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ME 439 Final Project: Kalman Filter and LQR for Mobile Robot

By: Team 5

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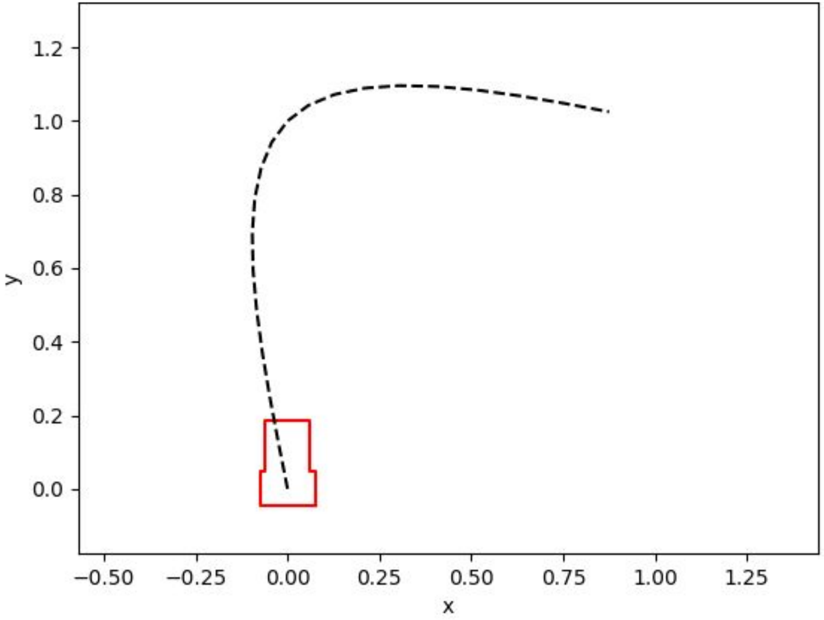
Goal of Project

- Improve state estimation method of the mobile robot by incorporating more sensors

- Improve the trajectory control of the mobile robot



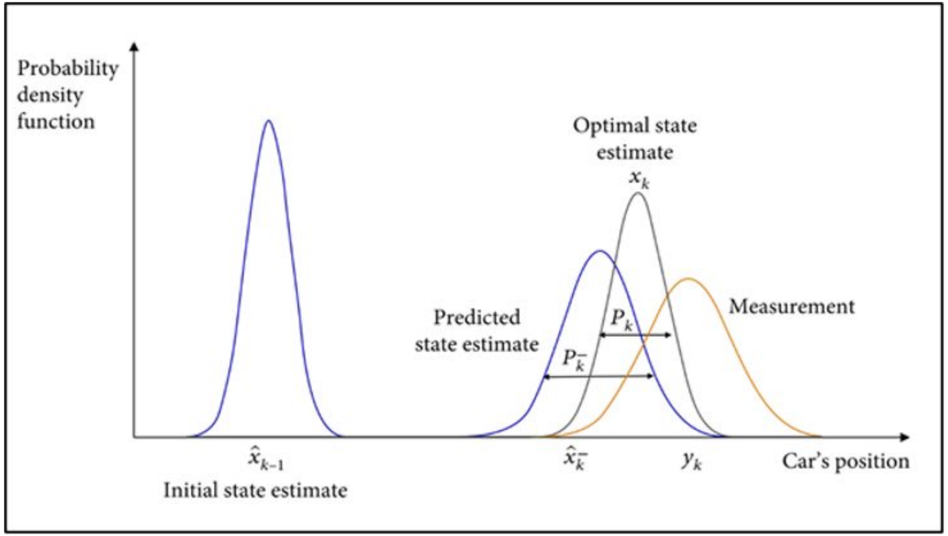
Brief description of Kalman Filter

Optimal State Estimator

- Prediction from the linear model of the robot

- Update from the sensor measurements

- Includes the sensor fusion of encoders & IMU



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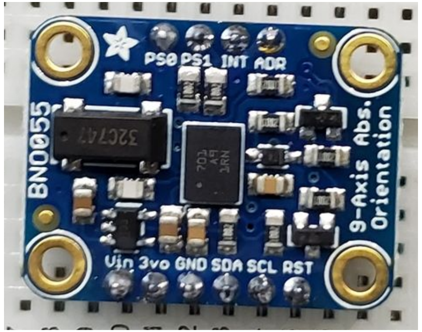
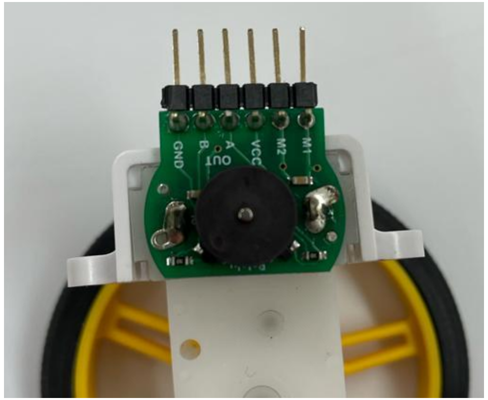
Sensors Used

