

Machine Harvesting

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SOFT FRUIT ROBOTIC HARVESTERS – LITERATURE REVIEW

13 harvester prototypes in the past 5 years

- 10 adopted off-the-shelf arms
- 6 achieve a pick rate higher than 75%
- Average pick cycle per fruit: 9.7 seconds
- All used machine learning to detect fruit

Most research projects focused either on the vision system or the fruit grasping task



Apple Harvester – Monash University

PRE-COMMERCIAL ROBOTIC HARVESTERS

No solution for the mango industry yet...



Ripe Robotics



FFRobotics



Tevel

CQU MANGO AUTO-HARVESTER

- 2 modules lifted vertically across the face of the tree
- Each module has:
 - 4 linear actuators equipped with a gripper
 - RGB-D camera
- YoloV8 to detect mango
- Current efficiency:
 - 79% Pick Success Rate
 - 5 seconds pick cycle per fruit
 - 90 seconds harvest cycle



CQU MANGO AUTO-HARVESTER



OFF-SEASON TESTS

Non-perishable Fruit Phantoms

- Silicone + wheat starch + mineral oil
- Low-cost: approximately \$20.0 per fruit
- Excellent shape and good surface detail
- Neodymium magnet to emulate stalk detachment



Material	Density (g/cc)	Firmness (HA, Type A)	Detachment Force (kgf)
Fruit – Honey Gold (<i>harvest stage</i>)	0.94	73.7	6.5
Fruit – Kensington Pride (<i>harvest stage</i>)	0.93	73.1	---
Fruit – R2E2 (<i>eating stage</i>)	0.95	43.9	---
Silicone + Wheat Starch (1:1 ratio)	1.14	33.2	6.9

GRIPPER DESIGN

Constraints imposed by the Auto-Harvester

- Grasp width: 175 mm
- Restricted from moving sideways

Constraints imposed by the mango

- Unregular shape
- Wide variety of sizes
- Resistance to sap/latex



Baseline Gripper

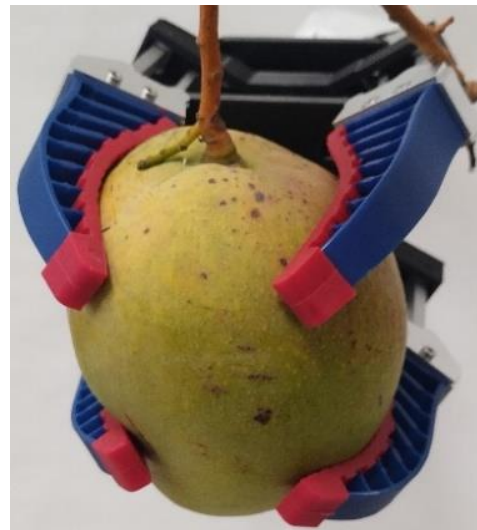
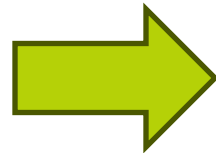
GRIPPER DESIGN

Chosen Variables

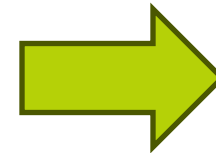
- Gripper Height
- Angle of the top/bottom fingers
- Number of fingers



