PICKASSO – The Grape Picking Robot

Goal: A fully autonomous grape picking robot capable of efficient and delicate grape picking with a focus on minimizing damage to the grapes and vines

Relevance: Grape picking is mostly done using human labor due to delicate nature and need for selective picking. It needs to be automated to minimize labor shortages and costs

Challenge: The robot should be able to navigate in the uneven terrain of a vineyard, detect and select ripe grapes and carefully handle the grape cluster

Solution:

- A tracked mobile base with a 5 DOF manipulator
- Custom made end effector for gripping and cutting
- RGB-D camera for detecting ripe grapes
- LIDAR based navigation system

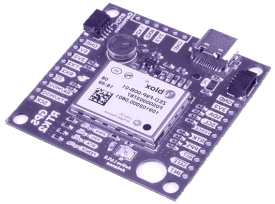
Sensing

Intel RealSense D435i

RGB-D camera for detecting and localizing the grapes

- Small form factor (90 × 25 × 25mm) for mounting on the arm
- Wide FOV(87° × 58°) and minimum depth(0.3m) fit the application
- Easy integration with ROS2 using SDK

Power = 5V × 700mA
3.5W



SparkFun GPS-RTK2 Board - ZED-F9P

Centimeter level position accuracy with precise timestamping for robot localization

- Easy setup with u-center
- Capable of 1 cm position accuracy
- First fix under 25 seconds
- 20 Hz RTK Navigation rate

Power = 3.3V × 98mA
0.3234W

Unitree 4D LiDAR L1

Real time dynamic mapping of the environment

- 360°×90° scanning up to 30m
- 21600points/s with ±2.0cm accuracy
- Compact(75×75×65mm) and lightweight(230g)
- Suitable for outdoor use
- Built-in 6-axis IMU, more reliable than the GPS's

Power = **6W**

CT1-00-2H Proximity Sensor

Helps align the gripper with the peduncle before cutting

- 40mm sensing distance
- Capacitive - works on non metallic objects
- Easy setup and adjustable sensitivity

Power = 24V × 20mA
0.48W

Total sensing power = 10.3W

Total sensing weight = 426g

Navigation and Harvesting

- Tracked mobile base with one MyActuator RMD-X8 S2 1:36 motors for each track - 40 rpm, 25 N-m (nominal)
- Track height = 25cm so that average load on motor is equal to torque at max efficiency
- Max speed of 1.1m/s. Though a tracked base reduces mobility, the robot mostly just moves in a straight line
- The manipulator used for harvesting is a 5 DOF cylindrical robot using Dynamixel MX-64AR motors

Manually drive the robot through the vineyard and collect sensor data

Create a point cloud using ROS and filter/correct the data using IMU and GPS data

Generate a 2D map and estimate height and spacing of grape clusters

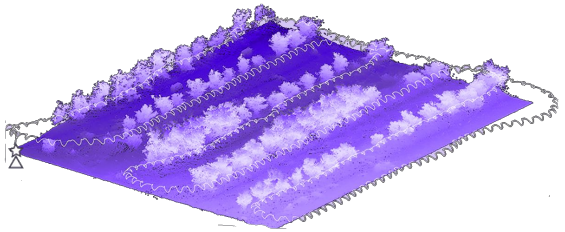
Use 2D map to generate a harvesting path with target poses (including the camera position)