- MPU6050
  - adafruit_mpu6050
  - Gyroscope only
- BNO055
  - adafruit_bno055
  - Gyroscope and magnetometer
- Pololu Encoders
  - encoders_and_motors.py

MPU6050



BNO055



Encoders

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Brief description of LQR

- Linear Quadratic Regulator
  - Minimizes certain objective cost function

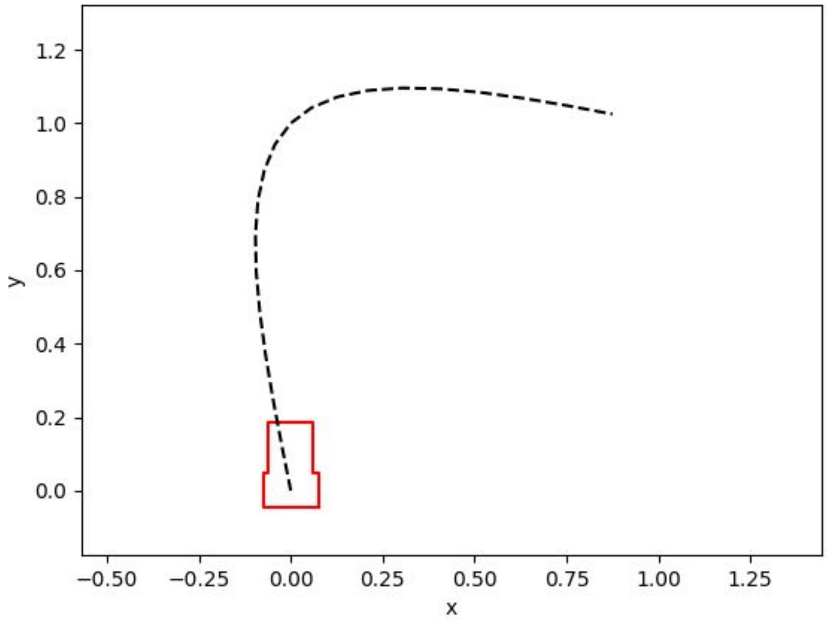
$$J = \int_0^\infty (x^T Q x + u^T R u) dt$$

State error Motor effort

  - Provides optimal feedback control between state error and motor effort

Trajectory Generation

- Generated cubic functions for smoother motion when following way points
- Satisfy differential flatness for mobile robot dynamics
  - Position, velocity, acceleration
- Simple trajectory for testing
  - [(0,0) ,(0,1), (1,1)]



