# Design and Evaluation of a Lightweight Soft Electrical Apple Harvesting Gripper


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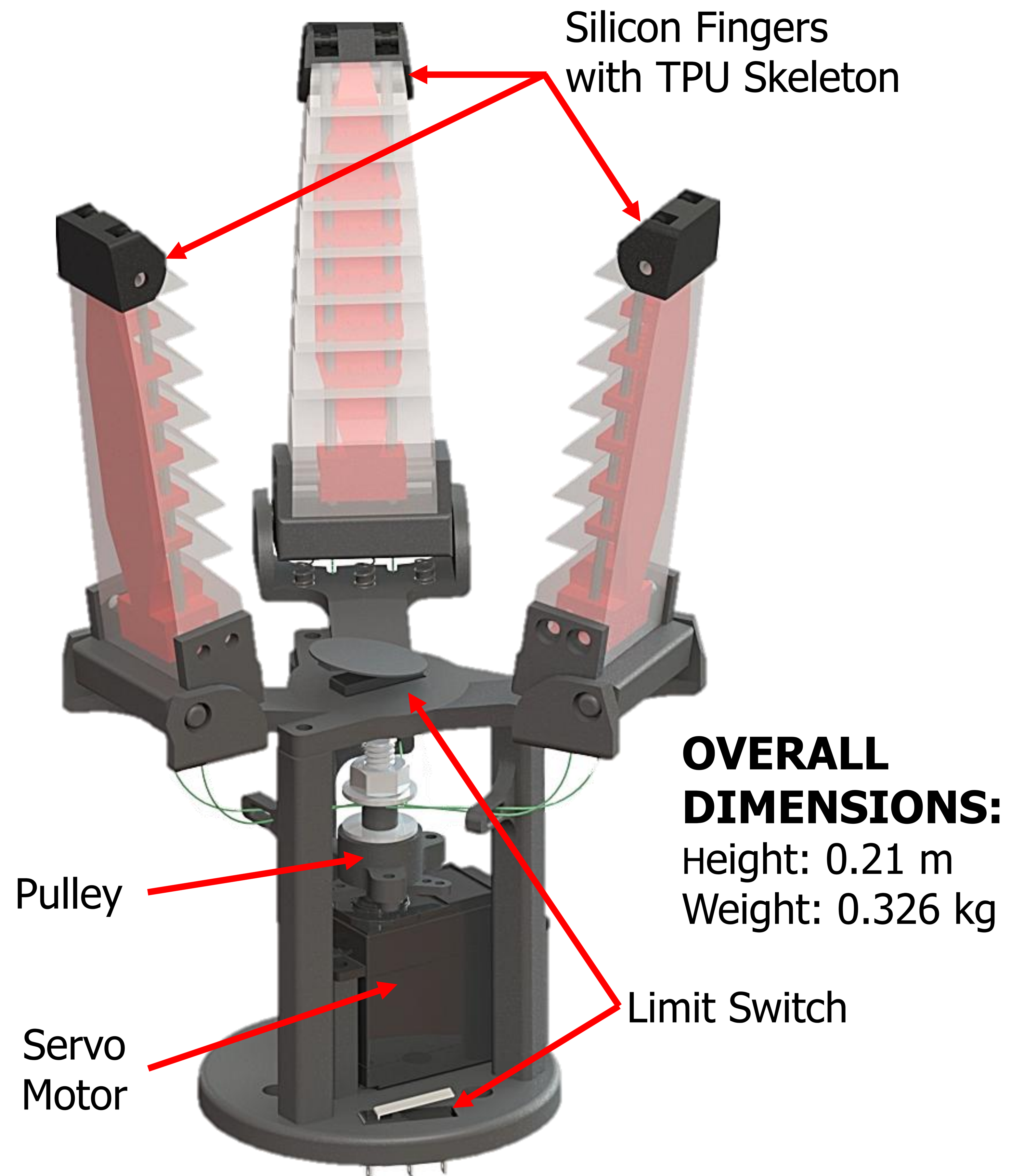
## ABSTRACT