Need to be done just once

Estimate the pose of the robot using the 3 sensors EKF and navigate

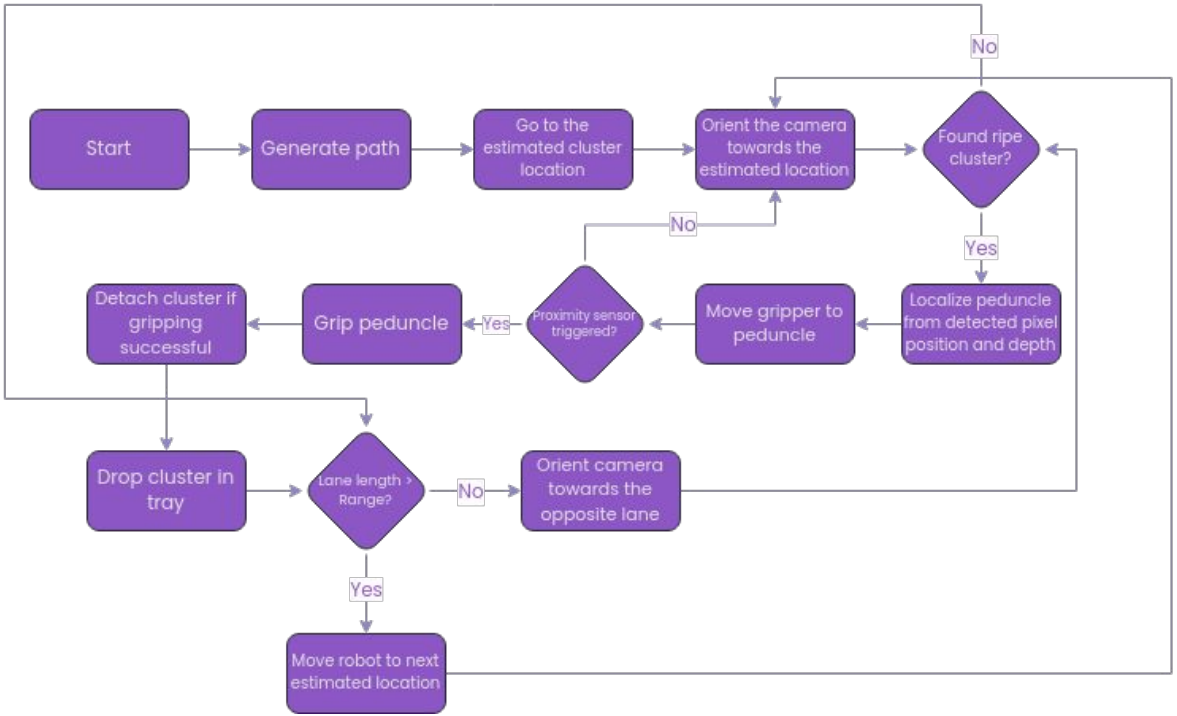
Obstacle avoidance using LiDAR data

Stop moving when a ripe grape is detected and harvest it



Software and Working

- Computing occurs on an NVIDIA Jetson TX2 (8GB) running ROS2 - 7.5W Power
- A YOLOv8 model trained on a custom dataset is used to detect ripe grapes
- Manipulator path planning is done using MoveIt 2



Software Subsystems

1. Navigation
   a. Path Planning
   b. Pose Estimation
   c. Coordinate transformation
2. Perception
   a. Grape detection
   b. Grape localization
3. Manipulation
   a. Arm control/path planning
   b. Proximity sensing and cutting
4. Sensing
   a. Sensor data processing
   b. Point cloud creation
5. Mapping
   a. Map generation
   b. Obstacle avoiding/Reactive path readjustment

Power Budget

Mobility:

Weight = Motor + Track + Frame + Grapes
= 900×2 + 1500 + 3500 + 2000 = **8800g**
Motor load = (Weight×(track height/2))/2
= **23.96 N-m**(close to rated torque)
Base is only used for around 60% of operation
Power = 110×2×0.6 = **132W**

Manipulation:

Cylindrical robots have no static torque. The arm is actuated for 50% of operation. Nominal current of motors used is 1.75A. Assuming gripper uses 5W of power,
Power = 5×(12×1.75)/2 +5 = **57.5W**
Assuming the manipulator weight to be motor + link + gripper + lead screw weight,
Weight = **3700g**

Battery:

Tattu Pro 22Ah 44.4V Battery pack- 6300g
Since some components need 12V, a DC-DC buck converter is needed. Assuming a 95% efficiency, Power loss = **10.4W**
Operation time = (44.4×22)/217.7 = **4.5 hours**

	Avg Power (W)	Weight (g)
Sensors	10.3	426
Mobility	132	8800
Computing	7.5	314
Manipulation	57.5	3700
Battery	10.4	6300
Total	**217.7W**	**19,540g**