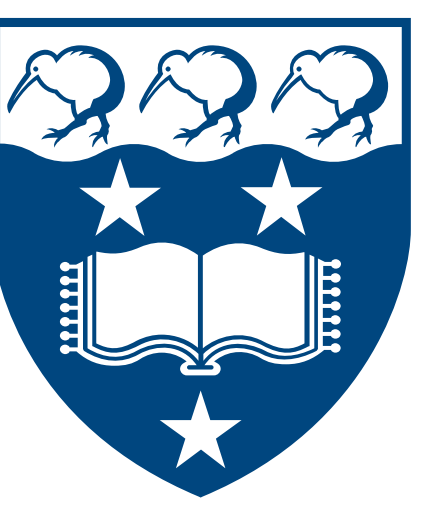




ROBOTIC HARVESTING OF KIWIFRUIT

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ABSTRACT

Harvesting kiwifruit, New Zealand's largest horticultural export, is a labour intensive task. An automated harvesting system is presented that utilises robotic arms controlled by a machine vision system. The machine vision system uses a convolutional neural network and stereo vision to detect and localise fruit. Four custom designed, servo-motor actuated arms provide highly accurate spacial positioning, necessary for carrying out the motions involved with picking. A pneumatically operated gripper, mounted to the end of each arm, mimics the action of a human harvesters hand by rotating the fruit about the stem-fruit intersection. The harvesting system is mounted on an autonomous vehicle that supplies both electrical power and pneumatic pressure. Field trials across three orchards have shown that the system can currently harvest 51% of fruit at a rate of one fruit every 5.5 seconds.

INTRODUCTION

Kiwifruit is New Zealand's largest horticultural export by value [1]. With the government's target of doubling the country's primary exports for the 13 year period ending 2025 [2], there will be increased demand for labour during this period. The majority of employment during peak harvesting and pollination seasons are filled by seasonal or casual workers [3]. Increasing automation in the kiwifruit industry offers a way to increase exports without having to increase demand on a casual or seasonal workforce.

The research presented is a continuation of the work completed by Dr. Alistair Scarfe as part of his PhD studies in which a prototype kiwifruit harvester was demonstrated.

REFERENCES AND THANKS

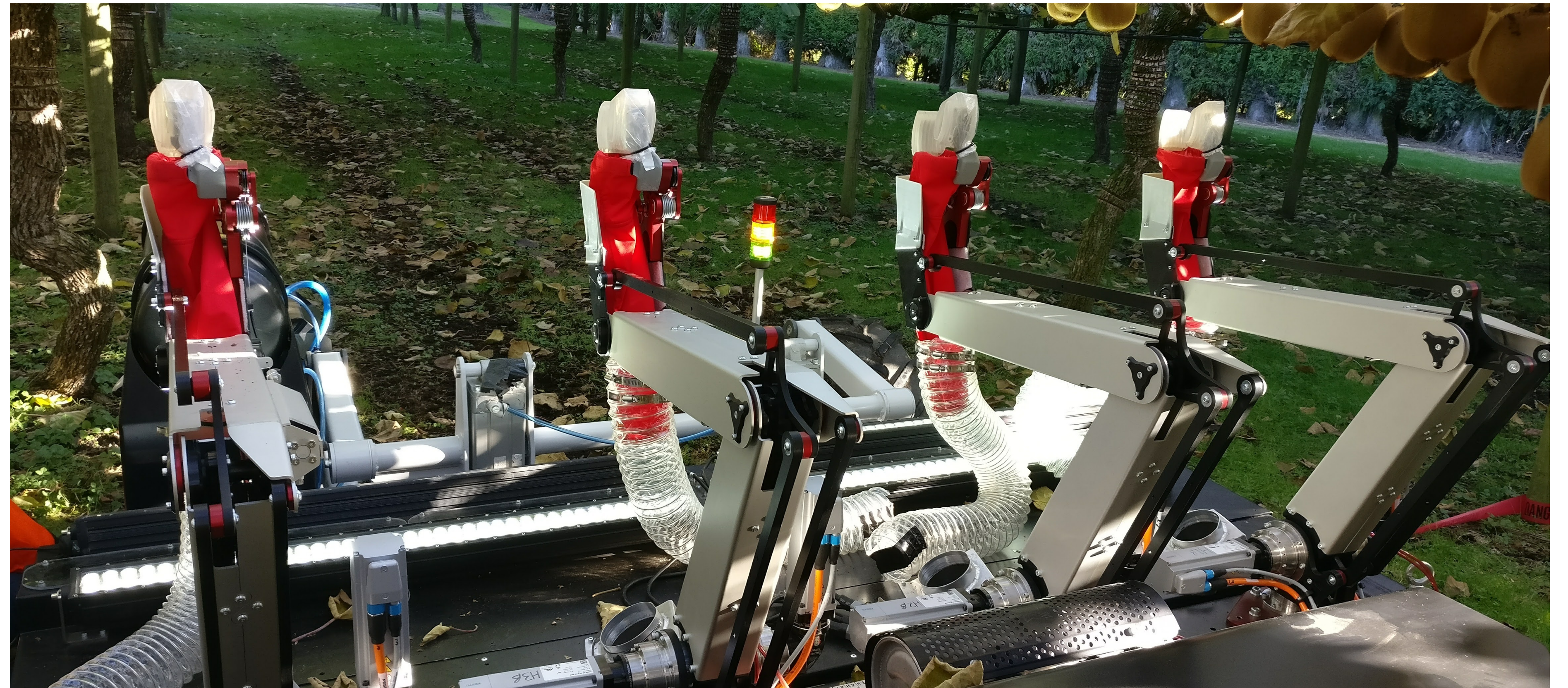
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DESIGN

