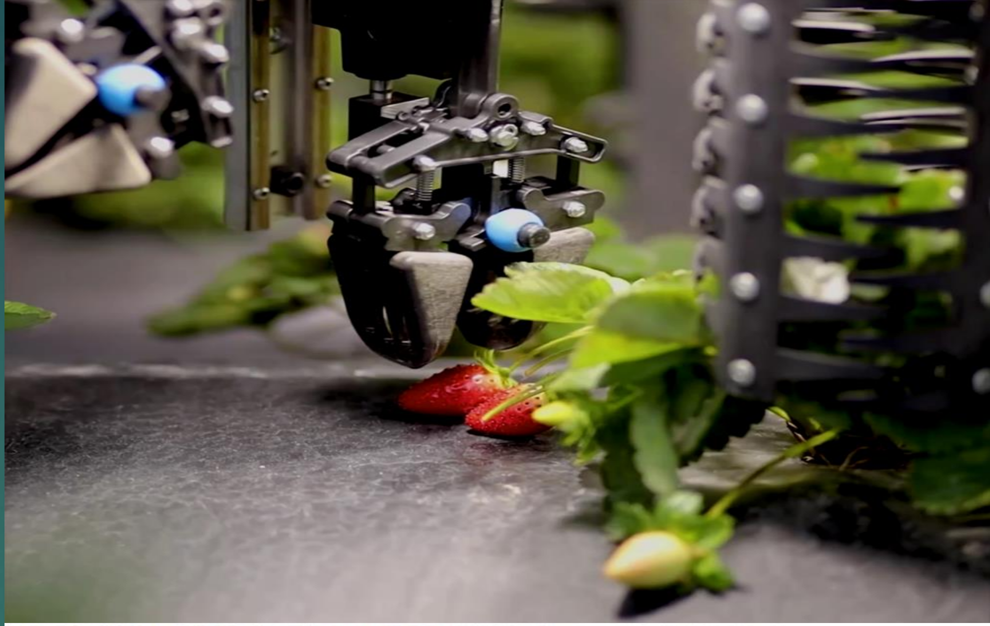
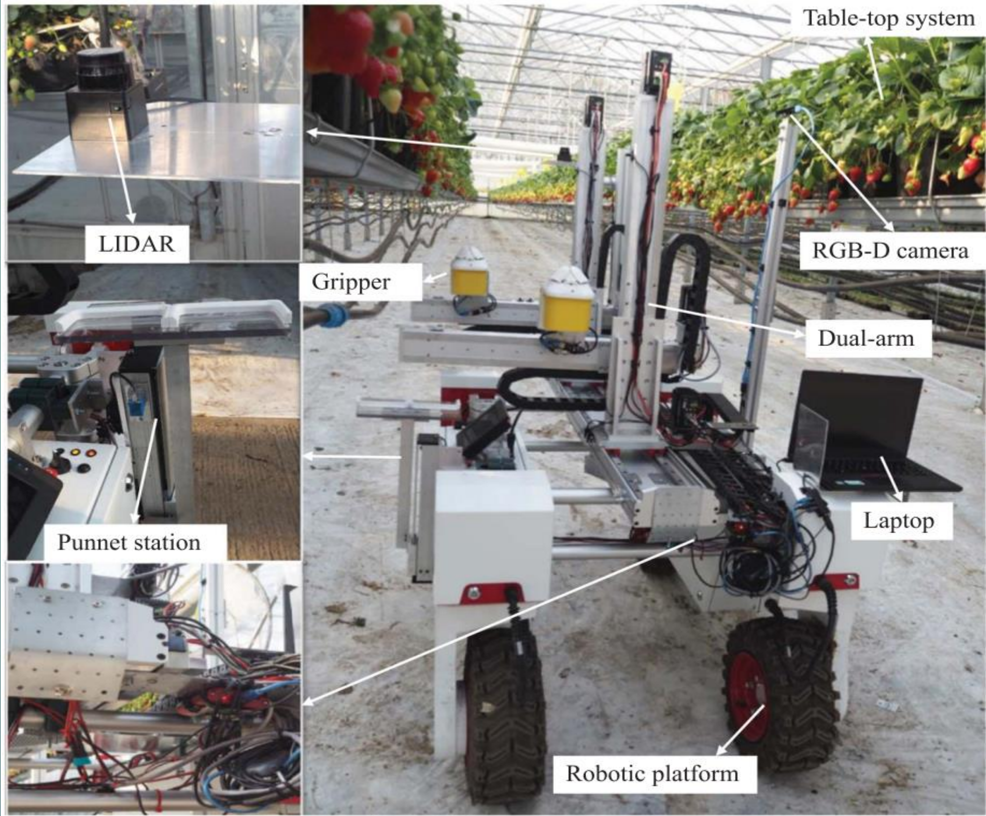
An autonomous strawberry-harvesting robot





- **Problem Statement :**

The global strawberry market amounted to 9.2 million tons, and strawberry production is heavily reliant on human labor, further the manual strawberry harvesting cost amounts as much as 60% of production costs. The dual labor challenges of shortages and high costs are, therefore, requires an advance robotic solution for strawberry harvesting operation.

- **Existing solutions and their drawback :**AGROBOT, OCTINION, Harvest CROO these are

some of the strawberry harvesting robots, but non of them successfully commercialize due to following issues:

- Efficiency of these robots is 32% and their harvesting time for single fruit is 19.8 sec.
- Detection rate of strawberries is 58% due to thresholding error.
- Suction end-effector did not greatly contribute to picking performance.
- Incorrect peduncle detection.
- High cost: Not appropriate commercialize farming.