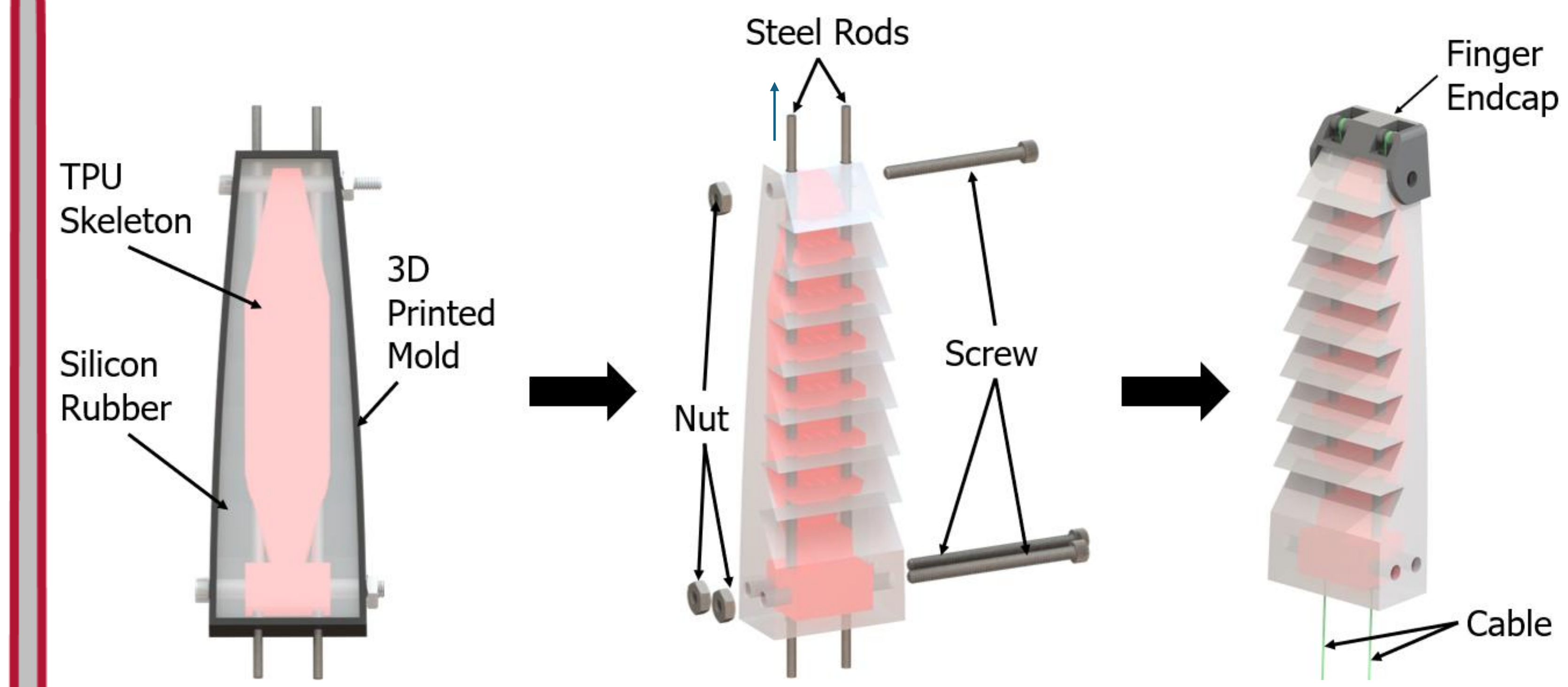
Washington State leads the nation in apple production, harvesting over 6 billion pounds of apples in 2022, and generating over $4 billion dollars to the U.S. GDP[1]. Washington State currently faces labor shortages due to factors such as an aging worker population, and a decreasing number of migrant workers.[2]. To address these issues, we are currently developing a Low-Cost, Rapid Response, Soft, Growing Manipulator Arm for apple harvesting[3]. As a safety measure, the operating pressure of the arm is set to under 10 psi (68.9 kPa). This constraint limits the payload of the arm to under 1.4 kg, with some apple varieties weighing up to and sometimes exceeding an 0.3 kg, the remaining payload including the end-effector must be under 1.1 kg. To guarantee the system can effectively harvest apples it is imperative that the end-effector must be lightweight enough to not exceed the payload limit and soft enough to harvest apples without causing damage to the fruit.