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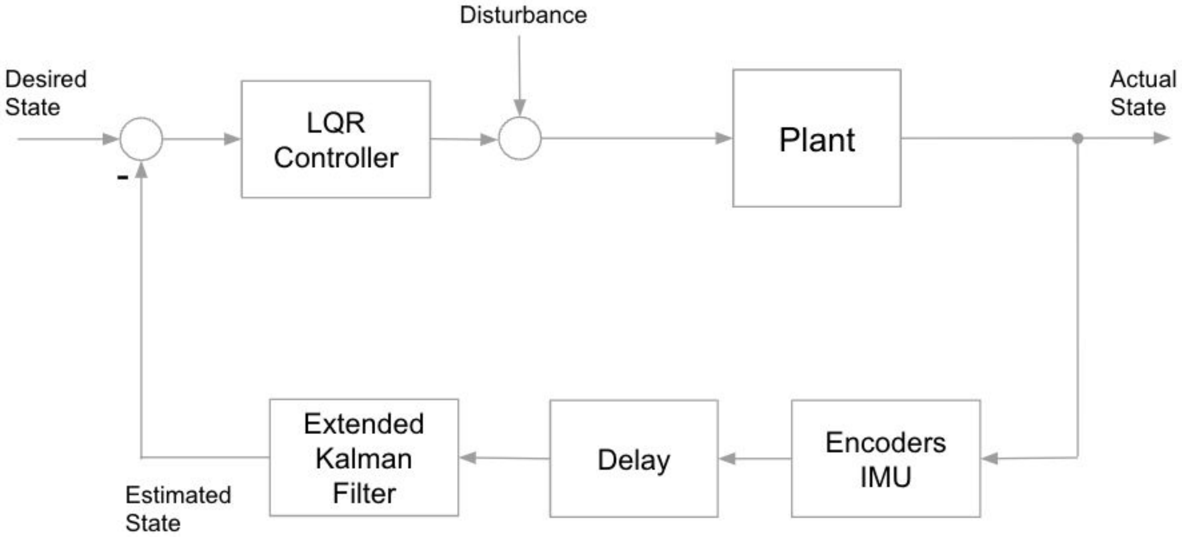
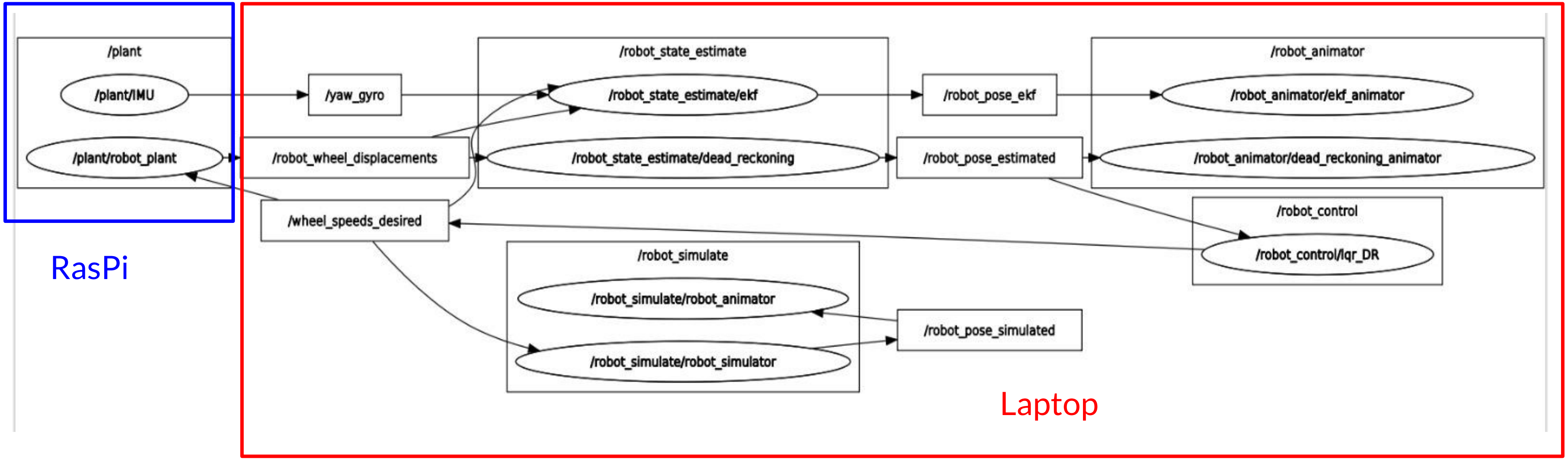
Block diagram for mobile robot control