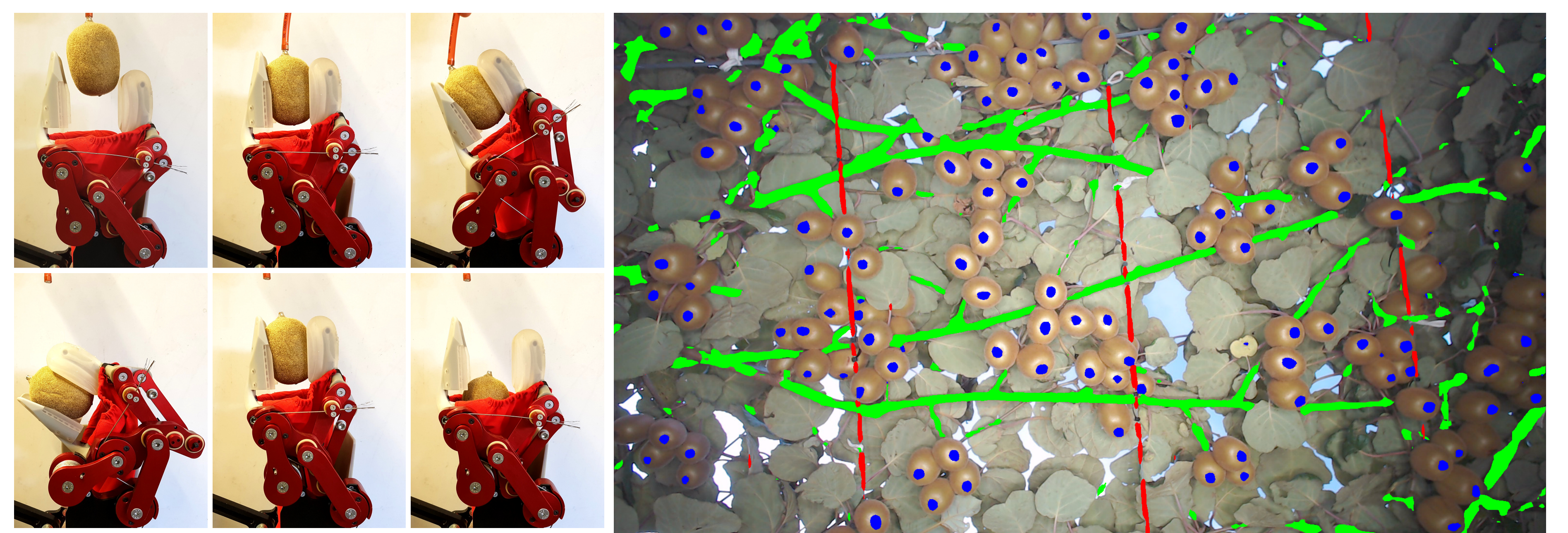


Arms - The robotic arms are custom designed for kiwifruit harvesting and consist of three servo-motor actuated axes. To move between fruit the arms complete a "U move" which ensures the the arms are only ever moving into and out of the canopy with vertical movements. A "U move" starts with a downward movement from the current fruit location, followed by a horizontal movement, before approaching the next fruit from directly below. The arms can be actuated at a rate of about one "U move" per second.

Grippers - The grippers consist of two 3D printed plastic paddles that are over-molded with soft silicon. An uneven four bar linkage system is used to perform the snapping action that removes the fruit from the canopy. A single pneumatic cylinder is used to actuate both the gripper and the snapping action via a cable and spring arrangement. Once detached, the fruit is dropped through the bottom of the gripper and travels down a flexible tube to a conveyor.

Vision - The vision system consists of a stereo pair of cameras per robotic arm, along with LED lighting to illuminate the canopy. Each pair of cameras is connected to a PC with 2x Nvidia GTX 1080 graphics processors. A convolutional neural network is used to detect fruit and stereo matching is used for localisation.

Scheduling - A scheduling system makes decisions on the order in which to pick fruit based on the geometry of the gripper and minimising fruit damage. The scheduling system also ensures the arms don't collide with each other.



RESULTS

The harvesting system was trailed in three commercial green kiwifruit orchards in the Bay of Plenty region of New Zealand. An area of canopy that seemed representative of the orchard was marked off and the total number of kiwifruit in the area was counted. Each kiwifruit was categorised as;

Harvested: Successfully detached from the canopy and down the evacuation tube.

Lost: Detached from the canopy and ended up on the ground.

Remaining: Not detached from the canopy.

Orchard	Kiwifruit (total)	Harvested (%)	Lost (%)	Remaining (%)	Duration (s)
1	340	48.5	28.0	23.5	1155
1	285	53.0	22.0	25.0	669
2	444	55.0	20.0	25.0	1140
3	387	47.5	28.0	24.5	1098
Total	1456	51.0	24.6	24.5	4062

Across the three trial orchards, the system harvested 51% of fruit with 24.6% knocked off or dropped and 24.5% left in the canopy. On average one fruit was harvested every 5.5 seconds.