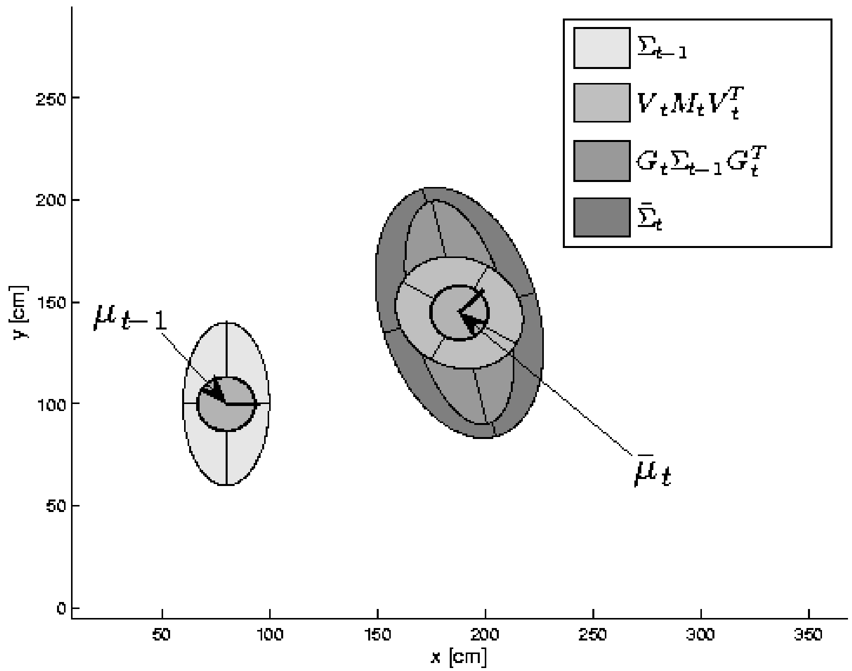
Day 26

EKF for localization

EKF and RoboCup Soccer

- simulation of localization using EKF and 6 landmarks (with known correspondences)
- robot travels in a circular arc of length 90cm and rotation 45deg



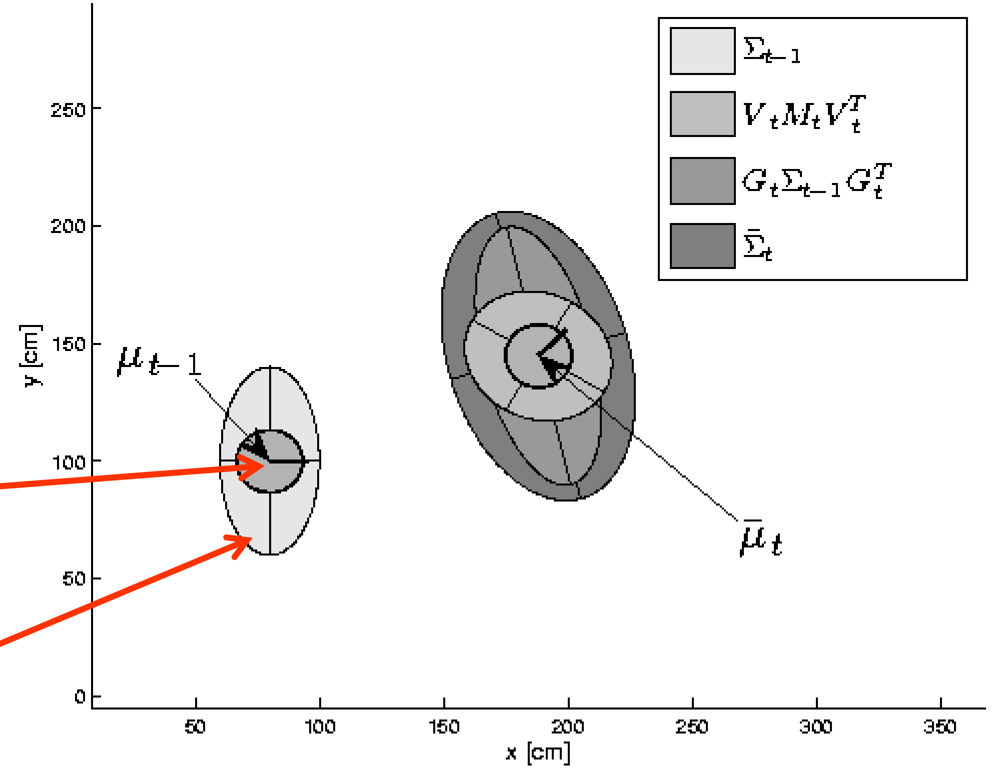
EKF Prediction Step

- recall that in the prediction step the state mean and covariance are projected forward in time using the plant model

