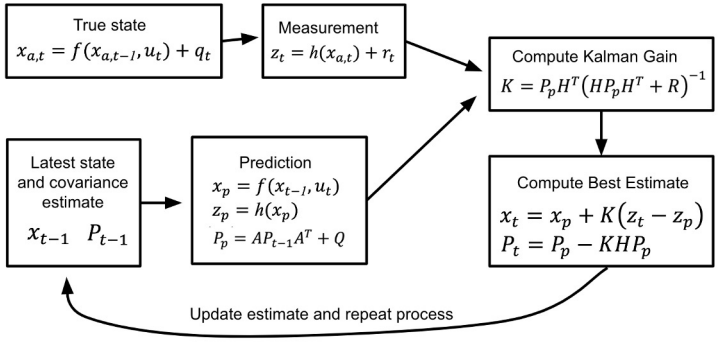
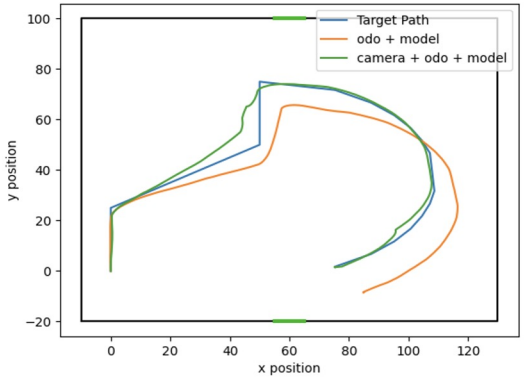
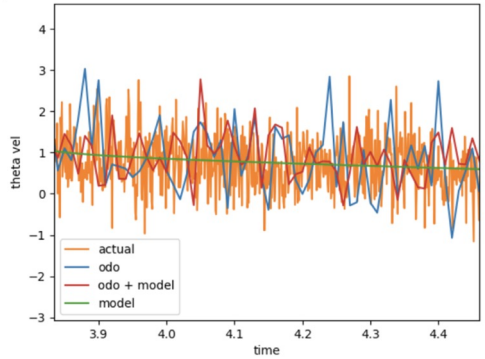
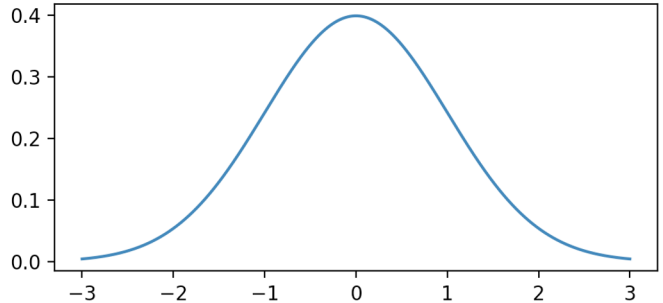



