Design of a Lightweight Soft Electrical Apple Harvesting Gripper

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***Abstract* - To address the labor shortage issue in apple harvesting in Washington State, a novel soft growing manipulator is being developed to overcome the current limitations of general robotic solutions in terms of cost and efficacy. One key aspect of this technology is the development of a lightweight (under 0.8 kg) apple picker effector, considering the strict payload limitations of the manipulator. This paper demonstrates the design of a lightweight cable-driven soft gripper, along with its force characterization and a picking case study conducted in a simulated lab. Future work will involve the commercial orchard evaluation of this technology.**

I. INTRODUCTION

In 2022, Washington State led the nation in apple production, contributing over $4 billion to the U.S. GDP [1]. To address increasing costs and labor shortages, we are currently developing a Low-Cost and Rapid Response Soft-Growing Manipulator for apple harvesting [2]. Our soft growing manipulator features faster linear extension, easier planning and control, safer human-robot interactions, easier maintenance, and lower costs compared to current rigid manipulators. However, the payload of our soft growing manipulator is typically under 1.4 kg because its soft body cannot tolerate pressures higher than 10 psi. Since apples can weigh upwards of 0.2 kg, the remaining payload must be under 1.2 kg. Therefore, in order for the system to function properly, our soft robotic gripper for apple picking must weigh less. This paper briefly introduces a prototype of our customized soft robotic gripper designed to meet the payload requirement of our soft growing manipulator.

II. GRIPPER DESIGN

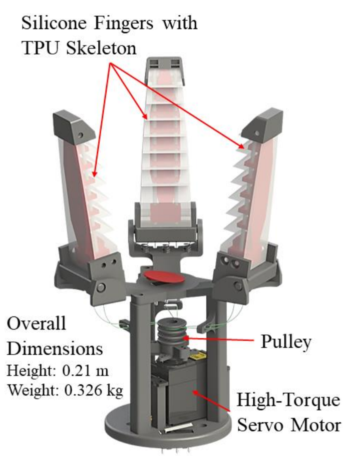

Fig. 1: CAD model of gripper.

The overall design of the soft gripper is displayed in Fig. 1, showcasing the major components that are labeled. The dimensions and weight of the gripper are as follows: a height of 0.21 m and a weight of 0.326 kg. The gripper design consists of three components: 1. The outer material of the fingers is constructed using Dragon Skin 30, a silicone rubber that minimizes surface damage to the apple. To enhance rigidity, each finger incorporates a 3mm thick TPU skeleton embedded within. 2. The cables, which run vertically along each finger, are connected to a pulley. When the pulley is actuated, it creates tension in the cables, resulting in the simultaneous collapse of the fingers. 3. The electrical system comprises a single high-torque servo motor responsible for actuating the fingers, accompanied by two limit switches. The top limit switch is triggered when pressed by an object, causing the fingers to collapse, while the second switch functions as a manual release when pressed.

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III. EXPERIMENTAL RESULTS

Experiments were conducted to measure the force output of a single finger. As shown in Fig. 2 the peak force produced was 5.25 kg. The performance of the gripper end-effector was evaluated using an artificial apple attached to a tree, as depicted in Fig. 3.

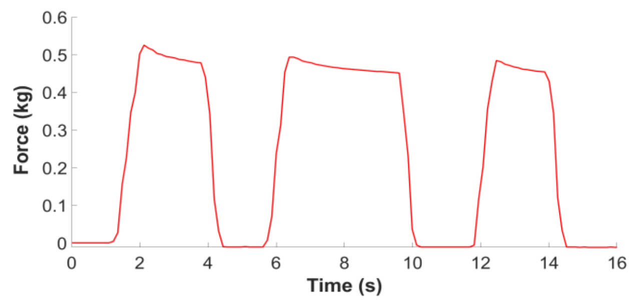

Fig. 2: Force output of one finger

Fig. 3: Gripper End effector approaching, capturing and detaching apple.

IV. CONCLUSION

This paper presents a prototype design, force characterization, and preliminary testing of a soft, lightweight gripper end-effector intended for mounting on our Soft-Growing Manipulator. The testing and evaluation of this prototype will be conducted in a commercial apple orchard during the 2023 harvesting season. Based on the findings, additional modifications will be made to enhance its overall effectiveness.

REFERENCES

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