$$\bar{\mu}_t = g(u_t, \mu_{t-1})$$

$$\bar{\Sigma}_t = G_t \Sigma_{t-1} G_t^T + R_t$$

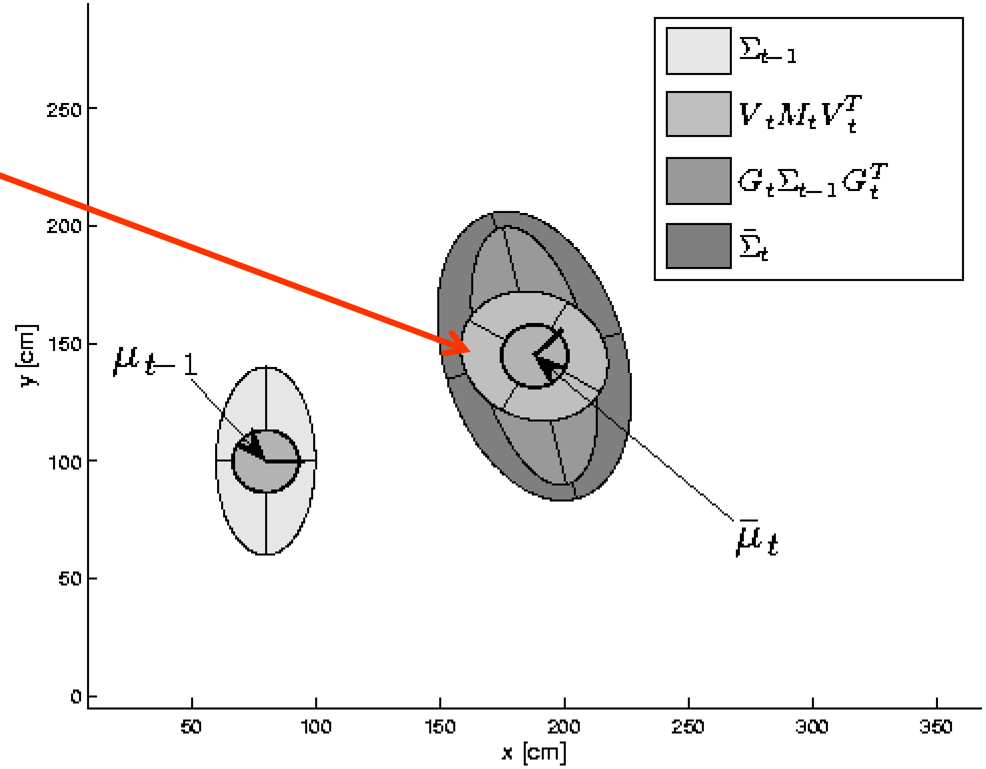
EKF Prediction Step



position and covariance at previous time step

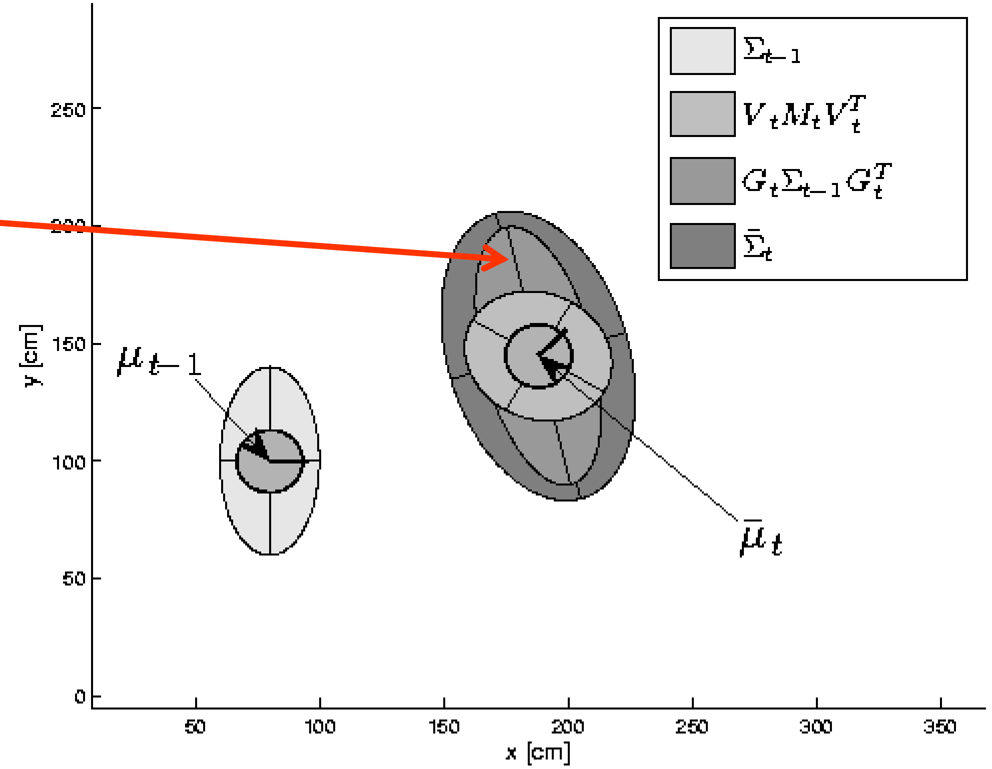
EKF Prediction Step

uncertainty due to control noise (small transl. and rot. noise)