# EKF State Estimation

By: Ethan Kou
Mentor: Acshi Haggenmiller

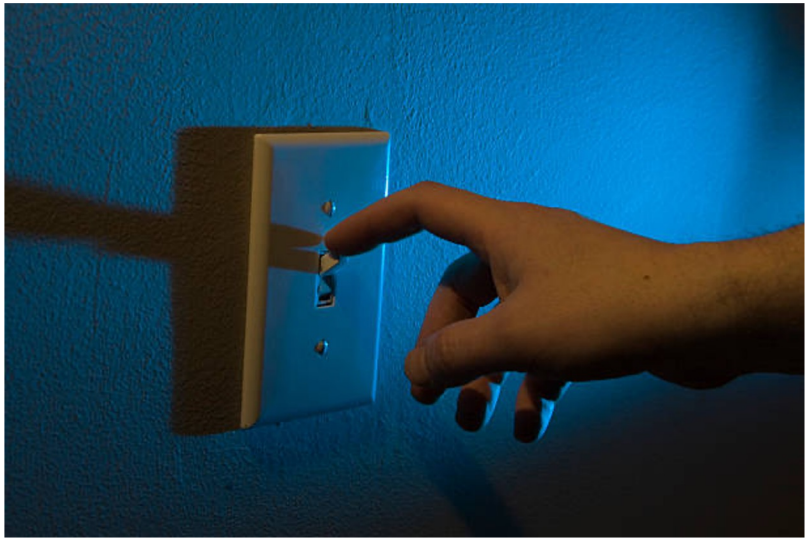


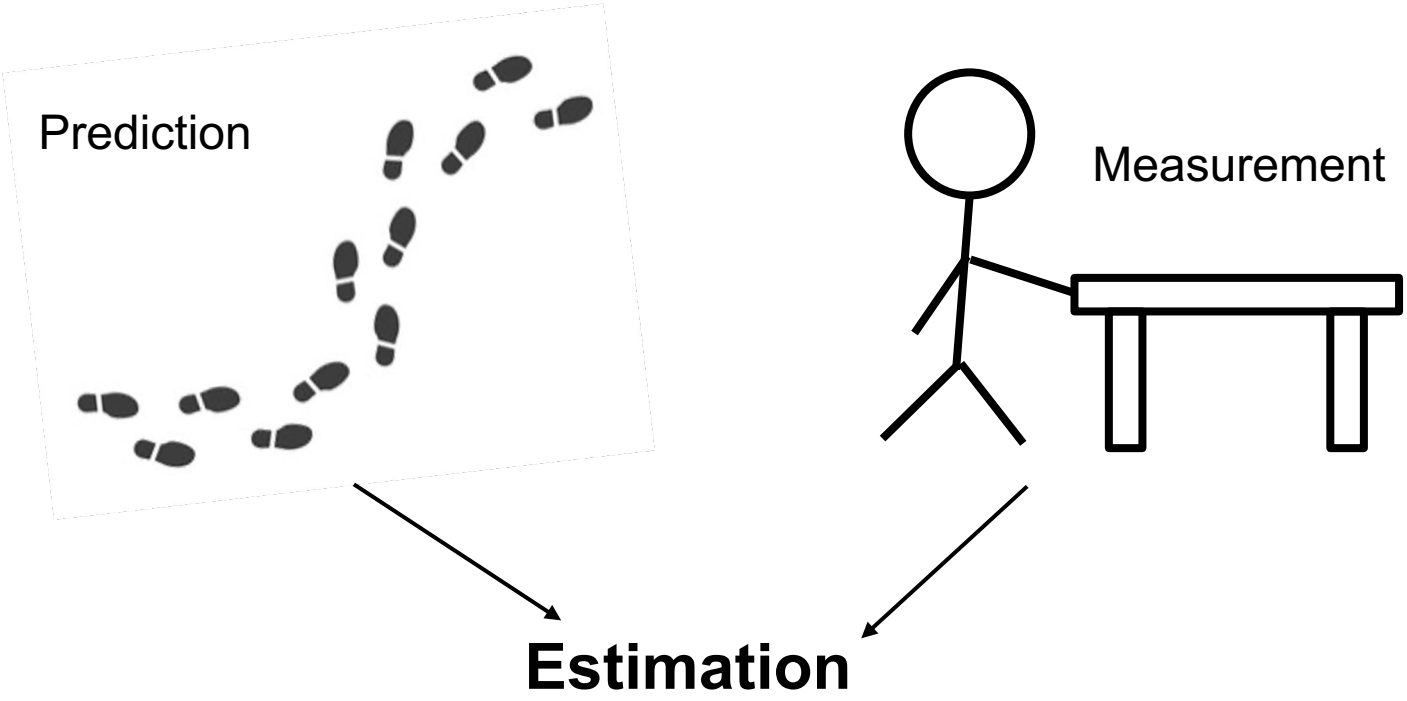
# Introduction

- What is the **Extended Kalman Filter**?
- Robot/simulation overview
- Metric and procedure for **localization experiments**
- Data and analysis
- Next Steps

