GrubTub

Team C9: Michael Li, Sebastian Montiel, Advaith Sethuraman

Product Pitch

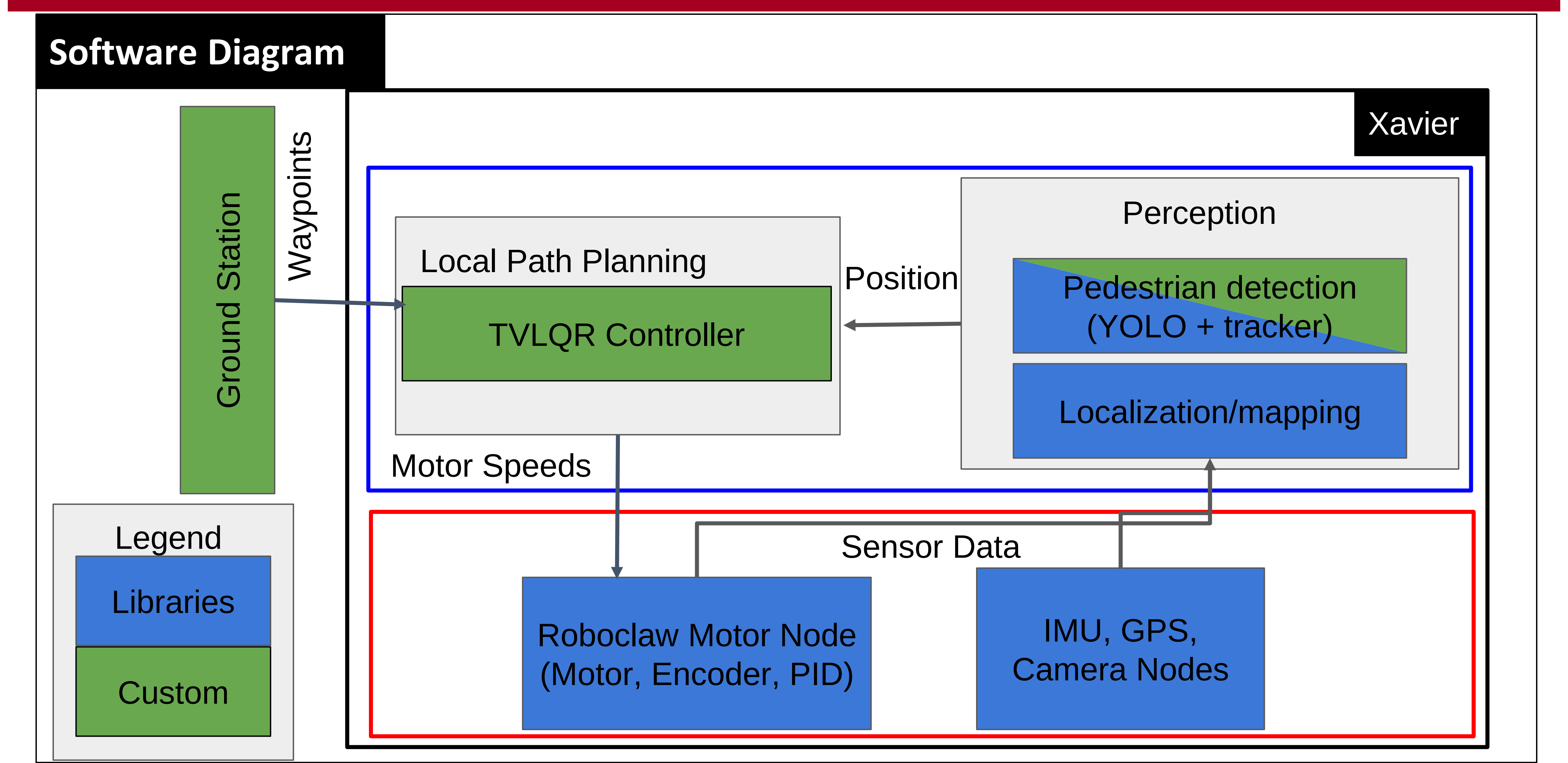
GrubTub is an autonomous, on-campus delivery robot which facilitates delivery between on-campus restaurants and buildings.

Core services: it must be able to deliver at least 2 kg of food intact across flat sidewalks of campus.
Pedestrian avoidance: it must be able to avoid pedestrians and collisions in-transit.
Quality: it must efficiently deliver the food close to the drop-off point and have at least 30 minutes of battery life.
Emergency operation: the robot must be able to connect to a ground station for emergency control with a maximum latency, and have minimal human intervention in its deliveries.