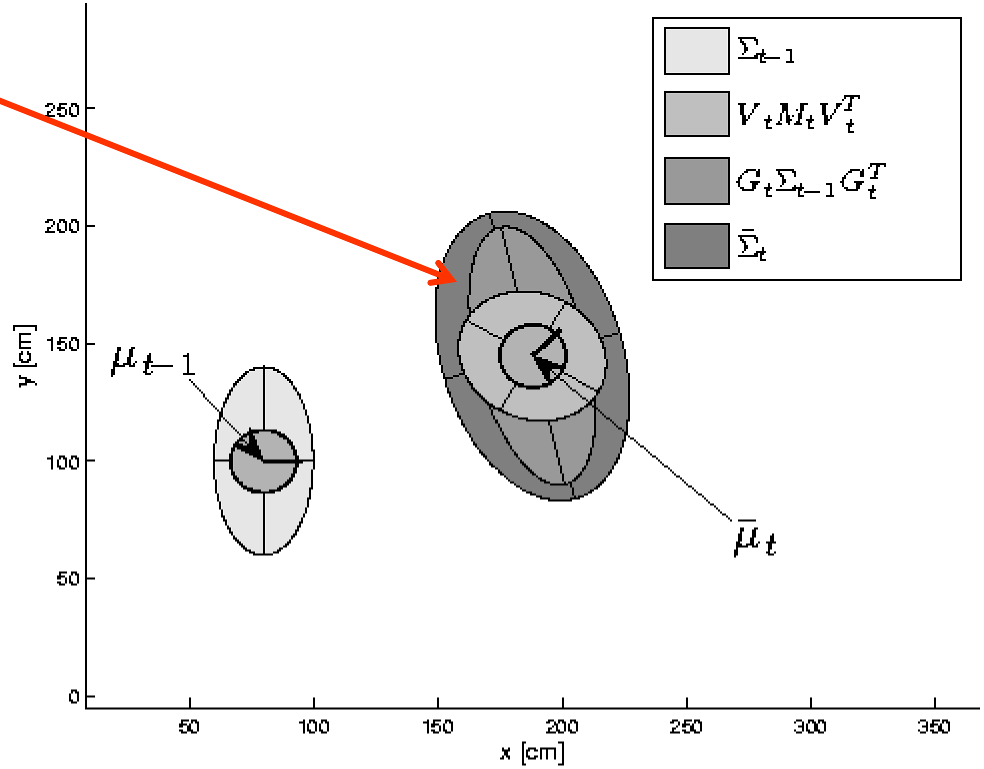
EKF Prediction Step

previous uncertainty projected through process model



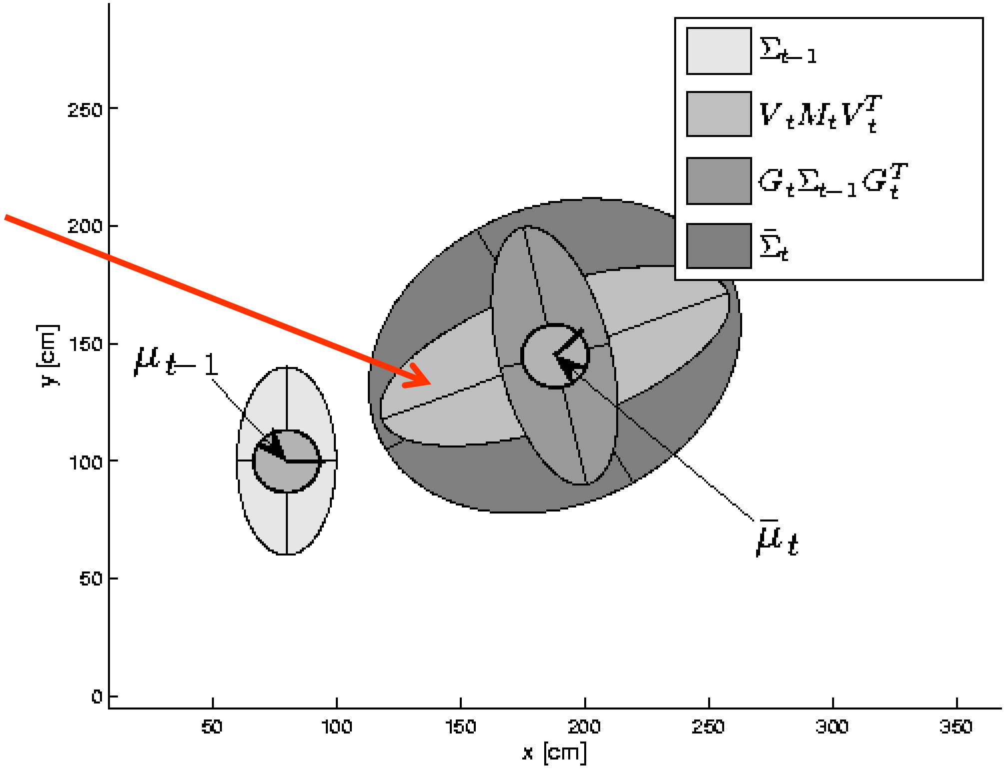
EKF Prediction Step

net predicted uncertainty



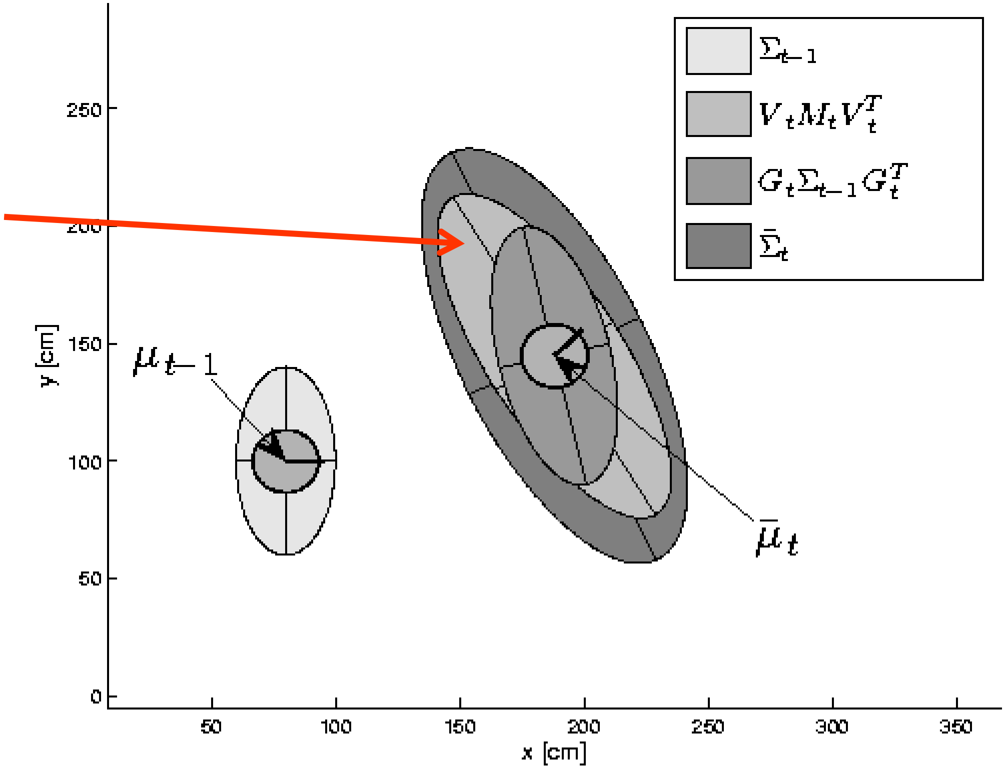
EKF Prediction Step