# Kalman Filter Intuition - Kitchen Analogy

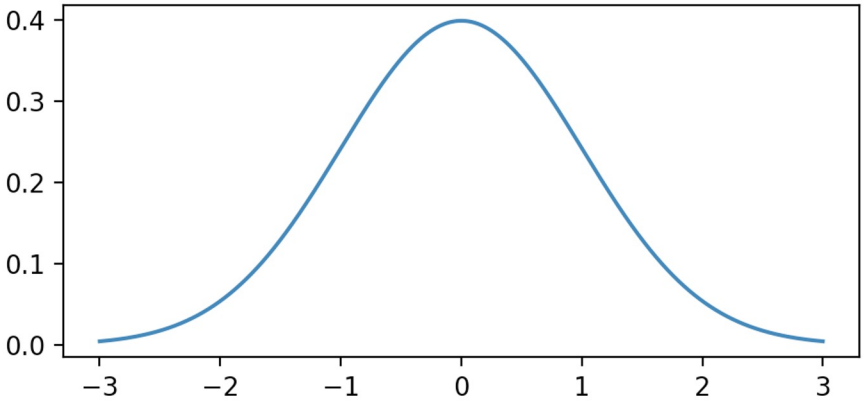


# Kalman Filter Intuition - Localizing

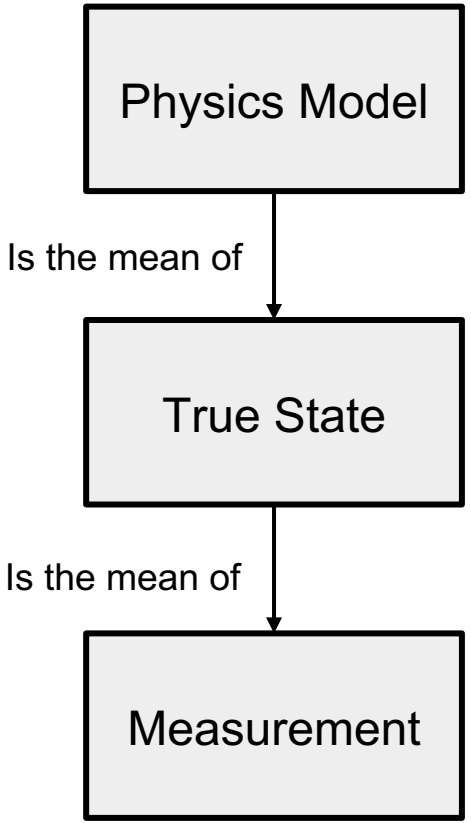


# EKF Assumptions

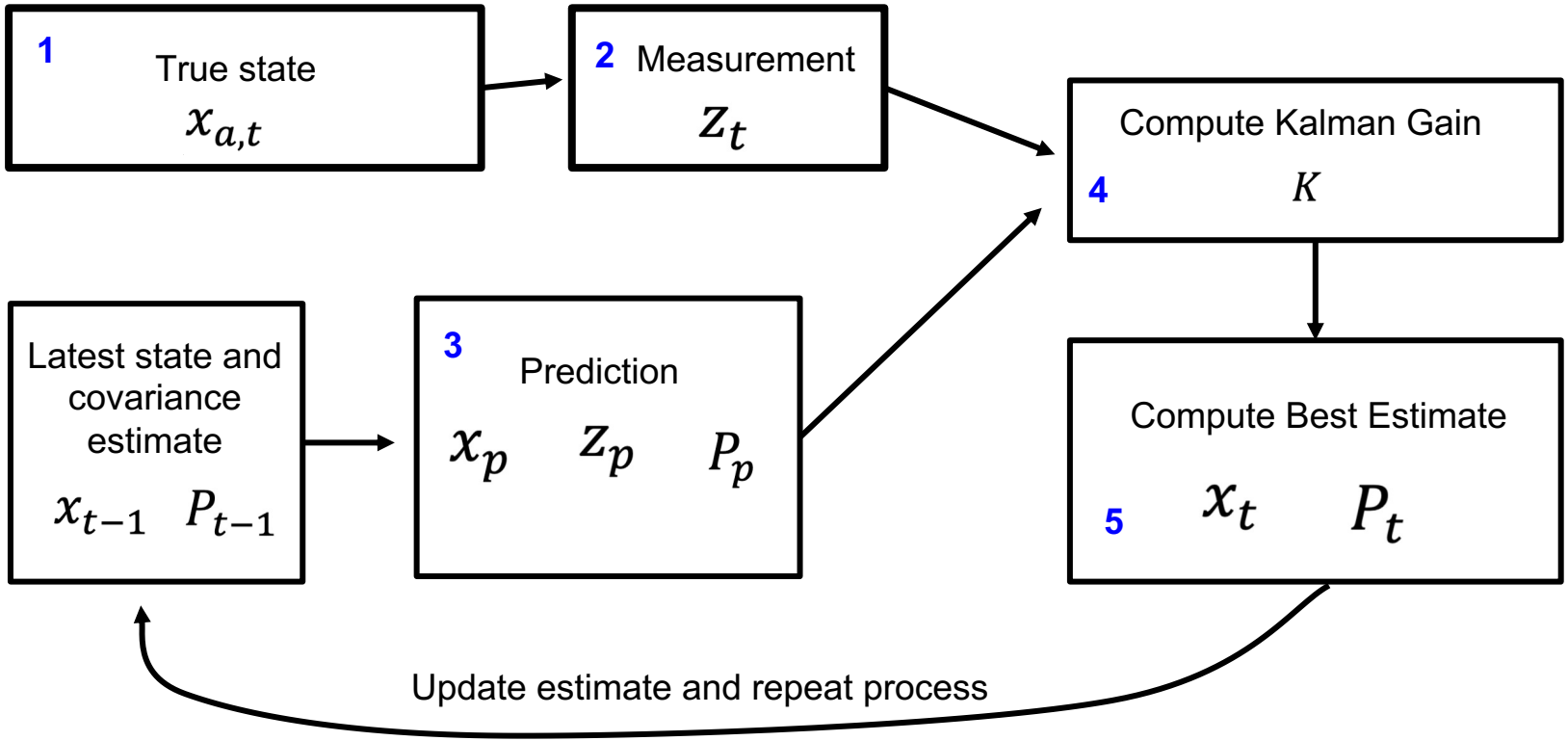
**IMPORTANT**: noise has a mean of 0



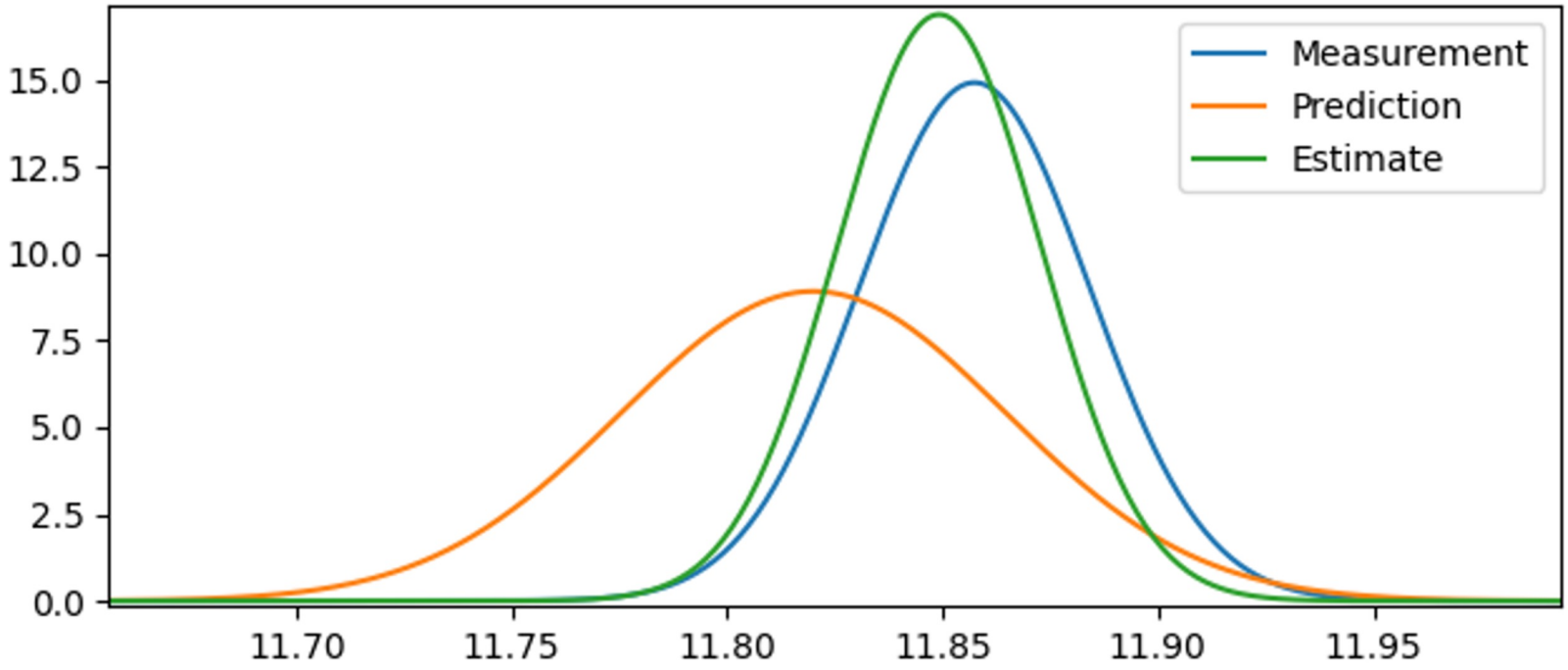