## DESIGN AND SPECIFICATIONS



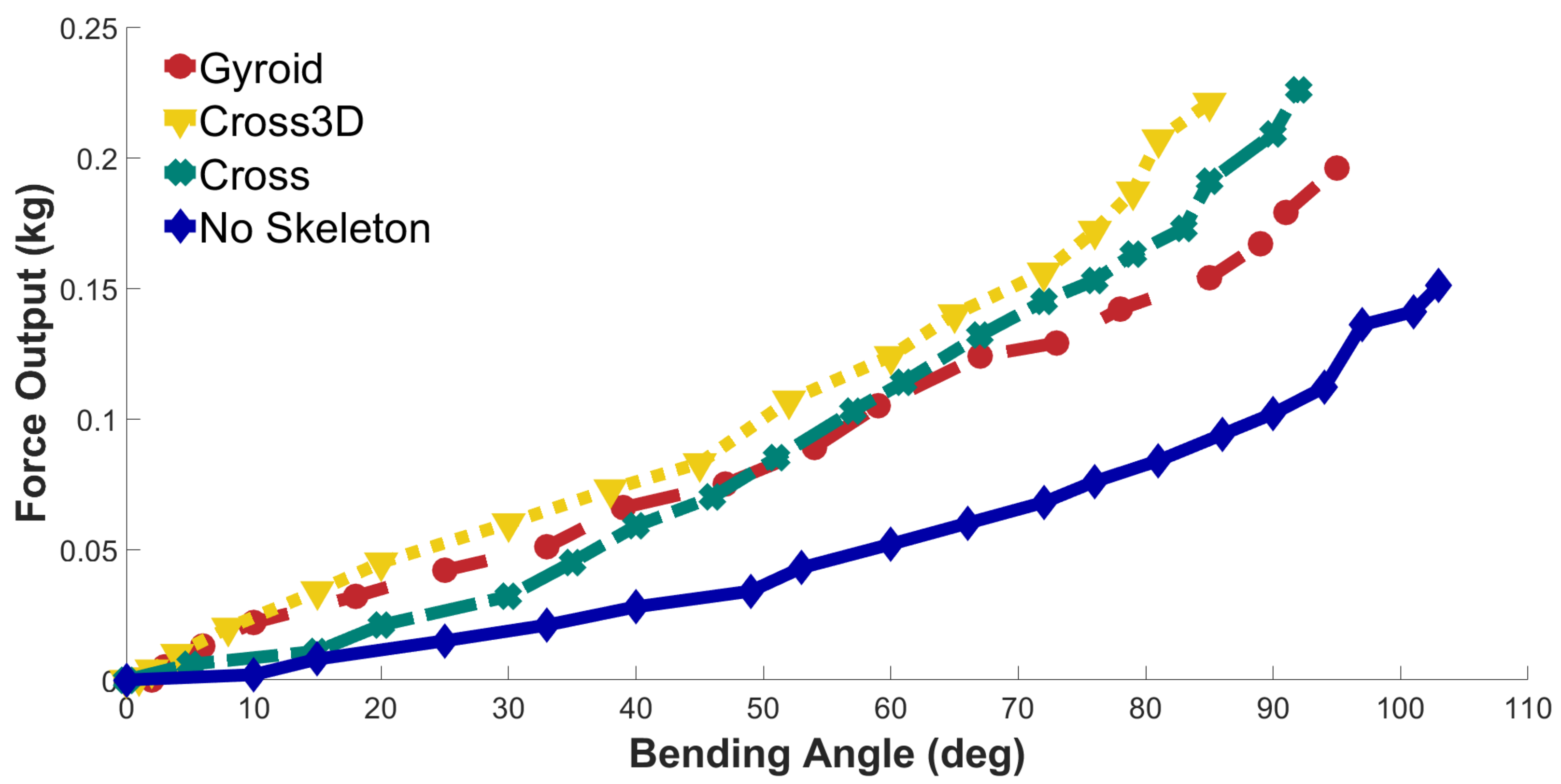

**OVERALL DIMENSIONS:**
Height: 0.21 m
Weight: 0.326 kg

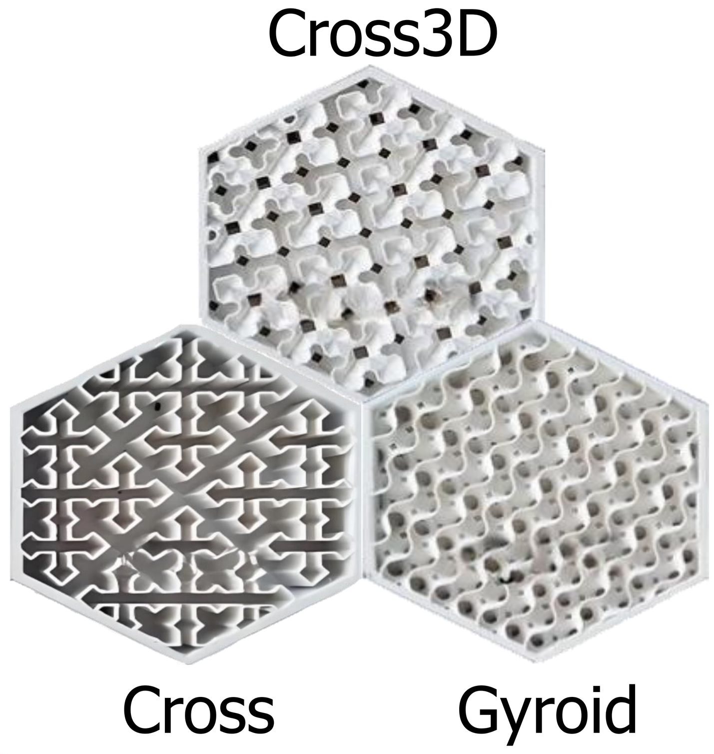
## FABRICATION

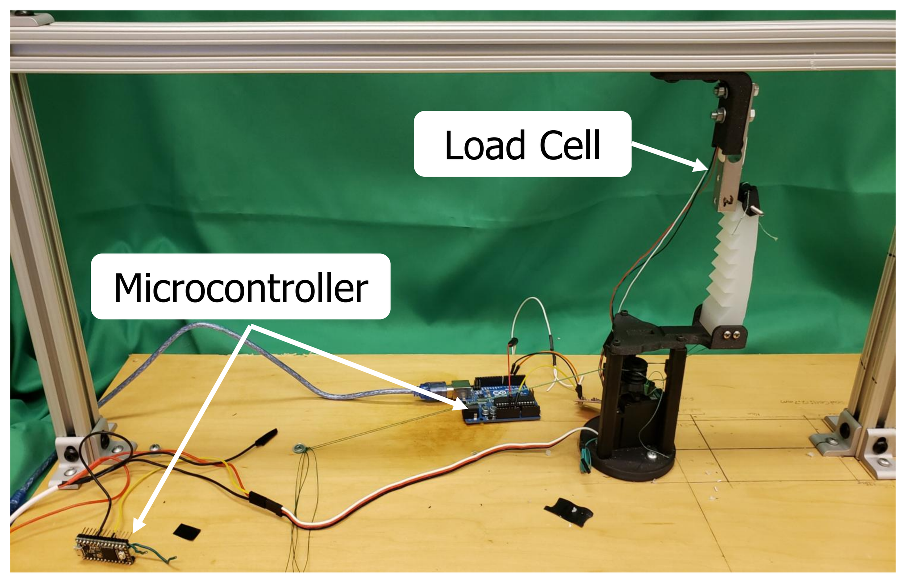



1. A Thermoplastic Polyurethane (TPU) skeleton is placed into a 3D printed mold of the finger. The skeleton is secured in place using two steel rods and three screws. Silicone rubber is poured into the mold.
2. Once the silicone finishes curing, the screws, nuts and rods are removed from the mold.
3. Cables are then threaded through the cavities left behind by the steel rods. The cables at the tip of the finger are tied to the endcap to firmly secure them in place. The other end of the cables wrap around the pulley.