uncertainty due to control noise (large transl. and small rot. noise)



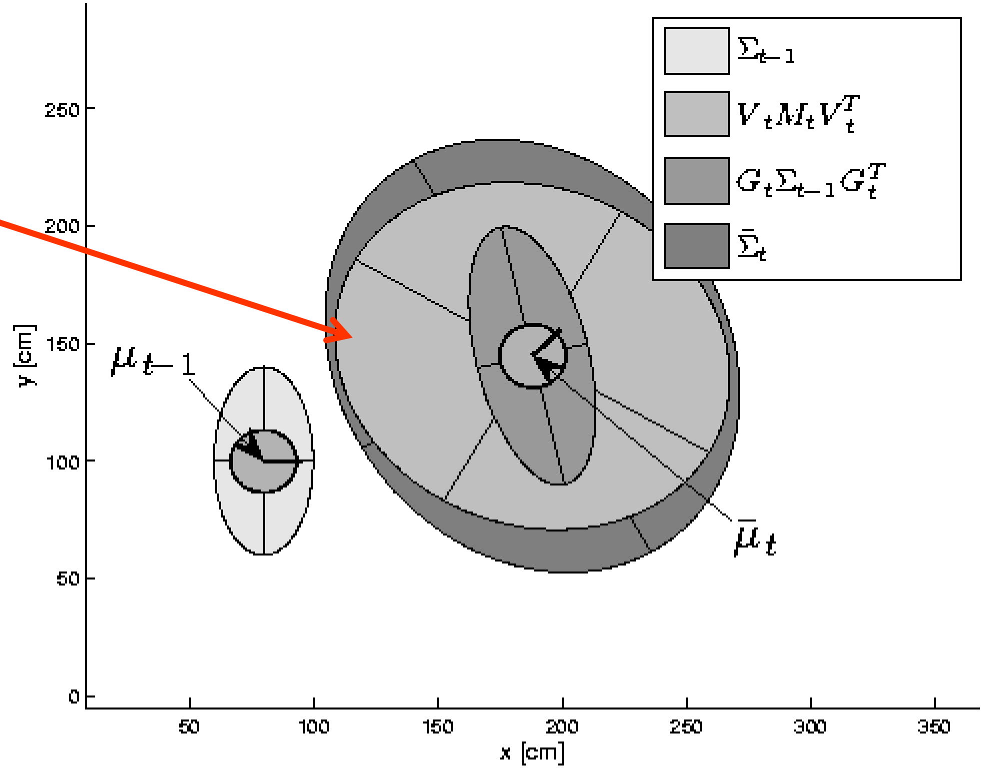
EKF Prediction Step

uncertainty due to control noise (small transl. and large rot. noise)



EKF Prediction Step

uncertainty due to control noise (large transl. and large rot. noise)