Gaussian (normal) Distribution



# Basic EKF Flowchart

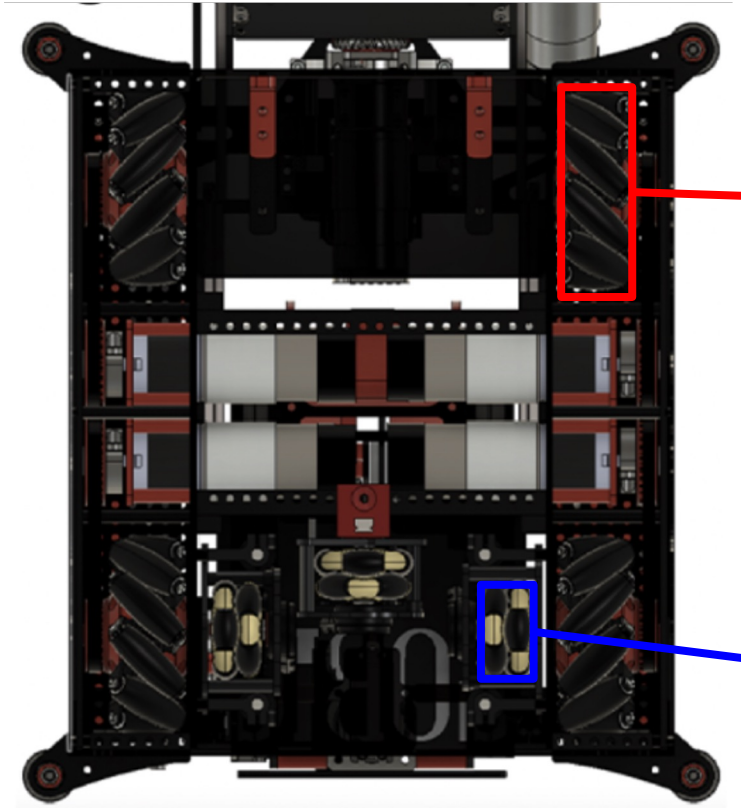


# State Estimation Visualization



# Robot Overview

Drivetrain




Mecanum wheel

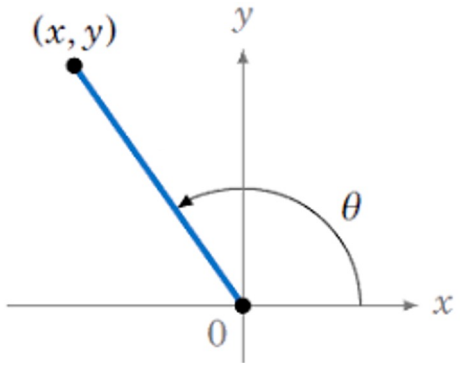
Camera


Odometry Pod

# State and Localization Types

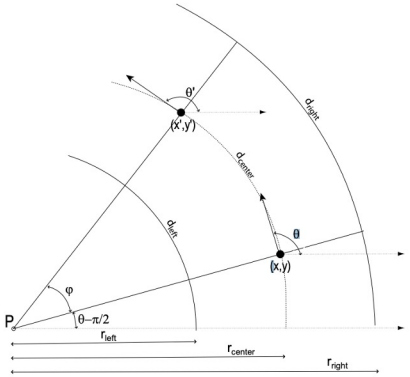