- **Challenges :**

- Robotic harvesting in cluttered and unstructured environment.
- Ripe strawberries are easily damaged and bruised.
- Strawberries are small in size and tend to grow in clusters, which makes it difficult to identify between ripe strawberries, green strawberries and leaves. and pick individual strawberries.

- **Solution :**

- A novel active obstacle-separation sensing, navigation and path-planning algorithm for cluster picking.
- Improvements to the vision system, the gripper, the arm, and the Control system to achive efficiency of 90% .
- A fully integrated harvesting system: The robot is able to pick strawberries continuously in polytunnels with harvesting time for single fruit is 7sec.

Sensing: The presented robot aims to be a low-cost autonomous platform for solving a wide range of tasks.

- Intel R200 RGB-D depth camera –For strawberry detection and localization.

ActivePixels color-1920 x 1080depth/IR-640 x 480 . Aspect ratio color-16:9,depth/IR-4:3 Framerate color-30fps, depth/IR-30/60 fps
Field of view (D x V x H) color-77° x 43° x 70° (Cone),depth/IR-70° x 46° x 59° (Cone)

- IR Sensors :For automatic updating thresholds by using the grippers IR sensor.

  IR sensors that can sense pure sunlight IR light intensity.

The operating voltage is 5VDC I/O pins – 3.3V & 5V Mounting hole The range is up to 20 centimeters The supply current is 20mA The range of sensing is adjustable

- PL-05N/2 Inductive proximity sensors : Used as end stops for homing the gripper arms and limiting their movement range.

•Response frequency: 800Hz
•Output method : NPN, 150mA load
•Hysteresis: <10% of sensing distance
•Protection degree: IP67
•Working temperature/Hum : -20 ~+80C, 35%~90%RH

- UM7 IMU : Its measurements are used for robot mapping and localization.

  The two drive modules are equipped with encoders, measurements from which are used for estimating robot velocity.

EKF estimation rate: 500 Hz, ±1° typical static pitch/roll accuracy, ±3°,typical dynamic pitch/roll accuracy ,±3°,typical static yaw accuracy, ±5°,typical dynamic yaw accuracy, 0.5°, angle repeatability ,<0.01° angular resolution

- Hokuyo UTM-30LX-EW 2D LIDAR :The robot uses this top mounting sensor for mapping and localizing in the map when driving from one set of rails to the next. The sensor is also used for obstacle detection.

Equipped with an Ethernet interface, it can obtain measurement data in a 270° field-of-view up to 30 meters

Navigation :

- The spacing between rows, as well as the overall layout of the tunnels or greenhouse taken into consideration while designing the robot.
- The robot has four-wheel drive and four-wheel steering, which enables it to move in any direction, and also turn in place, thus substantially increasing its ability to navigate tight spaces.

2D LIDAR to create a map using the GMapping (SLAM) technique During this process the robot is teleoperated.

The resulting map is stored and used by the robot during autonomous operation. The robot uses the map, LIDAR data, and Imu data to localize in the tunnel

First, the robot uses 2D LIDAR and IMU's reading together with a map &Automatically generated target poses to navigate and roughly position itself in front of a given set of lane.

Before the robot starts to drive, it stores its current pose in the map. This is given as the robot's pose in the map on return.

The robot estimates the location of the end of the lane by sensing the distance to the wall on the far side of the greenhouse from 2D LIDAR data..

Basic operation explained:

Robot starts from a corner of the lane , moves through the lane by using the 2d LIDAR and IMU data and locate itself. Uses RGB-D camera to detect the strawberries, algorithm distinguishes between leaves and strawberries. Arm does the gripers movement and strawberries are being pluck. the same process again.

Power :

Motor/Sensors	Weight(Kg)	Rated Voltage(V)	Rated Current(A)	Total Currant(mA)	Total Power(W)	Cost($)
Intel R200 RGB-D depth camera	0.135	5	0.38	380	1.9	300
IR Sensors	0.058	5	0.06	60	0.3	15
PL-05N/2 Inductive proximity sensors	0.0044	10	0.2	200	2	15
UM7 IMU	0.0035	4	0.0031	3.1	0.0217	40
Hokuyo UTM-30LX-EW 2D LIDAR	0.13	12	0.5	500	6	400
3-DOF Cartesian arm1	Self made using 3-D print (Approx. 2.5 kg) Payload: 0.75 kg	12	1.7 (Stall current)	8500	102	200 (Self made using 3- D print)
Stepper servo motors	0.5	3.2	2.8	2800	8.96	60
Dynamixel motors for base (Quantity 4)	0.165*4=0.6 6	12	1.7 (Stall current)	(1700x4) =6800	81.6	900

Battery info: 12v 100Ah LiFePO4 $600; Weight: 13.06346 Kg: Operating time = 12*100/195.5 = 6.13 hrs (then need to recharge) Robot base + Wheel (radius = 7.5 cm) weight: ~ 2 Kg ; Total weight = 3.491+2+13.06=18.551 N Torque required per motor = 1.5 Nm which is much less than the torque which motor can deliver (3.1 Nm).

Working :

Hardware consists primarily of four modules:

- An IntelR200 RGB-D depth camera- strawberry detection and localization.
- Single-rail dual-arm manipulator-picking strawberries along one side of the table-top trays.
- Two grippers, and Thorvald platform.
- Hokuyo LIDAR and IMU is mounted on the front of the robot for navigation sensing.

Software : The laptop is connected to the system.

Hue saturation value (HSV) images are transformed from the RGB images and used for image processing. The aim with this computer vision subsystem is to detect and localize ripe strawberries and to pass the detected strawberry bounding boxes to the other subsystems.