Fingers: 4, Angle: 0°



Fingers: 4, Angle: 30°



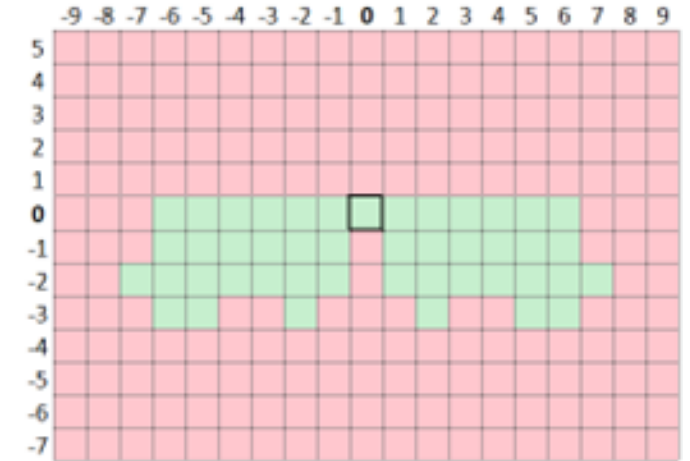
Fingers: 6, Angle: 30°

GRIPPER EVALUATION - METRICS

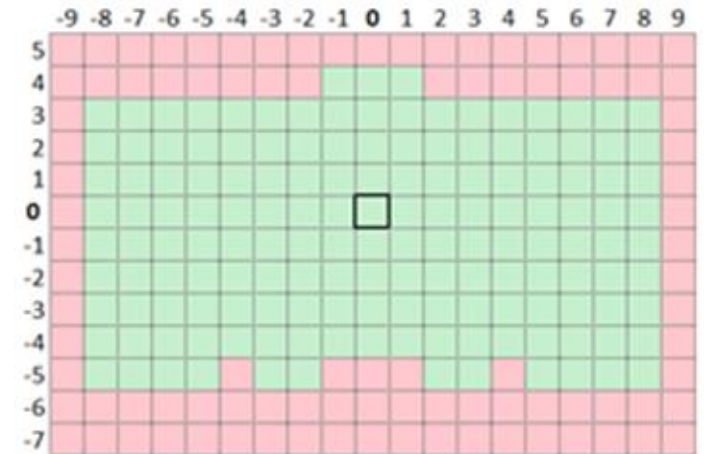
1 – Picking Area and Volume

- Mango with different sizes
- Grasping the mango from different sides

Design	Picking area (cm ²)				Mean
	378	512	636	836	
4F_0A_80H	81	84	86	77	82
4F_30A_95H	129	137	132	137	133.8
6F_30A_95H	134	151	151	150	146.5



Baseline Gripper



Fingers: 6, Angle: 30°

GRIPPER EVALUATION - METRICS

2 – Detachment and harvest success rate for orchard trials

- Detachment → brake stalk
- Harvest → place mango in the conveyor

Orchard	Design	Detachment success (%)	Harvest success (%)
Keitt	4F_0A_80H	77	56
	6F_30A_95H	71	51
Calypso	4F_0A_80H	67	54
	6F_30A_95H	67	50

