Localization and Reference Tracking in Mobile Robots

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Introduction

Case 1

Localization: Extended Kalman Filter with measurements from leader robot

Control: Linear Quadratic Regulator

Case 2

Localization: Extended Kalman Filter with measurements from beacons

Control: Lyapunov Based Controller

Case 3

Effects of Beacon Configurations and Robot Trajectories on Estimate Error

Applications

Curiosity Rover

Unmanned Autonomous Vehicle (UAV)

Motivation

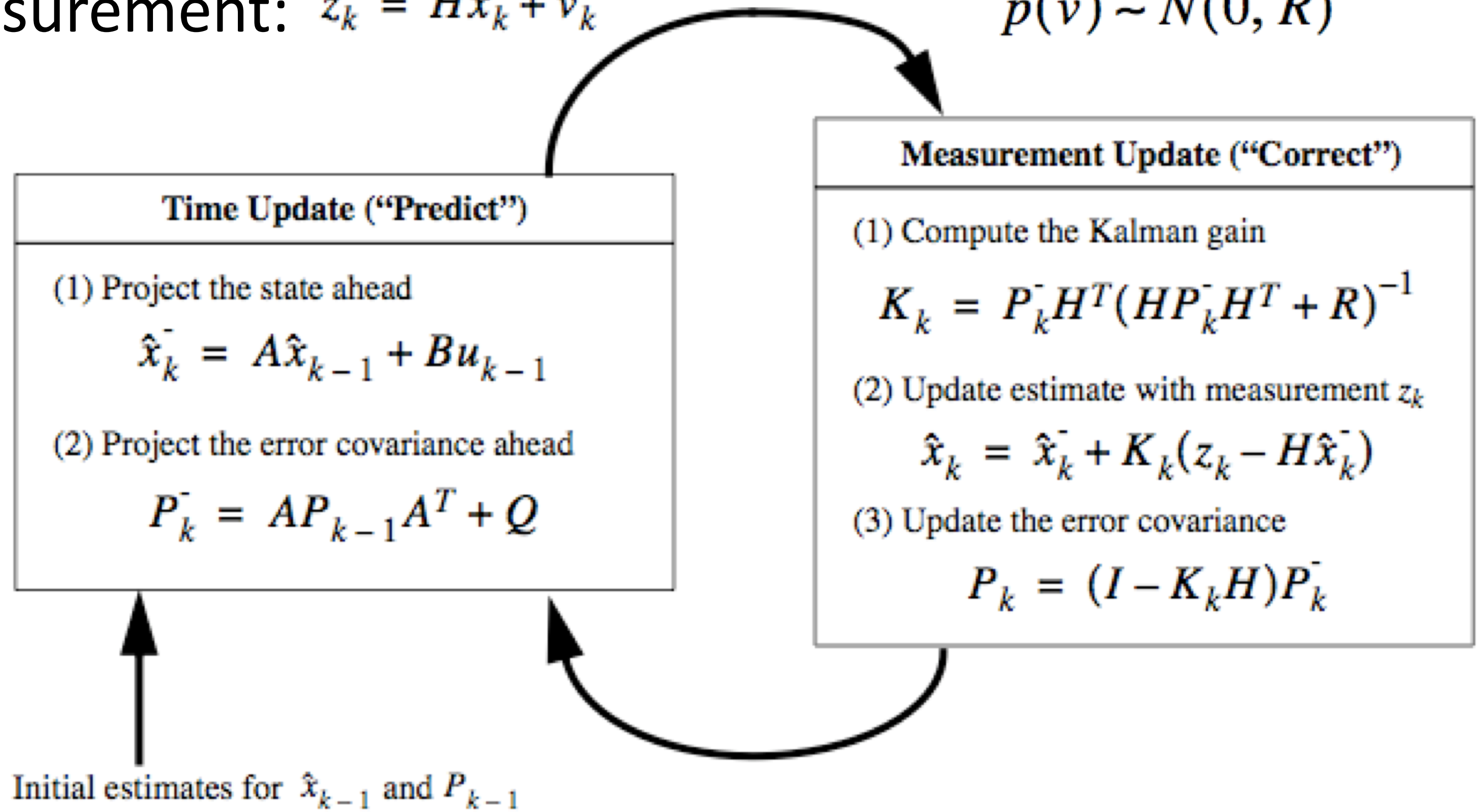
- Simultaneous Localization and Mapping (SLAM)
  - Exploring unknown territories
- Truly autonomous navigation