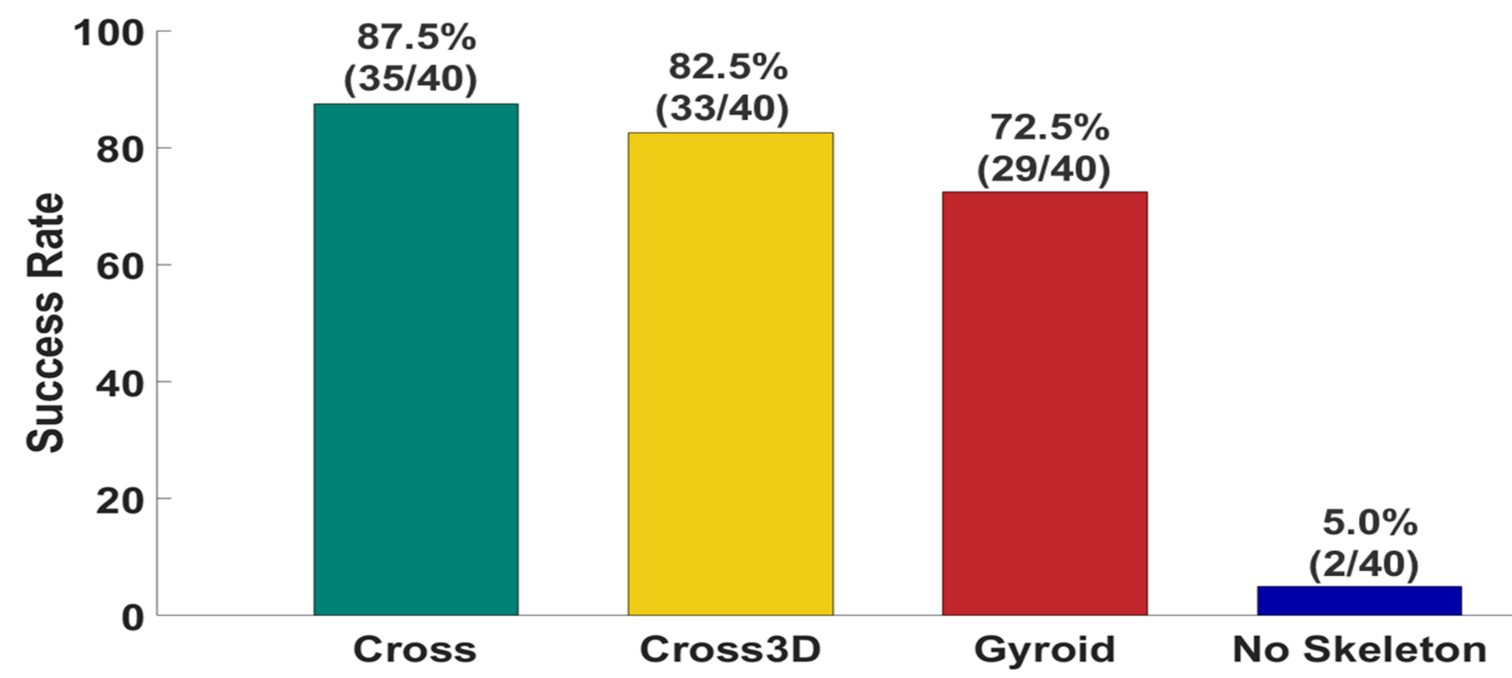
## FORCE ANALYSIS




## EVALUATION




Procedure:

- Four prototypes, each with a different skeleton infill patterns were tested during the 2023 harvesting season.
- A human operator held the gripper and approached the target apple.
- Once the gripper captures the apple, the human operator pulled back the gripper to pick the apple.

## FUTURE WORK

- Addition of a twisting motion, to mimic the natural motion of a human wrist.
- Assessment of any damage to the fruit caused by the gripper during the harvesting operation
- Integration with the soft growing robot to conduct an overall system evaluation.


## REFERENCES

[1] 2022 STATE AGRICULTURE OVERVIEW Washington, USDA, 28 Feb. 2023, www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=WASHINGTON.
[2] X. Hsu, Andrea Bustillio. (2023) As these farmworkers' children seek a different future, farms look for workers abroad.[Online]. Available: https://www.npr.org/2023/07/28/1189476655/farm-workers-labor-shortage-h2a-visa-dan-newhouse-immigration
[3] R. Dorosh *et al.*, "Design, Modeling, and Control of a Low-Cost and Rapid Response Soft-Growing Manipulator for Orchard Operations," *2023 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Detroit, MI, USA, 2023, pp. 4184-4190, doi: 10.1109/IROS55552.2023.10341507.



## ACKNOWLEDGMENTS

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