State Components:

- x position
- y position
- angle
- body x velocity
- body y velocity
- angular velocity




Localization Types:

- Odometry - velocity
- Physics Model - velocity
- Camera Landmark detection - position



# Accuracy Metric: RMSE

End Time

Estimated Value

True Value

$$RMSE = \sqrt{\sum_{t=0}^{t_f} \frac{(x_t - x_{a,t})^2}{n}}$$

Total time steps

RMSE Types:

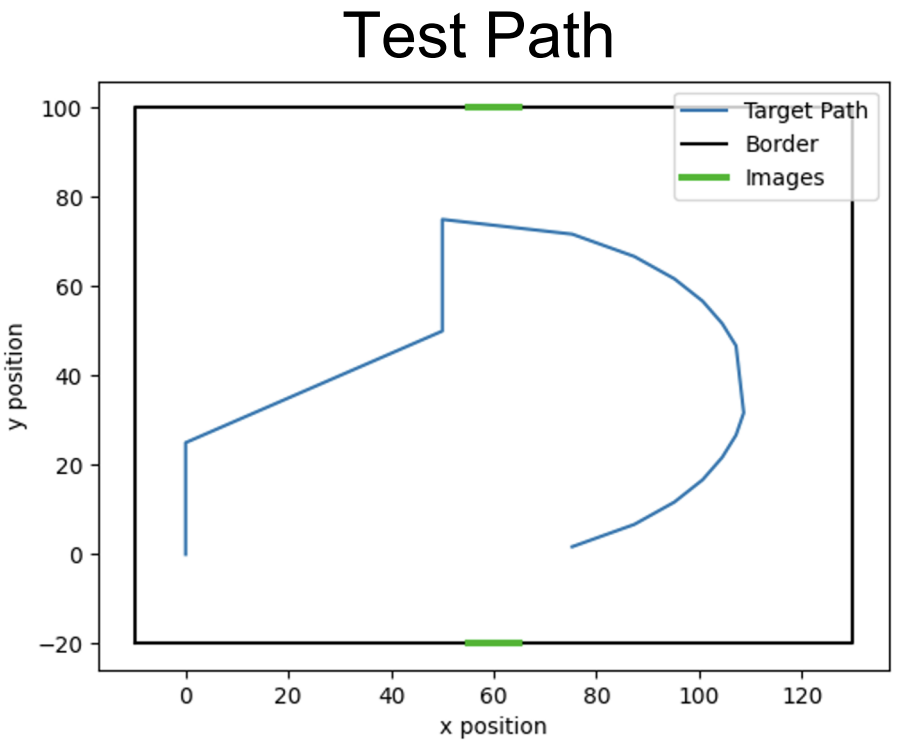
- (x, y) RMSE
- x RMSE
- y RMSE
- angle RMSE
- x velocity RMSE
- y velocity RMSE
- angular velocity RMSE

# Testing Procedure

1) Choose which localization sources to use.