Localization

Kalman Filter (for LINEAR systems)

Process: $x_k = Ax_{k-1} + Bu_{k-1} + w_{k-1}$ $\qquad p(w) \sim N(0, Q)$

Measurement: $z_k = Hx_k + v_k$ $\qquad p(v) \sim N(0, R)$

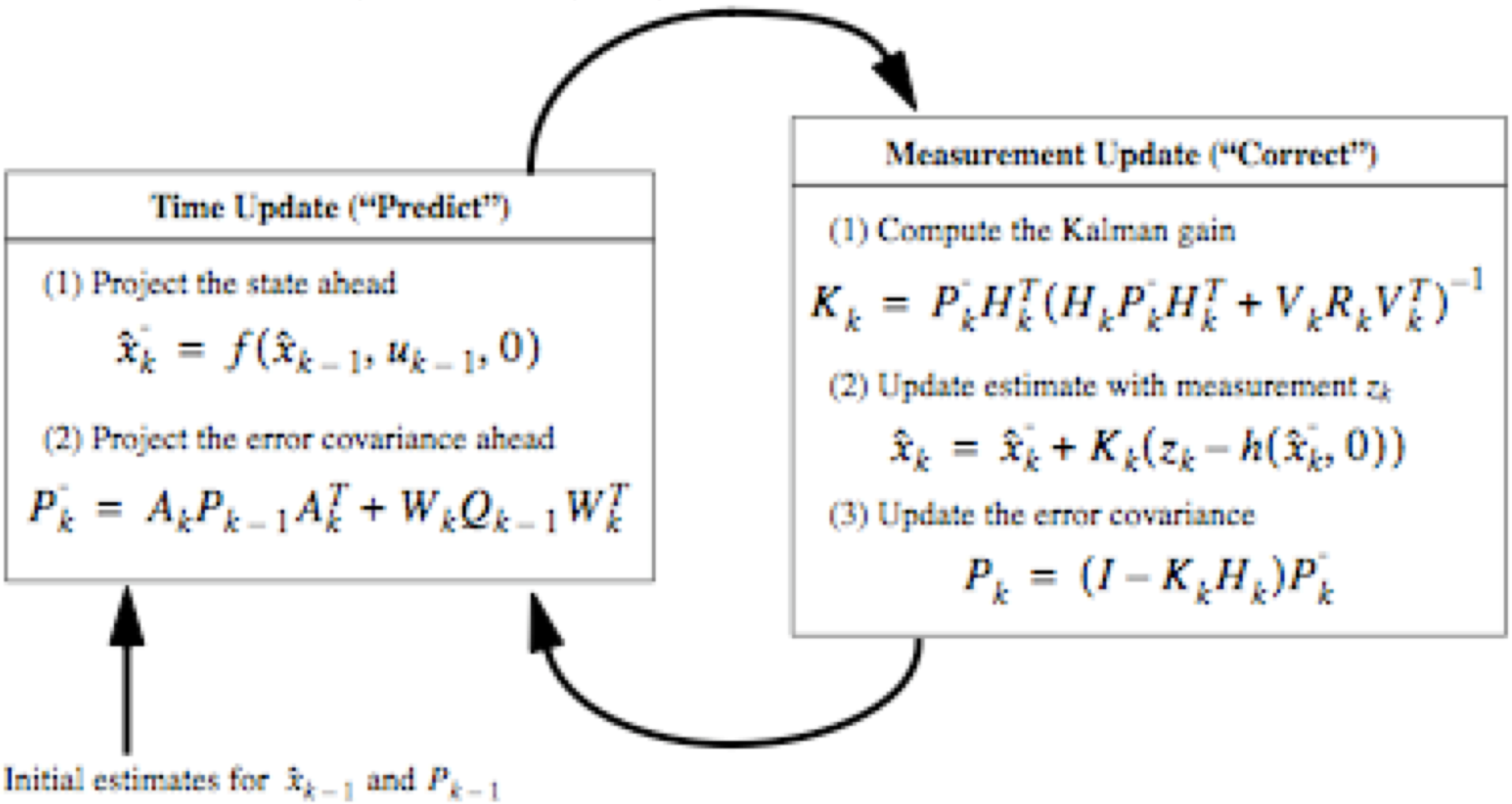


Localization

Extended Kalman Filter (for NON-LINEAR systems)