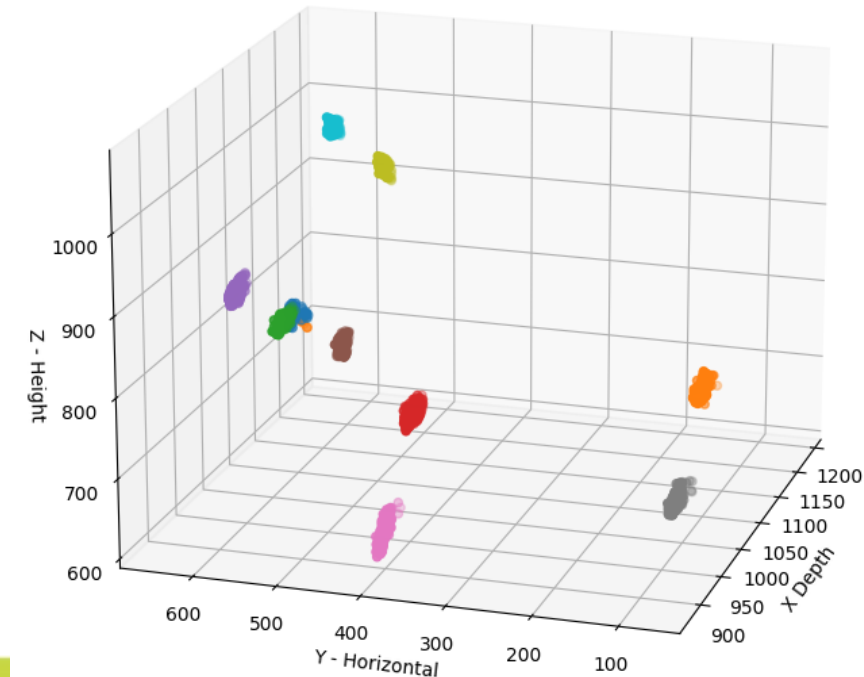
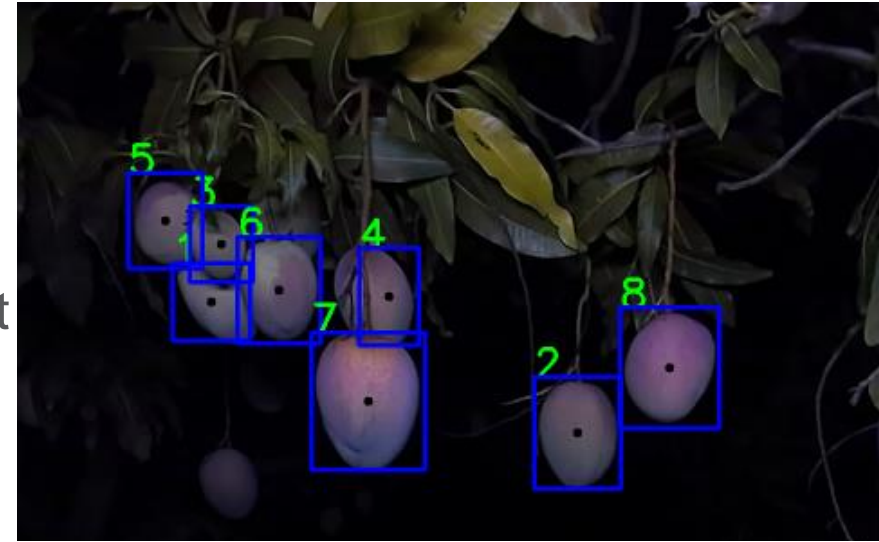
3 – Postharvest skin and flesh damage

- Fruit rarely damaged by the sharp aluminium edges of an adjacent rotating gripper
- Grasping: no visible damage after 48 hours stored at 20 °C

HARVESTING STRATEGIES

1 – Fruit Tracking

- Common frame of reference for all position estimates
- Euclidian distance to group estimates into instances of fruit
- Histogram to mitigate the impact of occlusion
- Result: Accuracy within ± 1 cm
- Limitation: the canopy as fruits are harvested

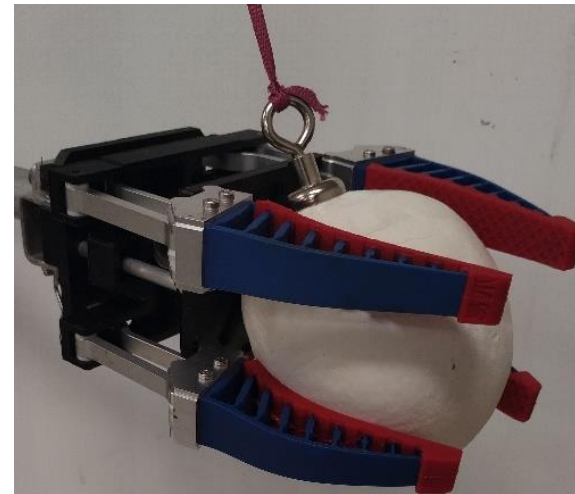
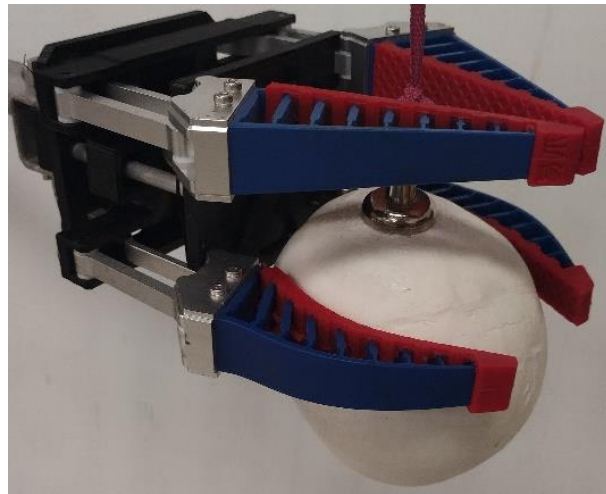


