Rooftop Assembly Inchworm Network & Swarm Tiling Optimization for Rooftop Maintenance

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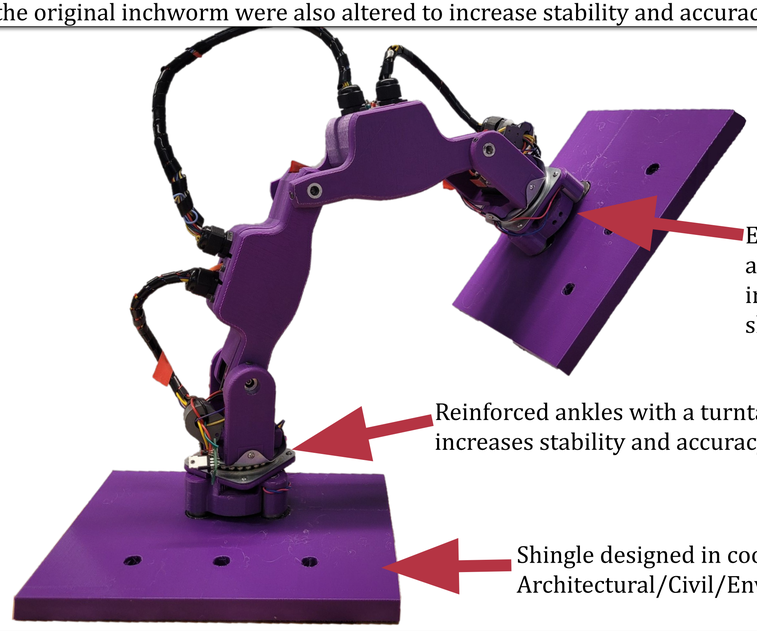
Abstract

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]

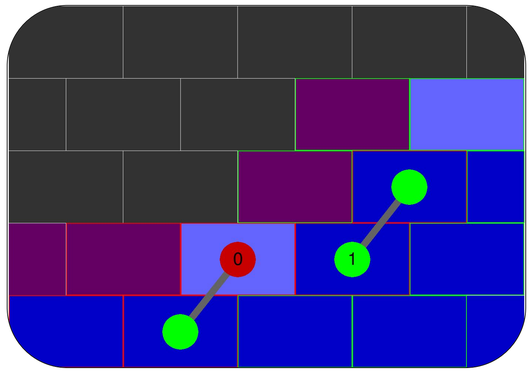
Contribution

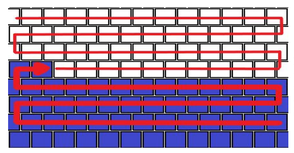
We developed a distributed swarm algorithm that allows inchworms to collaboratively shingle a roof. To show collaboration, we developed multiple simulators that can execute the algorithm and use different shingling parameters such as shingling pattern and the number of inchworms. We designed a end effector 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.

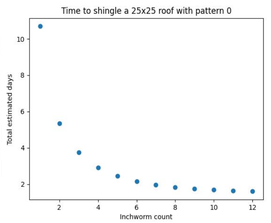


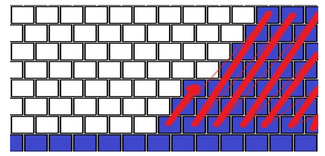
Shingling Algorithm

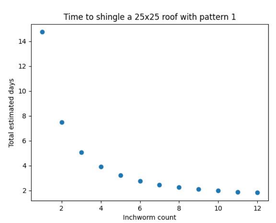
The algorithm tested two different shingling patterns: Boustrophedon (left), Diagonal (right)
Each of these patterns were tested with a centralized map and known information to create the optimal time to shingle seen in the graphs below.

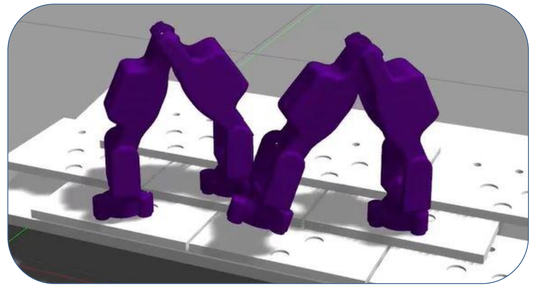








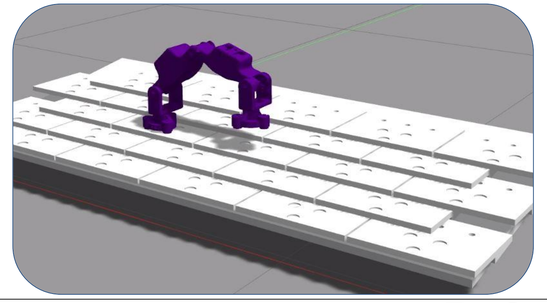


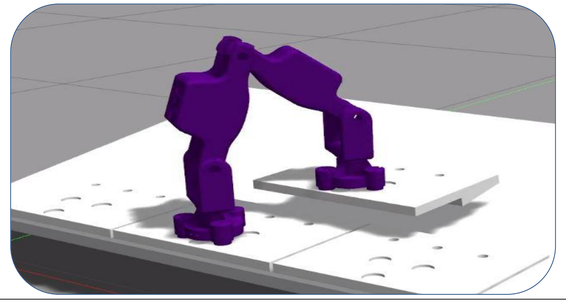


Physics Simulation

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





Process

The team broke the project down into a physic 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.

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.
[3] N. Koenig and A. Howard, "Design and use paradigms for Gazebo, an open-source multi-robot simulator," *2004 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (IEEE Cat. No.04CH37566), 2004, pp. 2149-2154 vol.3, doi: 10.1109/IROS.2004.1389727.
[4] J. Bohren, C. Paxton, R. Howarth, G. D. Hager, and L. L. Whitcomb, "Semi-autonomous telerobotic assembly over high-latency networks," in *2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI)*, Mar. 2016, pp. 149–156. doi: 10.1109/HRI.2016.7451746.
[5] "Palm Coast Asphalt Shingle Roofers (4.9/5 star reviews) | Elo Roofing," *Elo Roofing Palm Coast*. https://eloroofing.com/palm-coast/asphalt-shingle-roofing/ (accessed Apr. 11, 2022).