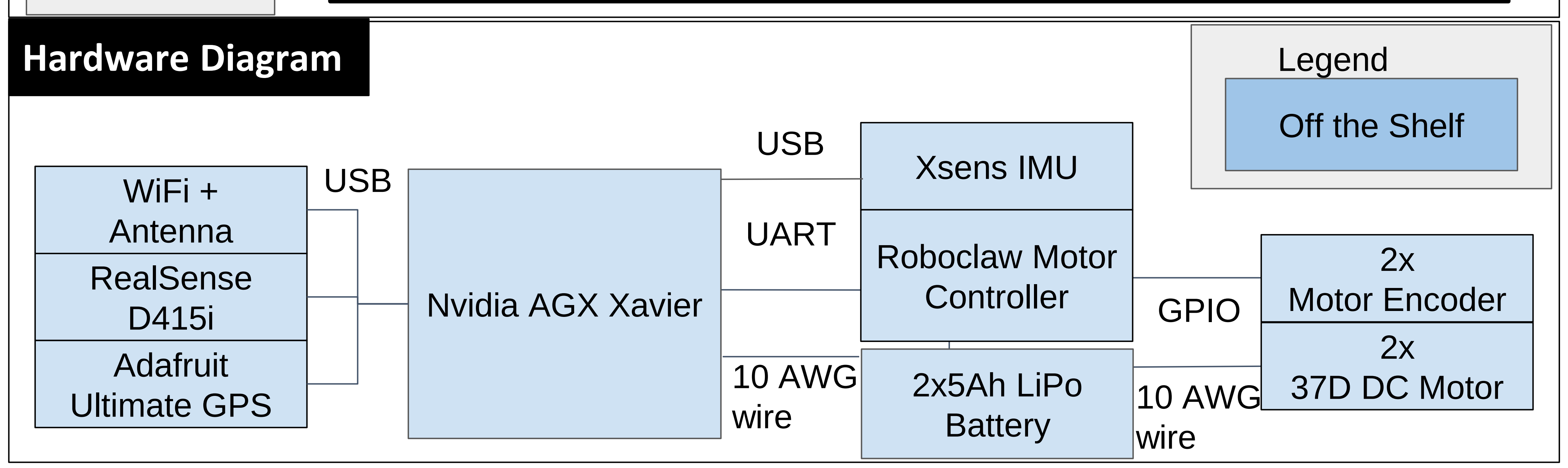
After rigorously testing the robot, we found that it **satisfies our "core services" requirements** and has met our **battery life and human intervention requirements**, but **cannot meet some of our "quality", "pedestrian avoidance", and "emergency operation" requirements** due to inconsistent on-campus wi-fi and noisy sensors.