HARVESTING STRATEGIES

2 – Manipulator Control

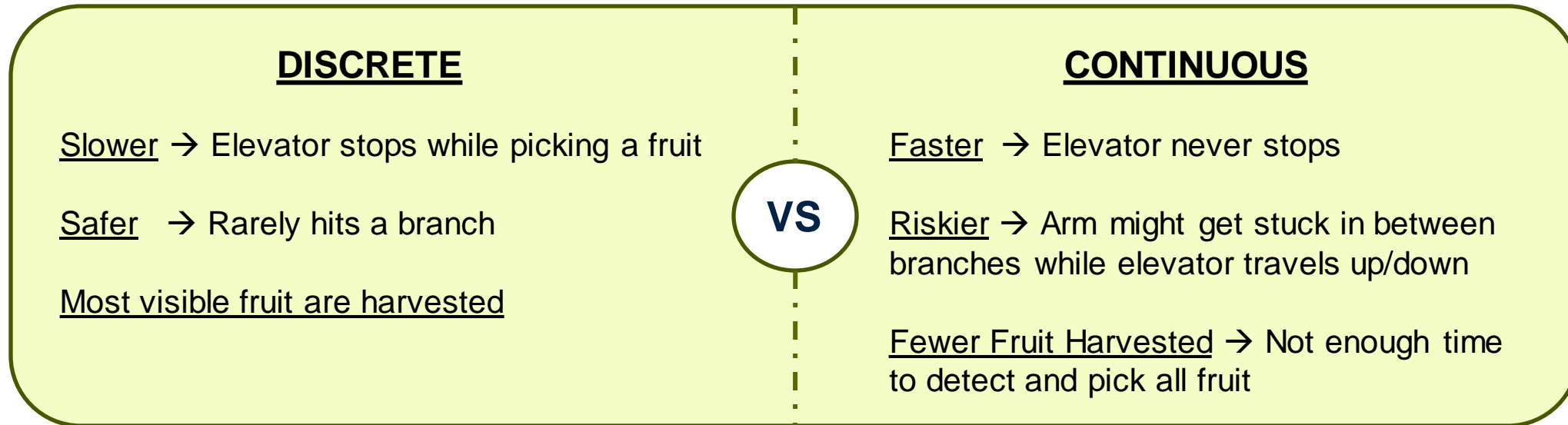
- Collaborative pick cycle
- Dual speed
- Push the fruit for an extra distance

Distance (m)	Pick Cycle duration (s)	
	Single Speed	Dual Speed
0.5	6.0	4.0
1.0	7.9	4.6
1.5	9.0	5.1



HARVESTING STRATEGIES

3 – Elevator Control



Harvest Strategy	Pick Attempts	Harvest Success Rate (%)	Harvest Duration (s)
Discrete	138	79	198
Continuous	51	78.5	93

Harvest Strategy	Detections	Harvest Duration (s)
Discrete	73	171
Continuous	65	93

FUTURE WORK

Replace Detection Boxes by Instance Segmentation

- Branch detection and avoidance
- Improve robustness to fruit occlusion



Mk4: Towards a Commercial Solution

- More arms
- Harvest aid
- Improved manipulator control → faster pick cycle
- Stronger grasp capability
- Easier maintenance