EKF Observation Prediction Step

- in the first part of the correction step, the measurement model is used to predict the measurement and its covariance using the predicted state and its covariance

$$\bar{z}_t = h(\bar{\mu}_t)$$

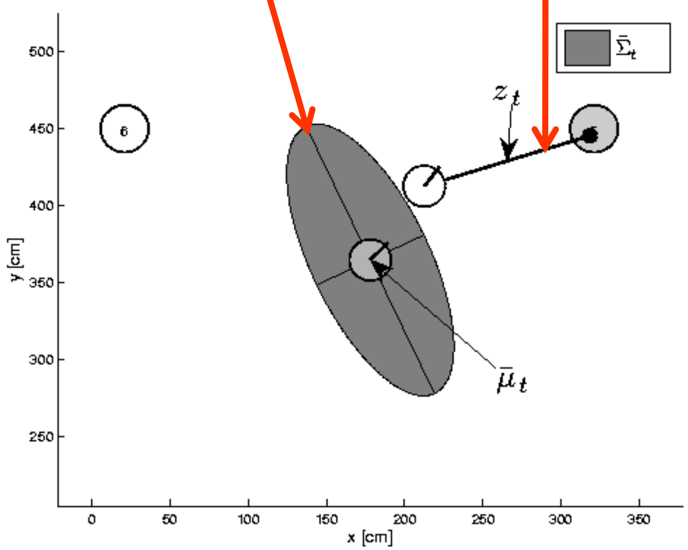
$$S_t = H_t \bar{\Sigma}_t H_t^T + Q_t$$

