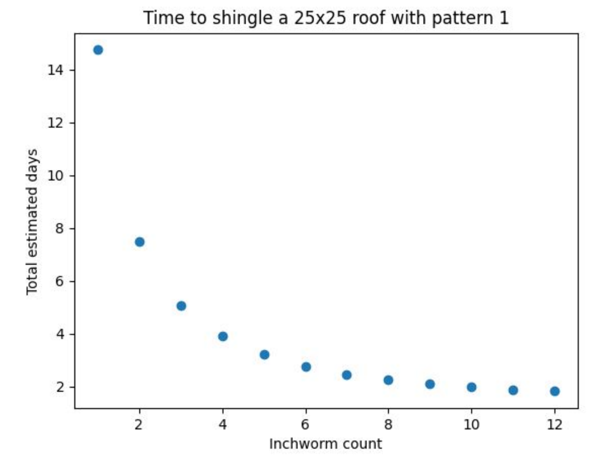
Each of these patterns were tested with a centralized map and known information to create the optimal time to shingle seen in the graphs below.







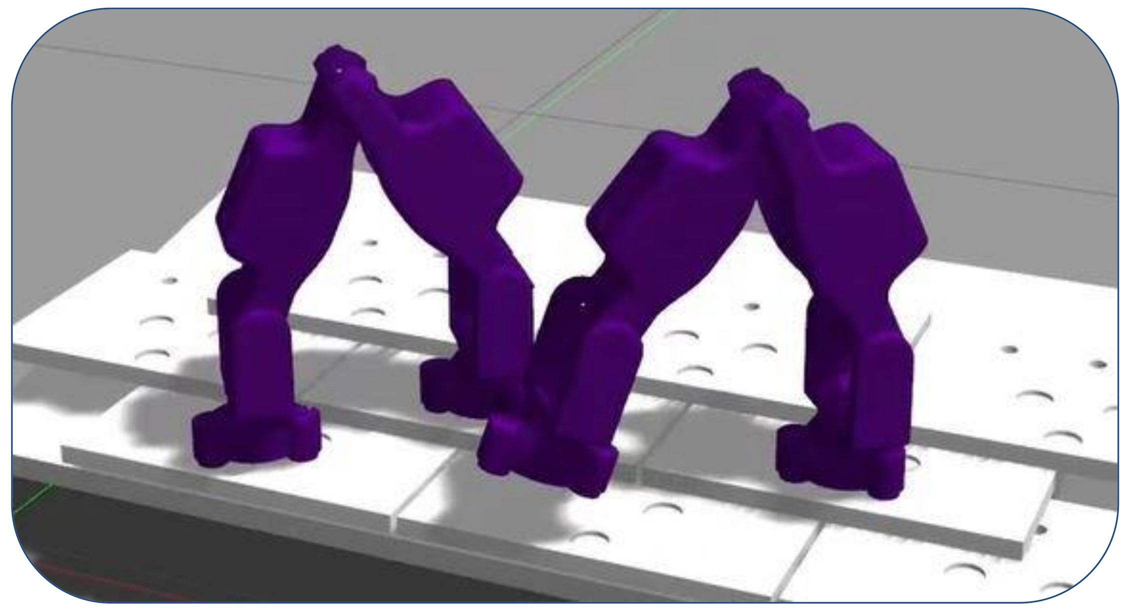


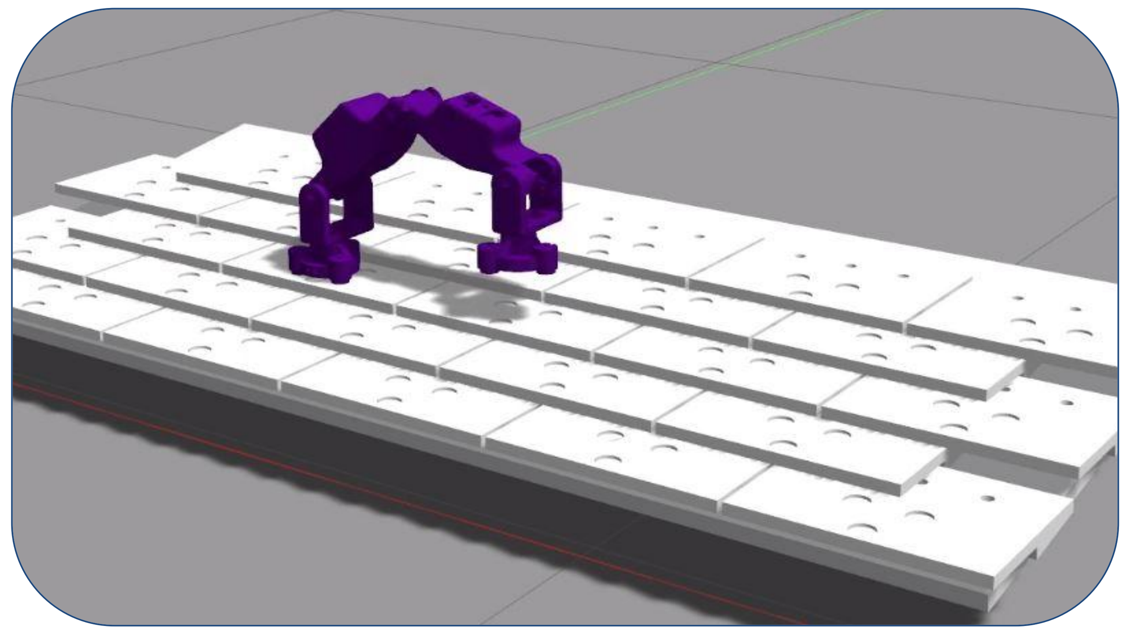


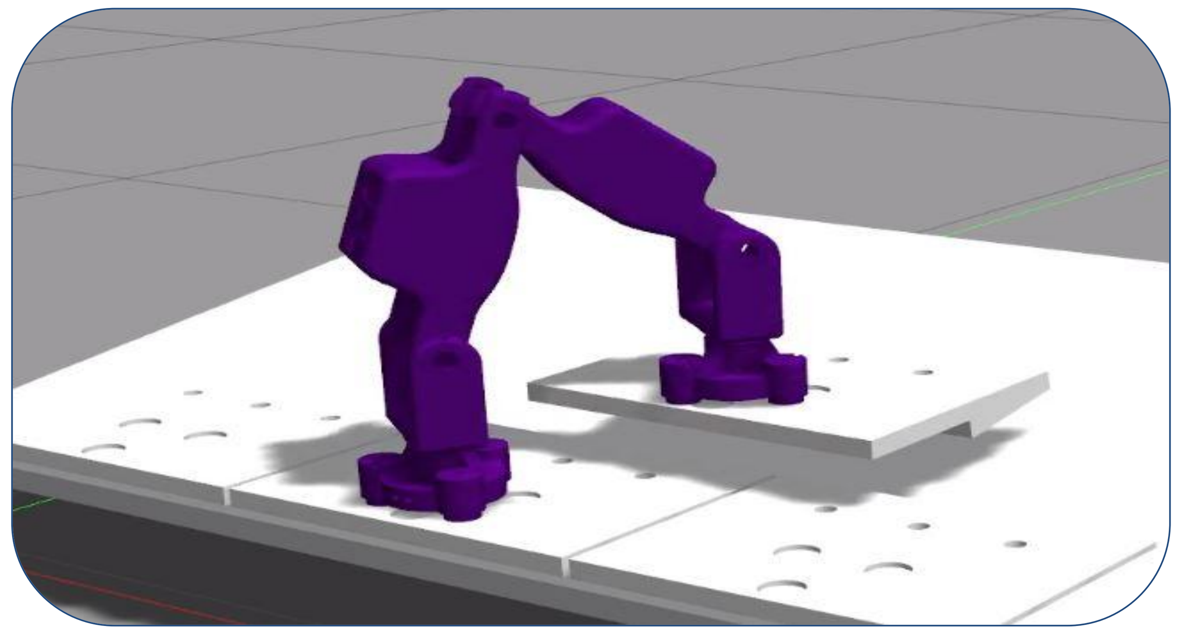
Physics Simulation

This allows us to:

1. Simulate robot kinematics
2. Demonstrate actions in 3D
3. Command real robot hardware
4. Simulate multiple robots and their interactions







References

[1] "Commonly Used Statistics | Occupational Safety and Health Administration." https://www.osha.gov/data/commonstats (accessed Sep. 15, 2021).

[2] M. Quigley et al., "ROS: an open-source Robot Operating System," vol. 3, no. 3.2, 2009.

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