1) Run 100 simulations of the robot following the test path

1) For each trial, find the RMSE and then find the average RMSE of all trials



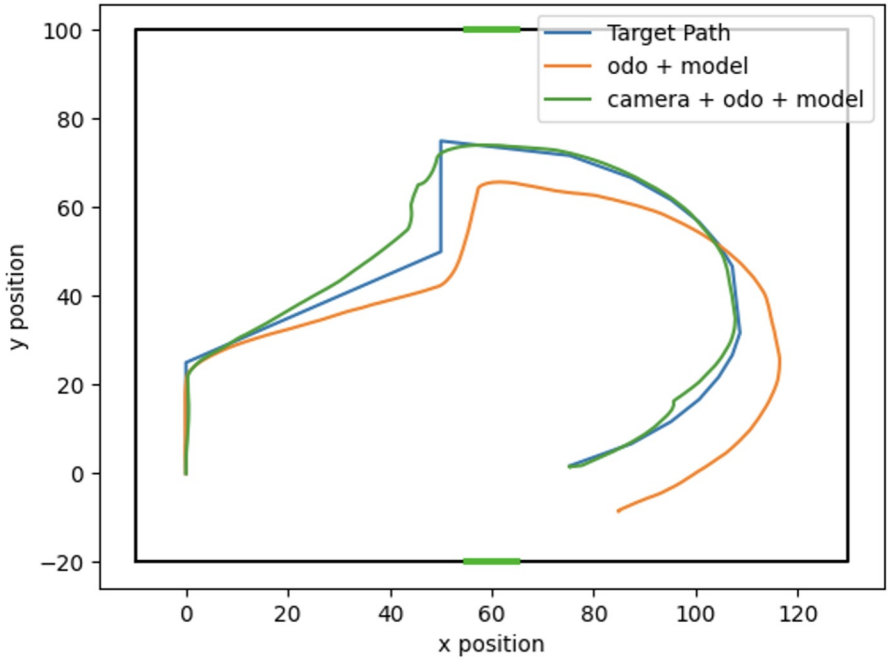
# Velocity Accuracy

Not lower position RMSE

| | model | odo | model + odo |
|---|---|---|---|
| (x, y) RMSE | 2.2432 | 2.9770 | 2.8704 |
| θ RMSE | 0.1179 | 0.1903 | 0.1864 |
| $\dot{x}$ RMSE | 0.6692 | 0.4578 | 0.3589 |
| $\dot{y}$ RMSE | 0.6717 | 0.4120 | 0.3271 |
| $\dot{\theta}$ RMSE | 0.6698 | 0.2286 | 0.1996 |