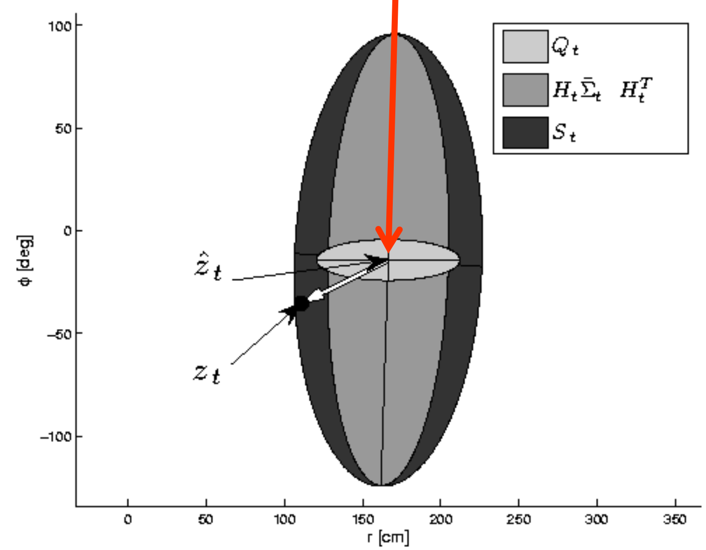
EKF Observation Prediction Step

predicted state with covariance

landmark observation

predicted landmark observation



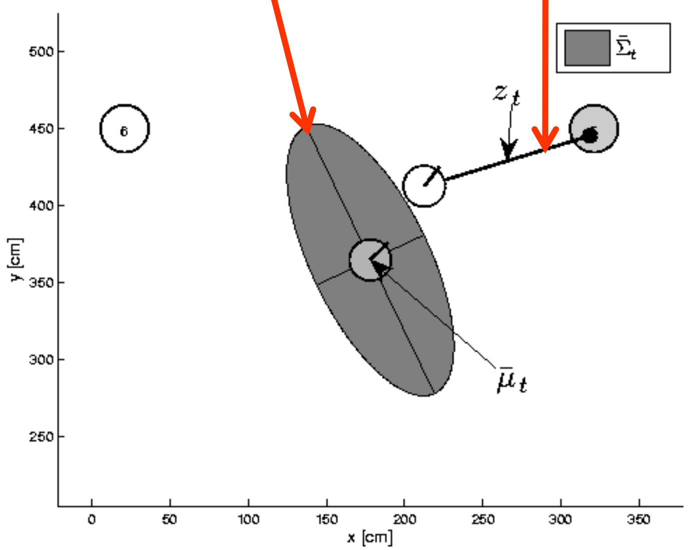


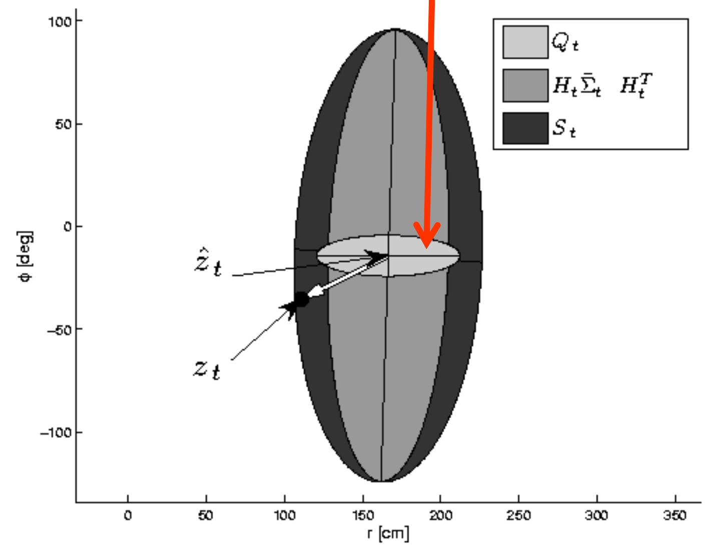
EKF Observation Prediction Step

predicted state with uncertainty

landmark observation

observation uncertainty



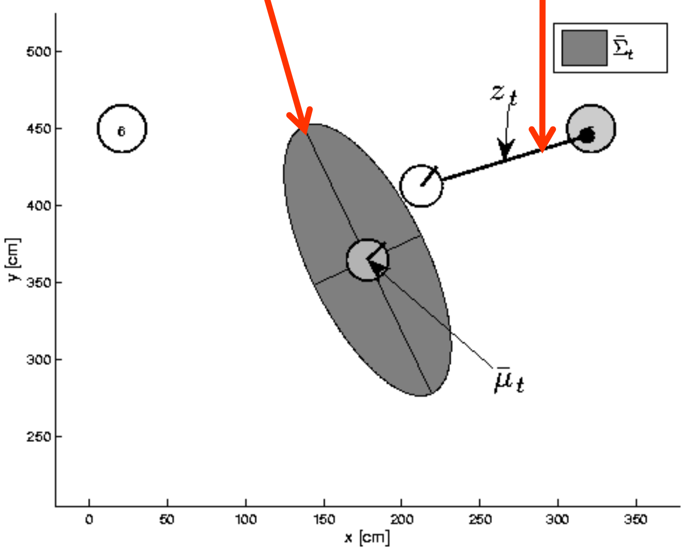


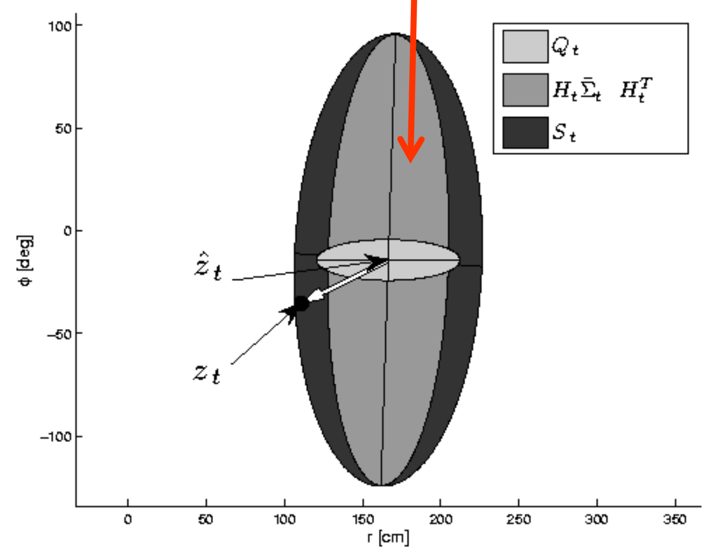
EKF Observation Prediction Step

predicted state with covariance

landmark observation

uncertainty due to uncertainty in predicted robot position



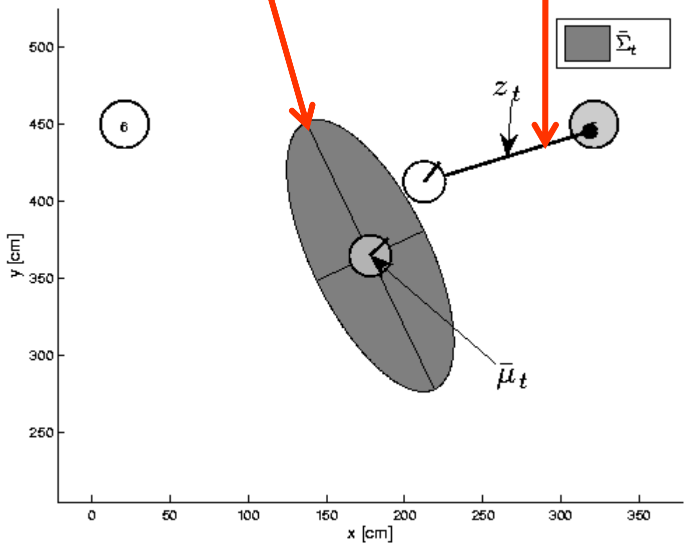


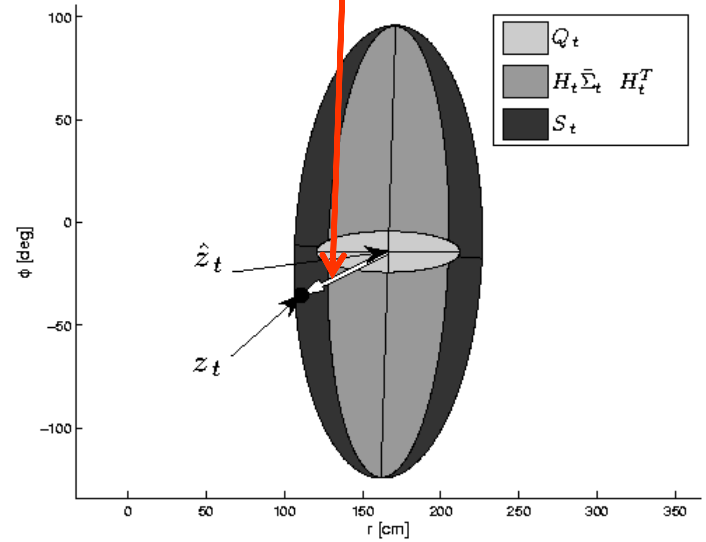
EKF Observation Prediction Step

predicted state with covariance

landmark observation

innovation (difference between predicted and actual observations)