Process: $x_k = f(x_{k-1}, u_{k-1}, w_{k-1})$ $\quad p(w) \sim N(0, Q)$

Measurement: $z_k = h(x_k, v_k)$ $\quad p(v) \sim N(0, R)$

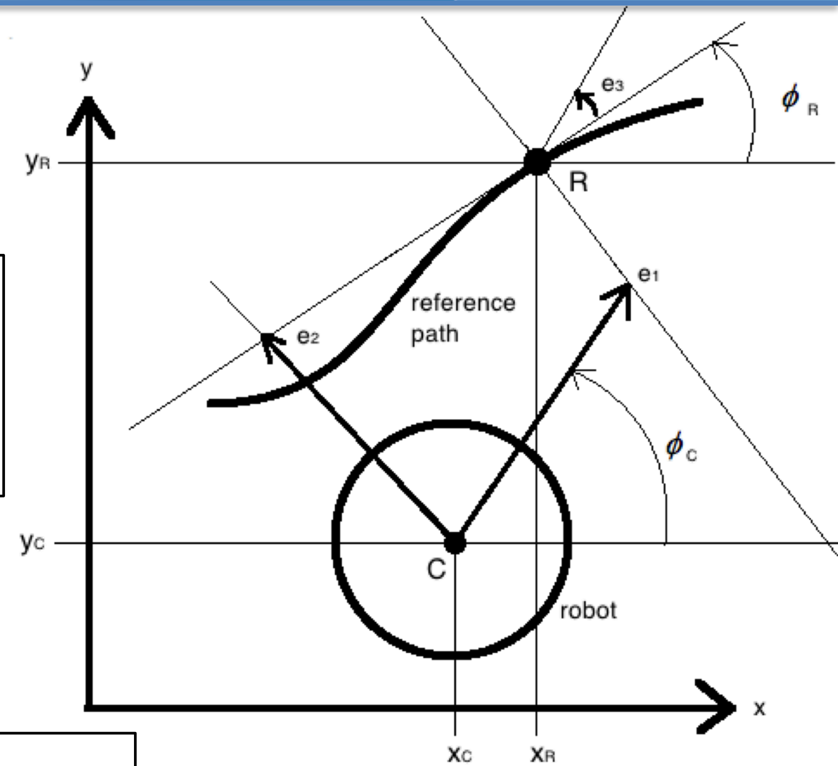


Control

Lyapunov-based Controller

Positive definite: $V(x) > 0, x \neq 0$

$$V(0) = 0$$



$$V = \frac{1}{2}e_1^2 + \frac{1}{2}e_2^2 + \frac{1-\cos e_3}{k_2}$$

$$\frac{dV(x(t))}{dt} = \frac{\partial V(x(t))}{\partial x} \times \frac{dx}{dt} < 0, x \neq 0$$

$$v = v_r \cos e_3 + k_1 e_1$$

$$\omega = \omega_r + k_3 e_3$$

Control

Linear Quadratic Regulator

system: $\dot{x} = Ax + Bu$

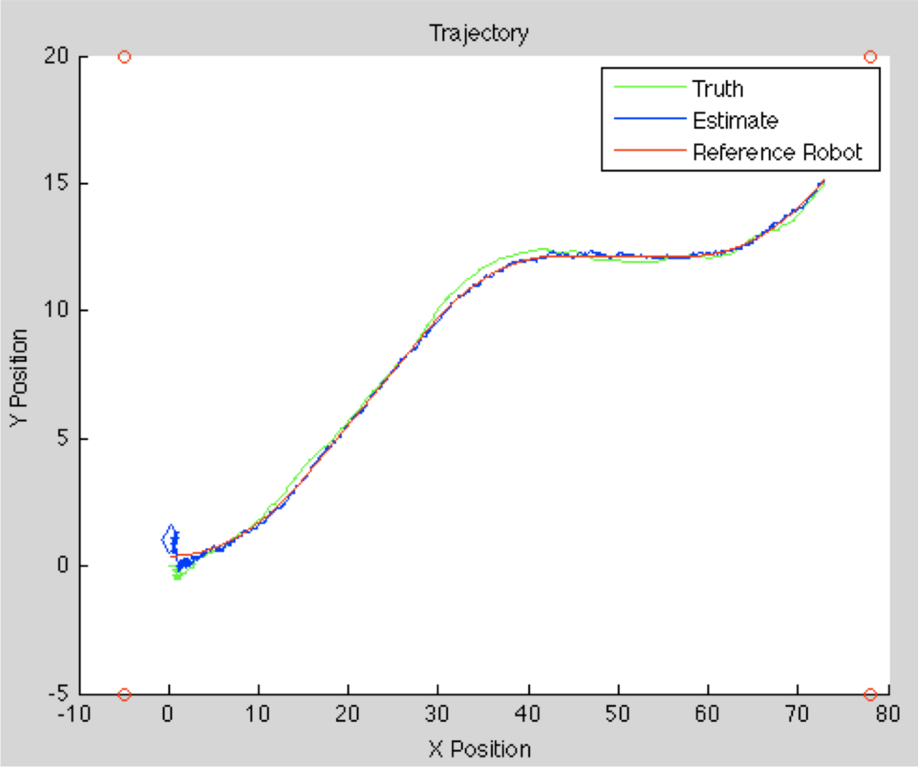
cost function: $J = \int_0^\infty [x^T Q x + u^T R u] dt, \ldots Q \geq 0, R > 0$