System Architecture

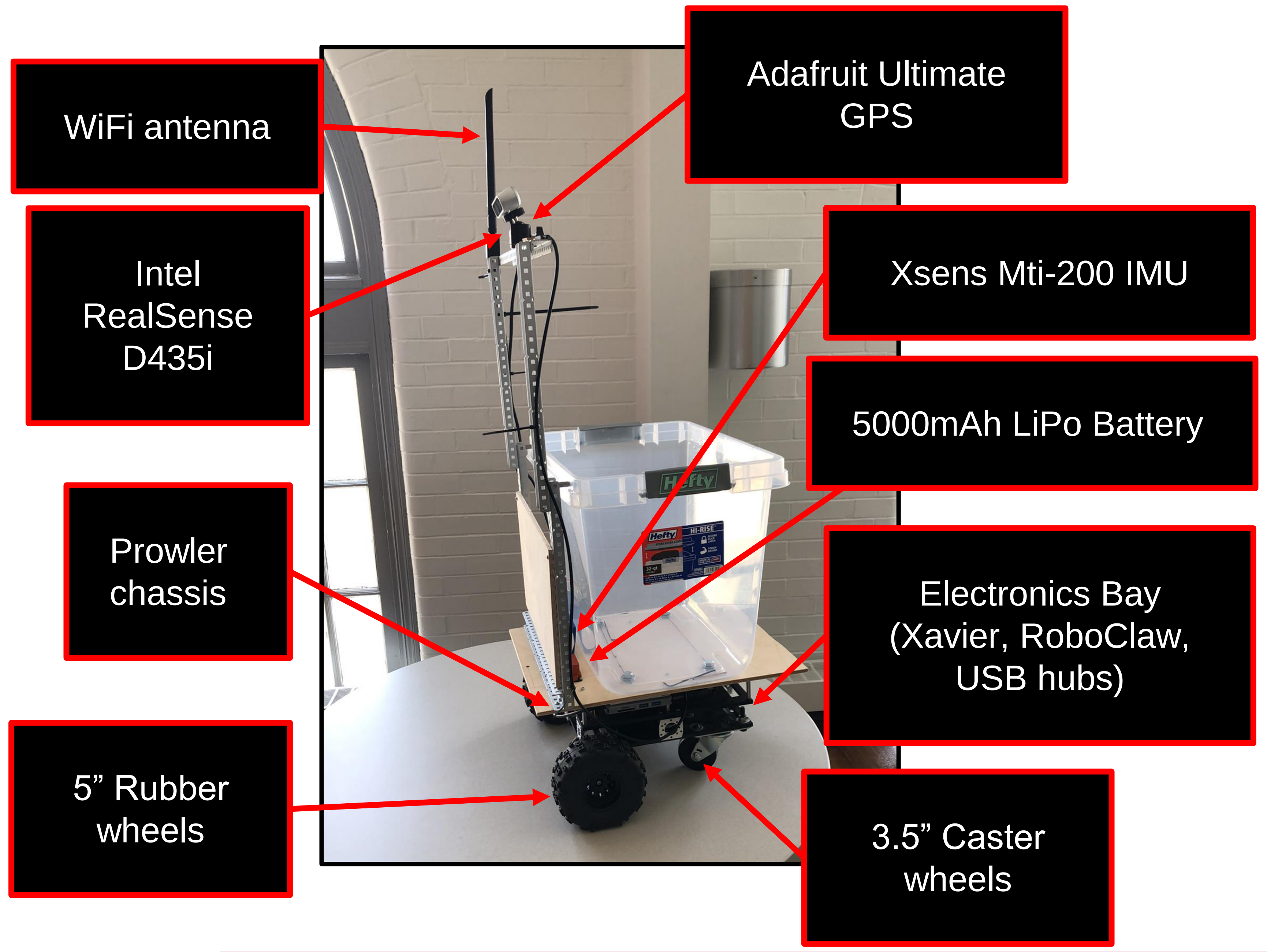
Software Diagram



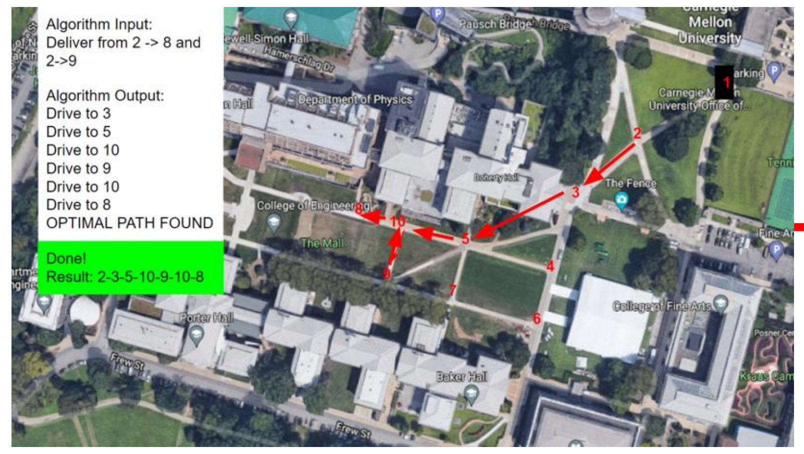
Hardware Diagram



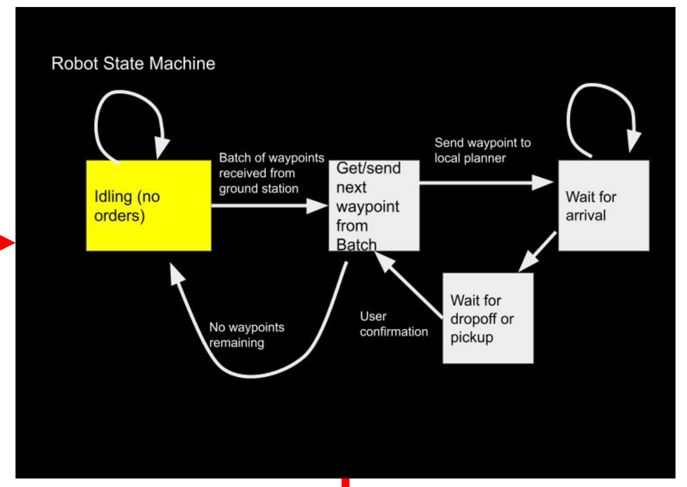
System Description



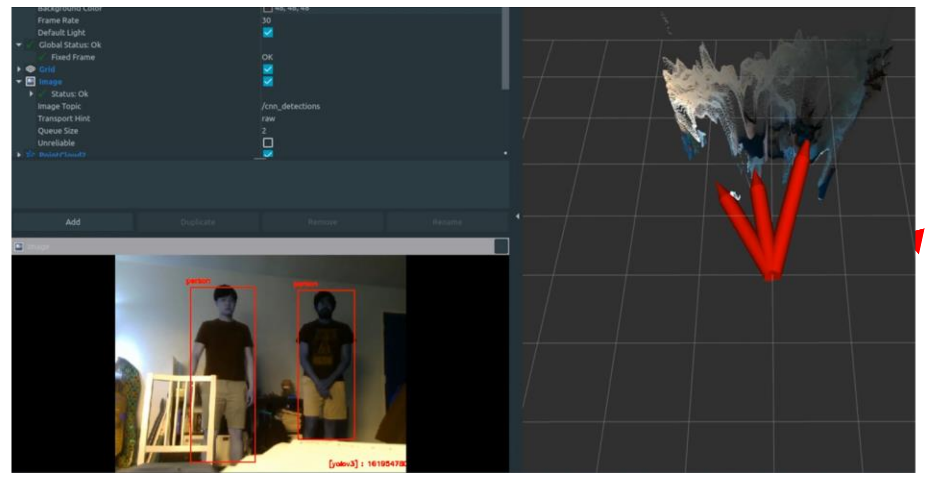
Dynamic Programming Multi-Order Planning Algorithm



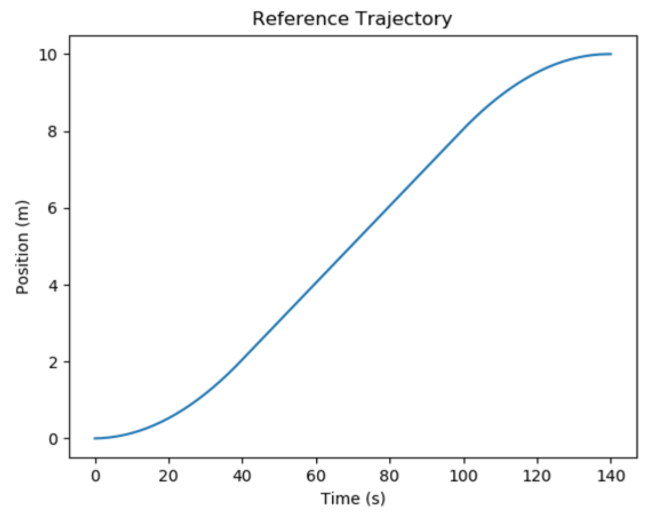
Robot Finite State Machine



3D Multi Target Tracking + Data Association



TVLQR Controller



System Evaluation

Method	Pros	Cons
Online	Emergency Operator/Ground Station can connect	Need constant network connectivity, otherwise ROS hangs
Offline	Can travel across areas without Wi-Fi	No emergency operator/ground station for routing- all onboard
RTABMAP	Lower position error than GPS when it tracks	Bad tracking above 0.5 m/s, when turning, or being outdoors Poor recovery from lost tracking (robot usually lost it in tests)
ORBSLAM	Loses tracking less often than RTABMAP Better recovery from lost tracking than RTABMAP	Less than ideal tracking outdoors, still loses tracking given only turns
GPS/IMU/Encoder	Does not lose tracking at higher speeds (not affected by motion blur/camera framerate)	GPS jitter causes issues in the filtered position data Wheel slipping in grass causes encoders to disagree with the IMU
RVO	Automatic pedestrian avoidance	Very sensitive to noise in input sensor data (drove into grass)
TVLQR	No parameter tuning, only specifying a trajectory Solves for the optimal controls	Can only specify a continuous combination of function trajectories Have to specify reference trajectories and velocities
PID	Simplest controller, intuitive	Parameter tuning is a massive time sink, may never be consistent Not optimal, only minimal oscillations/quicker convergence

Metrics (N=10)	Grass time (s)	Grass time (%)	1M accuracy (m)	3m accuracy (m)	Food Intactness (Bool)	Interventions/Meter	HRTT Time (s)	Robot Time (s)	% Over HRTT	Path Length (m)
Average	121.9	30.67%	2.03	2.03	Intact	0.015	240	397.1	0.6545833333	160
Success Threshold	N/A	65.00%	1	3	Intact	0.02	N/A	240	0	N/A
Metric Success Rate	N/A	100%	10.00%	100%	100%	90%	N/A	0.00%	0.00%	N/A