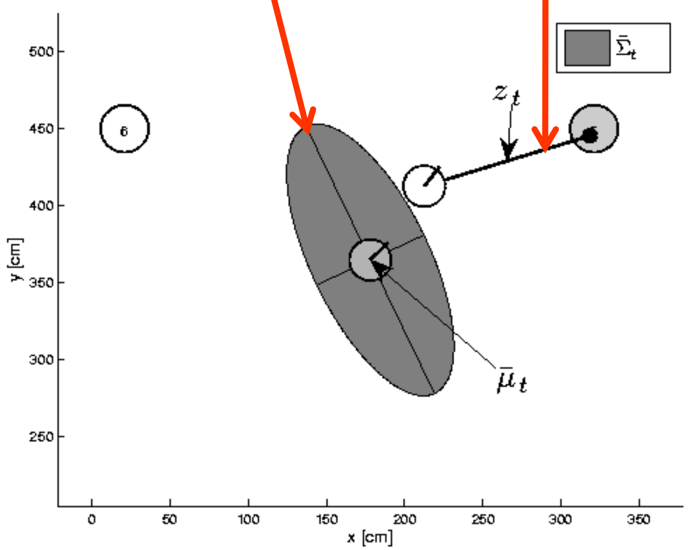


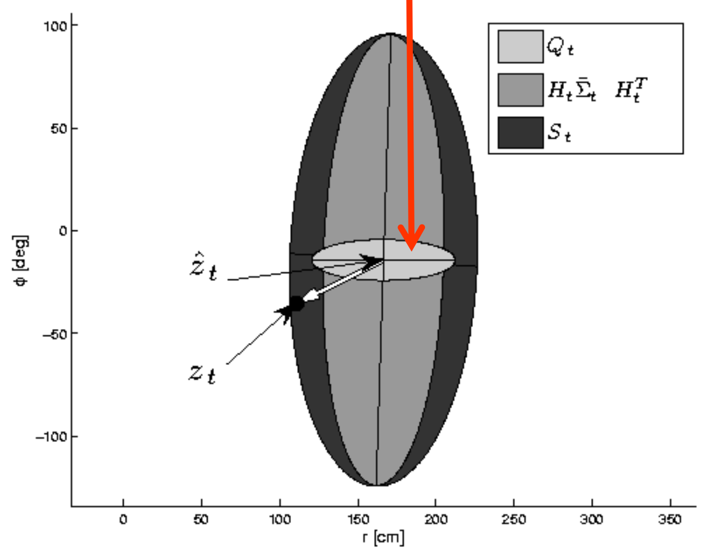
EKF Observation Prediction Step

predicted state with uncertainty

landmark observation

observation uncertainty (large distance uncertainty)



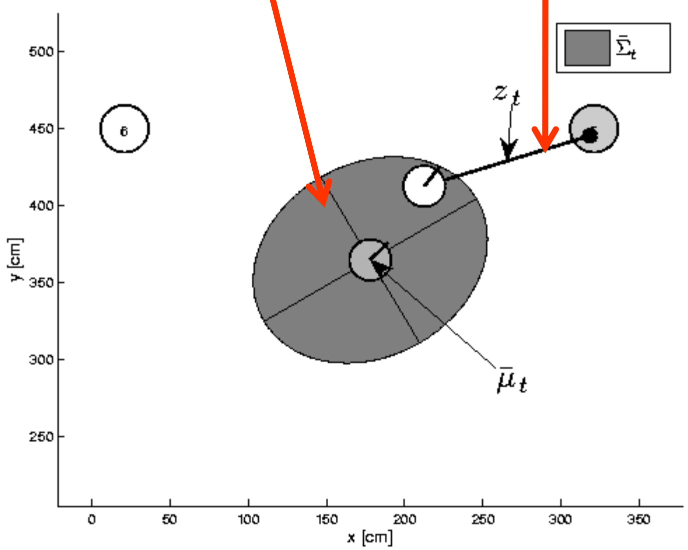


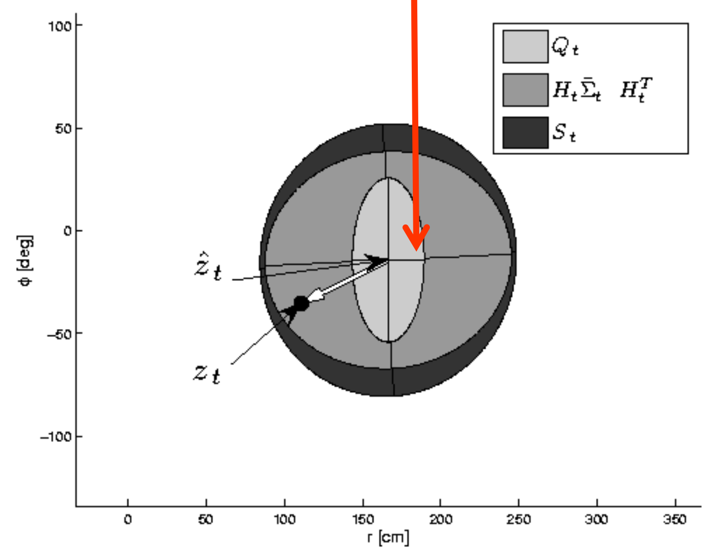
EKF Observation Prediction Step

predicted state with uncertainty

landmark observation

observation uncertainty (large bearing uncertainty)