Lower velocity RMSE when an EKF is used to fuse both data sources

# Position Accuracy

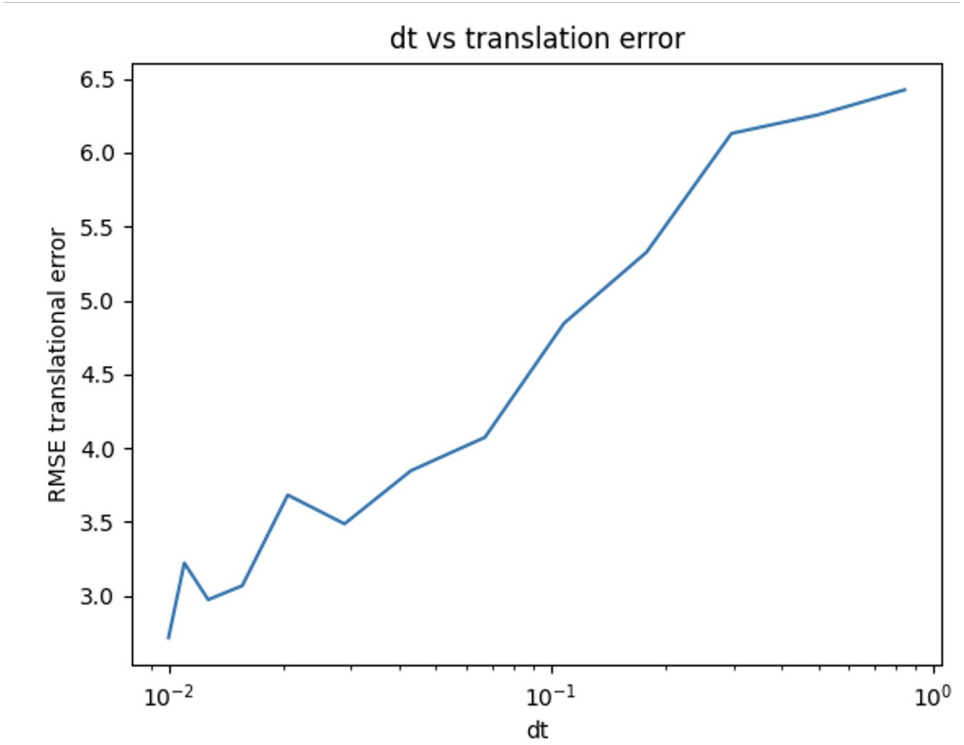



| | Model + odo | model + odo + camera |
|---|---|---|
| (x, y) RMSE | 2.8704 | 1.2140 |
| x RMSE | 6.4336 | 1.6400 |
| y RMSE | 8.0909 | 1.8259 |
| θ RMSE | 0.1864 | 0.0956 |

Position RMSE with a camera is lower

# EKF Drawbacks

- High Δt
- Very nonlinear systems



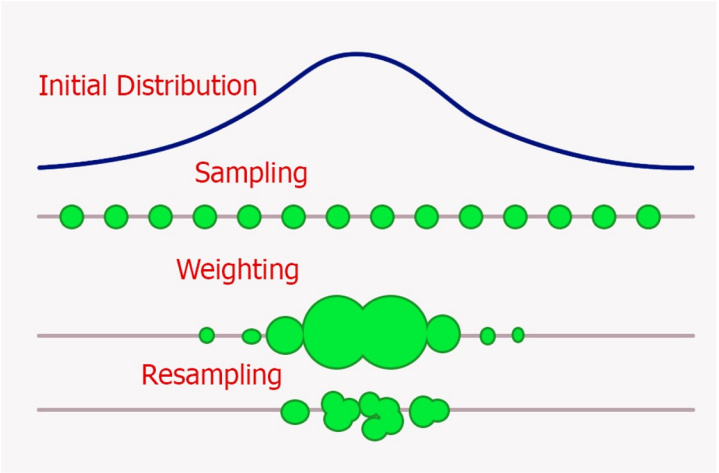
# Conclusion

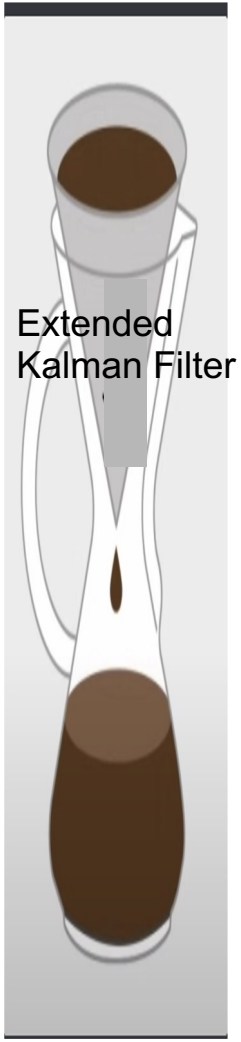
Results:

- Successfully fused multiple data sources
- Generally improves accuracy

Next Steps:

- Particle Filter
- Trained physics model






# Questions?