



Renfu Lu



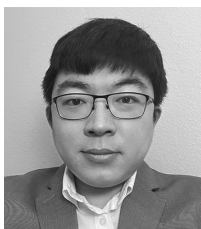
Zhaojian Li



Kyle Lammers



Kaixiang Zhang



Pengyu Chu

### **A New Robotic Apple Harvesting Technology**

Awardees Renfu Lu, Zhaojian Li, Kyle Lammers, Kaixiang Zhang, Pengyu Chu have developed a robotic harvesting technology that features a simple, compact manipulation system with three degrees of freedom plus a rotation mechanism for fruit detachment. The robot can position itself quickly in the x and y coordinates by using a pan and tilt mechanism with two precision servo motors, while movement in the third dimension is achieved by using a linear actuator. Another innovative feature is that the robot arm is only composed of a vacuum tube of 30 mm diameter coupled with a specially designed end effector (or suction cup). This end effector is fabricated using soft silicon material and 3D printing, and it has no moving parts and handles fruit gently during picking. A specially designed perception system based on the laser triangulation technique is used for fruit detection and localization. After a target fruit is detected and localized, the robot then reaches out to the fruit; it first suctions the fruit and then holds it on the end effector, which causes the vacuum pressure in the tube to drop quickly, which is monitored by a sensor in real time. Once the vacuum pressure reaches a pre-determined value, the rotation mechanism is activated to detach the fruit. The current version of the end effector had superior performance in the field trial of 2022 harvest season, achieving 100% successful picking rate. During the 2021 field test, the robot has achieved an overall picking speed of 3.6 s per apple when it was operating in continuous picking mode. Post-harvest analysis results showed that at least 80% of the harvested fruit were free of bruises and 100% picked fruit have met the USDA Extra Fancy grade (the highest quality grade). Compared to the other state-of-the-art harvesting robots, this robot has no problem picking clustered fruit and is dexterous and fast due to the use of a vacuum-based picking mechanism with a passive soft end effector and a pan and tilt mechanism for the manipulating system.