

# CSE4421: Assignment 4

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Due: End of class on Mon Apr 8, 2013

1. Implement an extended Kalman filter (EKF) where the plant model is linear and the measurement model is non-linear. Use your EKF to solve the following localization problem:

Suppose that you have an omnidirectional robot (see slides from Mar 13) robot moving in an environment with two point landmarks  $m_1$  and  $m_2$  and a known goal location  $g$ . The coordinates of the landmarks are  $m_1 = [5 \ 0]^T$  and  $m_2 = [10 \ 0]^T$ . The coordinates of the goal are  $g = [15 \ -2]^T$ . At each time step, the robot can move one unit towards the goal (in a straight line from its estimated current position towards the goal); this is the control input  $u_t$ . Assume that the control input is accurate (has zero mean error) but has covariance  $Q$ :

$$Q = \begin{bmatrix} 0.25^2 & 0 \\ 0 & 0.25^2 \end{bmatrix}$$

The state of the robot is its estimated current location

$$x_t = \begin{bmatrix} x \\ y \end{bmatrix}$$

Assume that the robot is equipped with a sensor that can measure the distance to each landmark simultaneously and unambiguously (i.e., the robot can measure the distance from its true location to both landmarks and it knows which landmark produces which distance measurement). Assume that the distance measurement is accurate (has zero mean error) but has variance equal to  $0.25^2$ . In other words, each measurement is

$$z_t = \begin{bmatrix} d_1 \\ d_2 \end{bmatrix} + \delta$$

where  $d_1$  is the distance to landmark 1,  $d_2$  is the distance to landmark 2, and  $\delta$  is the zero mean Gaussian measurement noise with covariance

$$R = \begin{bmatrix} 0.25^2 & 0 \\ 0 & 0.25^2 \end{bmatrix}$$

(a) What is the matrix  $H_t$  obtained after linearizing the measurement model? Give the full equation for each element of  $H_t$ .

(b) Implement the EKF for the robot and show the localization results using the EKF at each time step  $t = 0, 1, 2, \dots, 25$ . Your plots should show the estimated location of the robot (using the EKF) and the true location of the robot. Show the results for two different estimates of the starting location  $x_0$ :

$$x_0 = \begin{bmatrix} 0 \\ 9 \end{bmatrix}$$

and

$$x_0 = \begin{bmatrix} 0 \\ -5 \end{bmatrix}$$

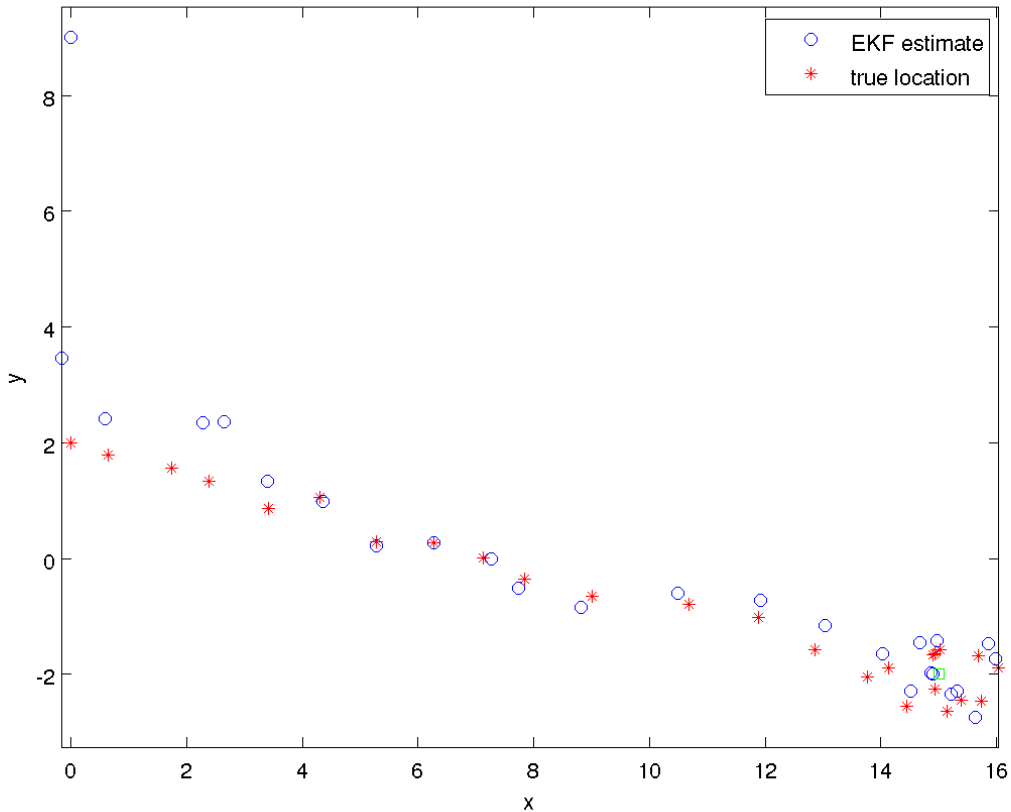
For the estimated state covariance use

$$\Sigma_0 = \begin{bmatrix} 4 & 0 \\ 0 & 4 \end{bmatrix}$$

The true starting position of the robot is always

$$x_{\text{true}} = \begin{bmatrix} 0 \\ 2 \end{bmatrix}$$

(c) My results using  $x_0 = [0 \ 9]^T$  are shown below:



The results using  $x_0 = [0 \ -5]^T$  should be quite different. Explain why the two different starting points produce such different results.

Submit written solutions for questions 3(a) and 3(c). Submit Matlab scripts for question 3(b).

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