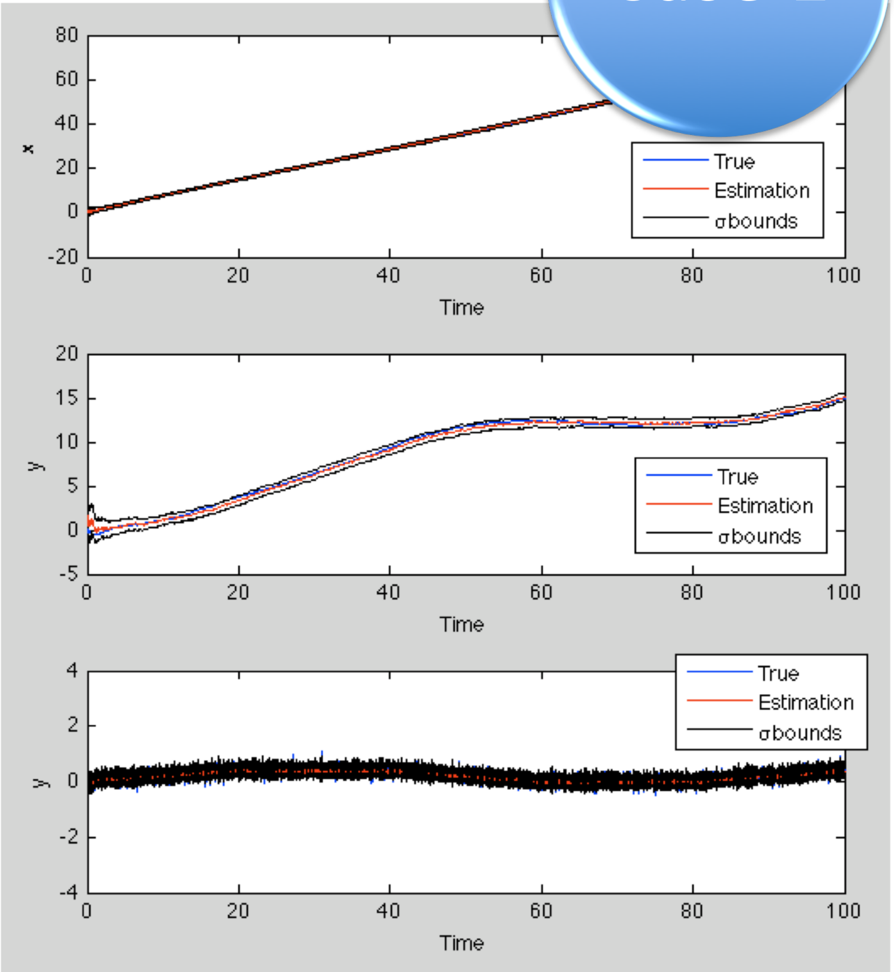
feedback: $u = -Kx$

Simulation Results

Kalman Filter and Lyapunov Controller

Case 1

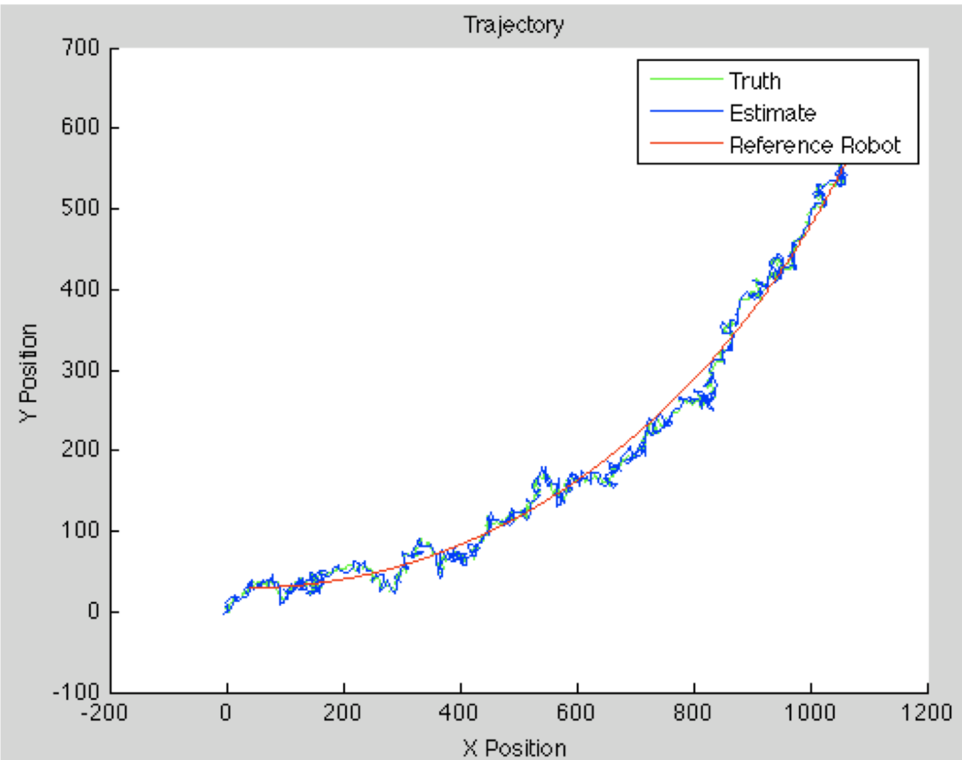


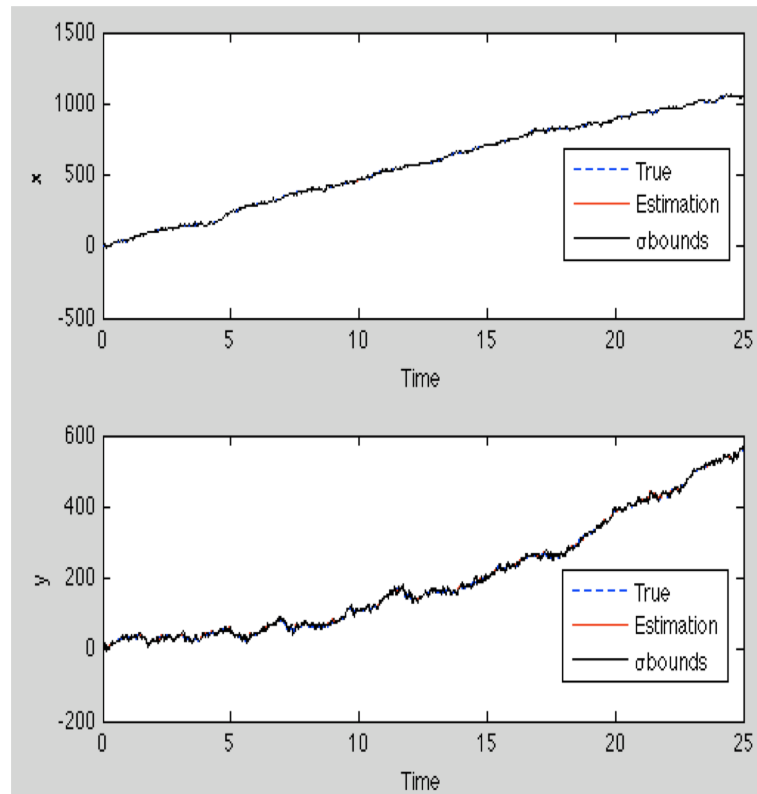


Simulation Results

Kalman Filter and LQR Control

Case 2





Simulation Results

Beacon Placement

Observed changes in the following variables:

- Number of beacons
- Distance from trajectory
- Beacon configurations
- Robot trajectory

TurtleBot

- Personal mobile robot-kit with open-source software
- Implemented Robotic Operatic System programs to perform SLAM

TurtleBot

Future Work

- Look further into Lyapunov controller to increase scope
- Create nonlinear LQR controller
- Include mapping in current localization algorithms
- Implement new algorithms on Turtlebot