Offboard implementation of Controller

- ROS Networking between RasPi and Linux Laptop



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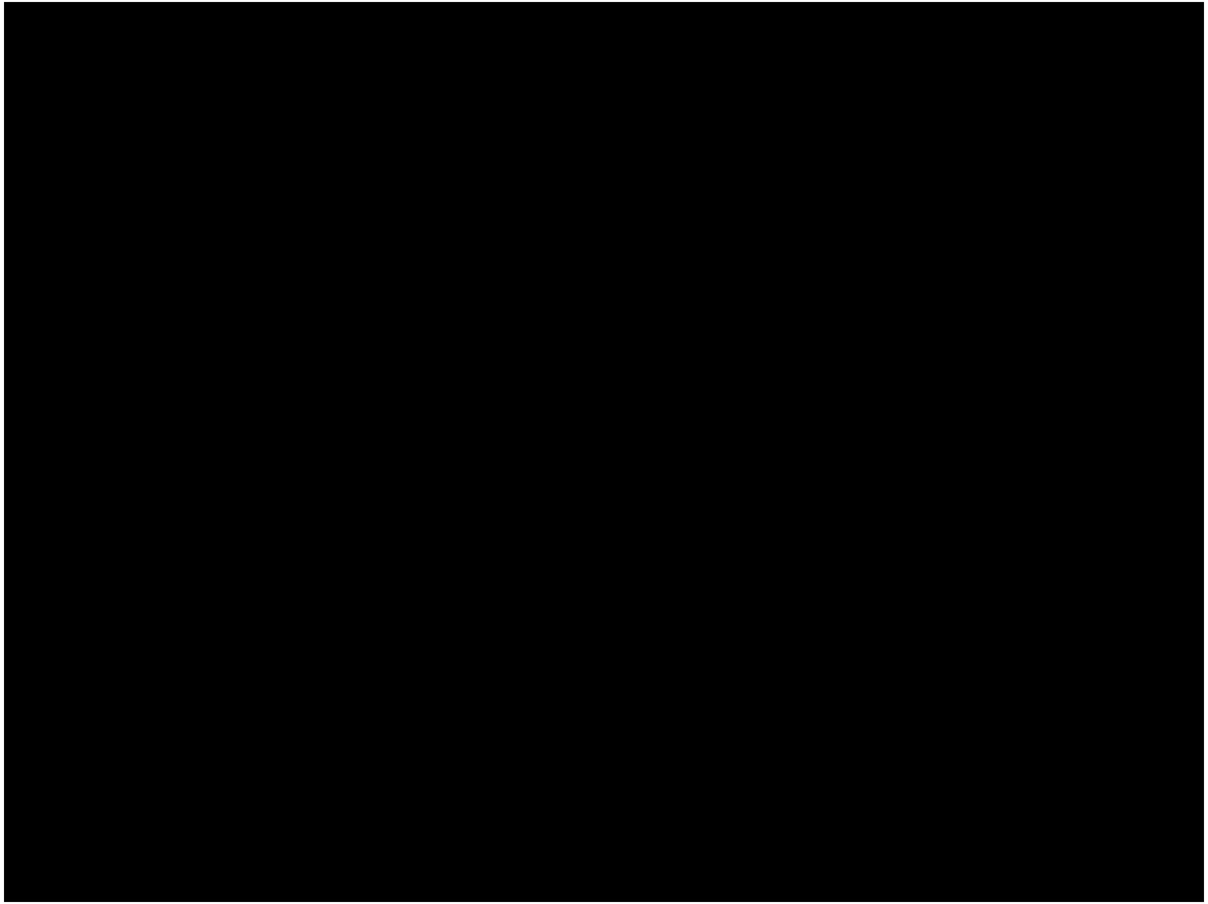
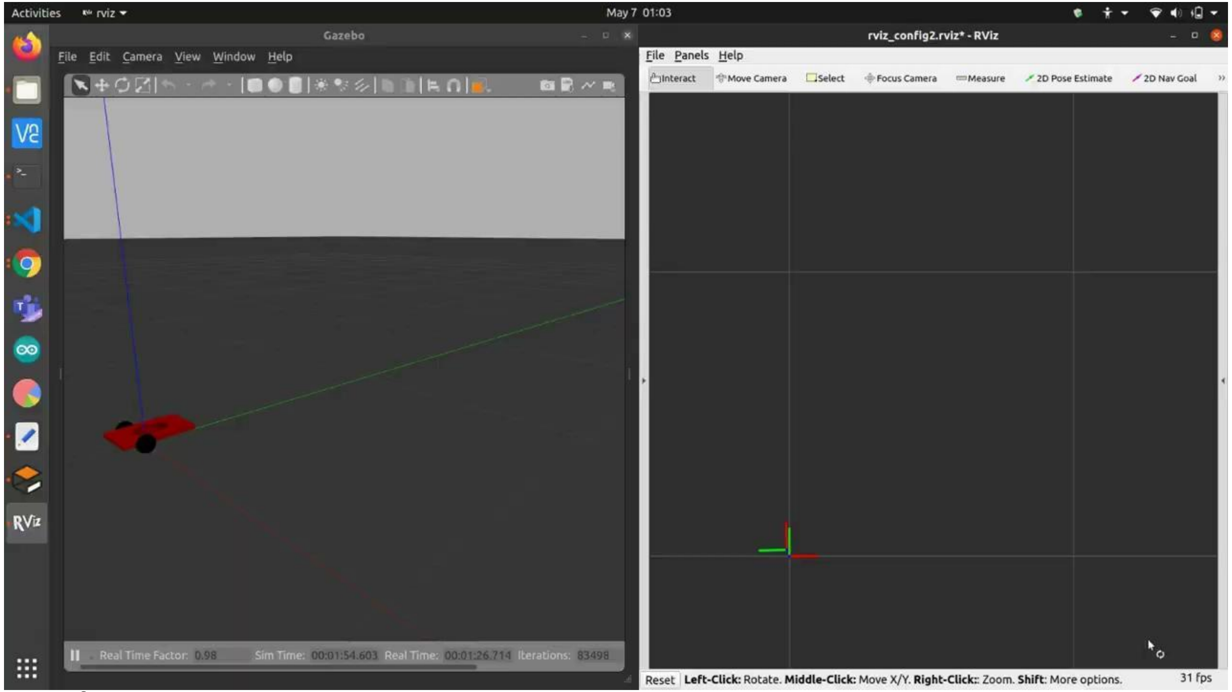
*Disclaimer: /robot_controller/lqr_DR, can subscribe to /robot_pose_ekf instead of /robot_pose_estimated

Demonstration of LQR & EKF on robot



Simulation using Gazebo and rviz for Tuning

- ros1 for running code and rviz
- ros2 for simulation on Gazebo
- ROS1-ROS2 Bridge



Next Steps/Challenges

- Tune Kalman Filter Covariances and LQR matrices
  - Able to obtain sensor measurement covariances only
- Creating a trajectory for tracking
  - Parametrized cubic spline trajectory wrt time
- Implementing a Kalman/Madgwick/Complementary filter for better IMU yaw angle
- Modeling system dynamics to account for inertia using Euler/Lagrange (double integrator) as opposed to system kinematics (single integrator)
  - We just used the single integrator method

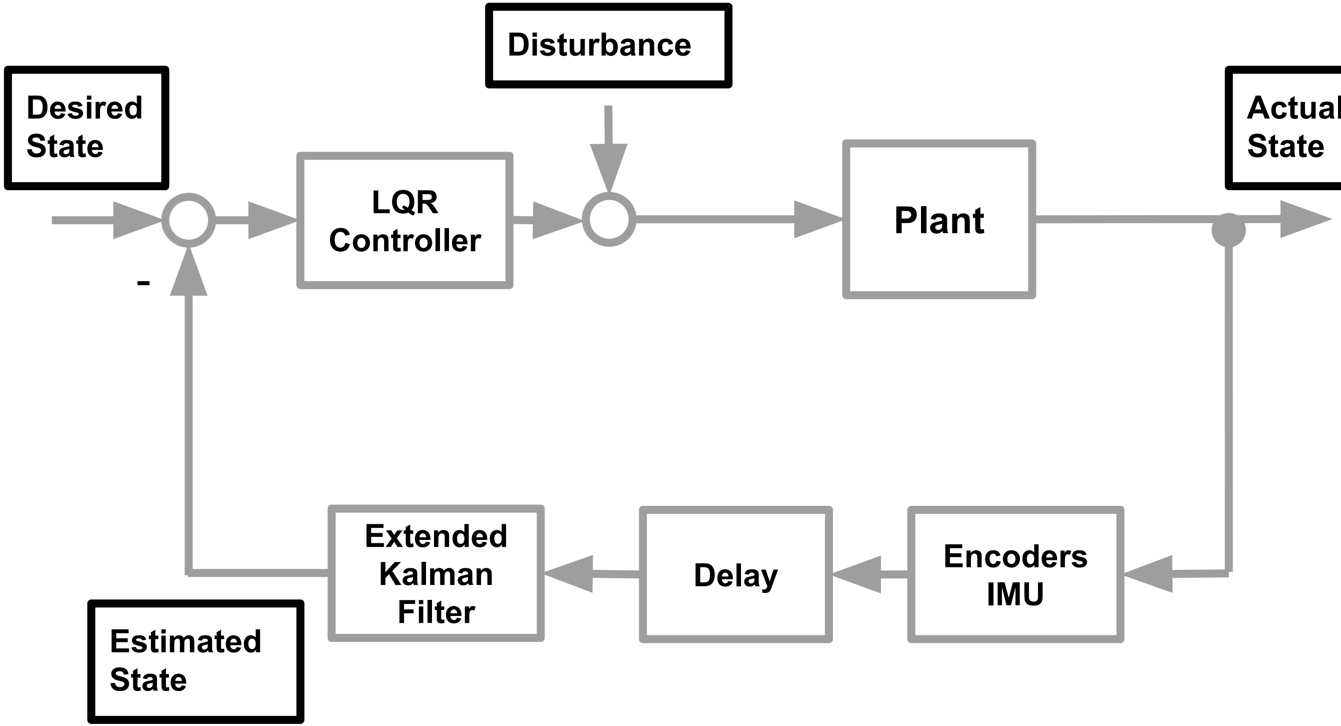
Questions, Comments, Concerns?

Ros 1: EKF + LQR Code

Ros 2: Simulation Code

References

[1] Hindawi, Kalman Filter: Historical Overview and Review of Its Use in Robotics 60 Years after Its Creation, 2021. [Online]. Available: https://www.hindawi.com/journals/js/2021/9674015/fig1/. [Accessed: 02-May-2022].


Disturbance
Desired State
LQR Controller
Plant
Actual State
-
Extended Kalman Filter
Delay
Encoders IMU
Estimated State