EKF Correction Step

- the correction step updates the state estimate using the innovation vector and the measurement prediction uncertainty

$$K_t = \bar{\Sigma}_t H_t^T S_t^{-1}$$

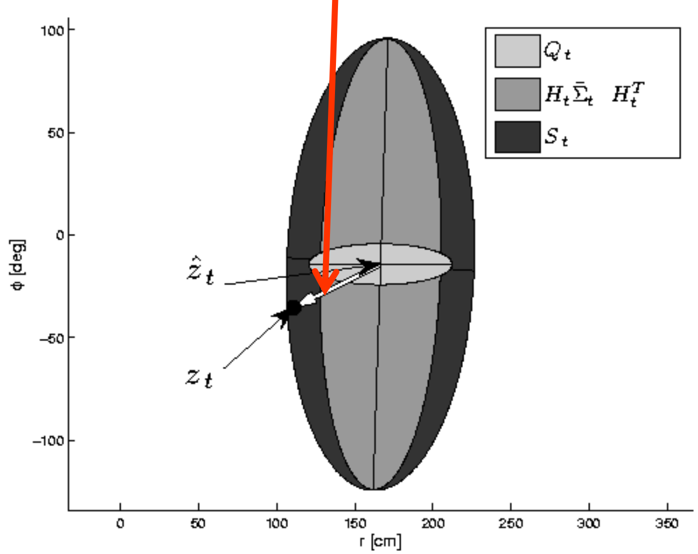
$$\mu_t = \bar{\mu}_t + K_t (z_t - \bar{z}_t)$$

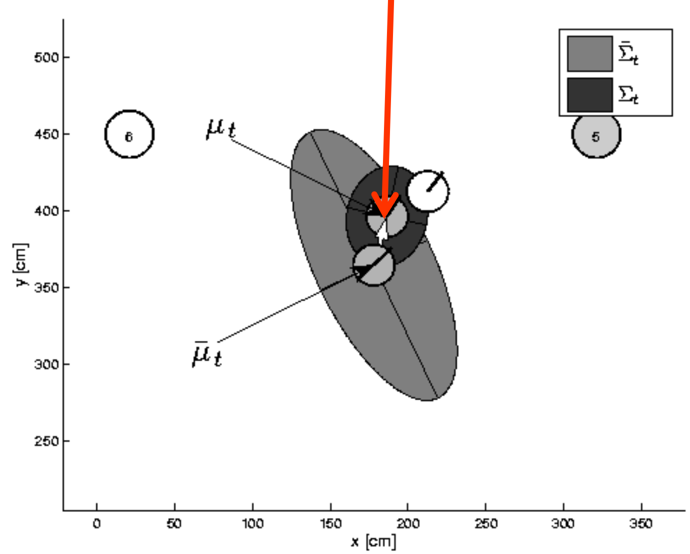
$$\Sigma_t = (I - K_t H_t) \bar{\Sigma}_t$$

EKF Correction Step

innovation (difference between predicted and actual observations)

innovation scaled and mapped into state space

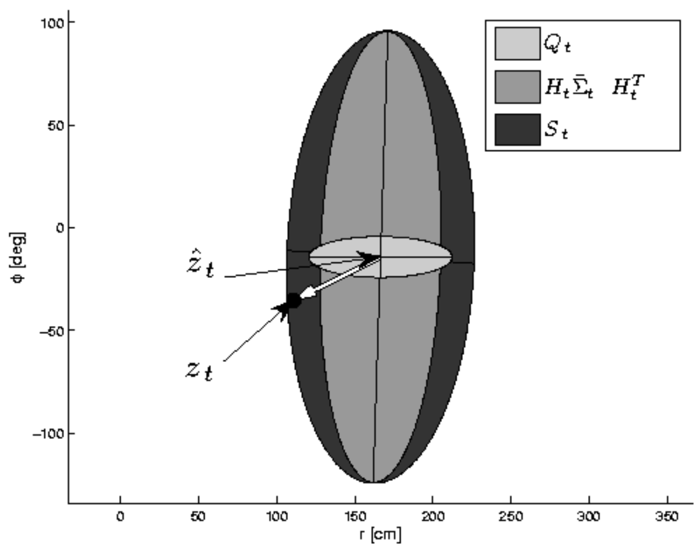


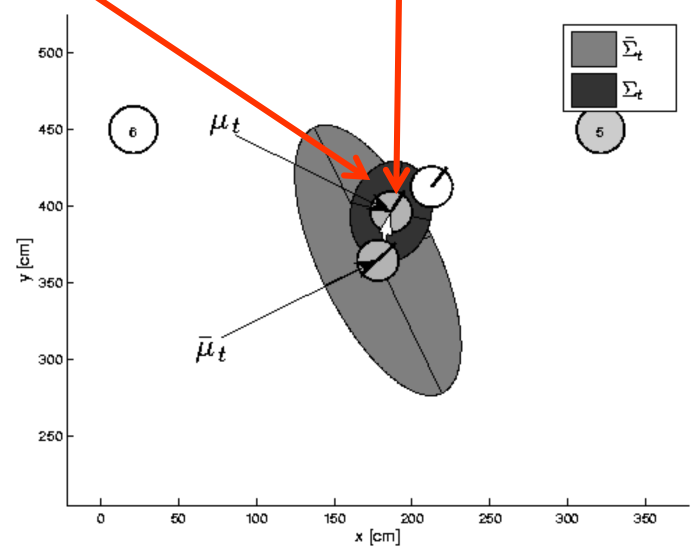


EKF Correction Step

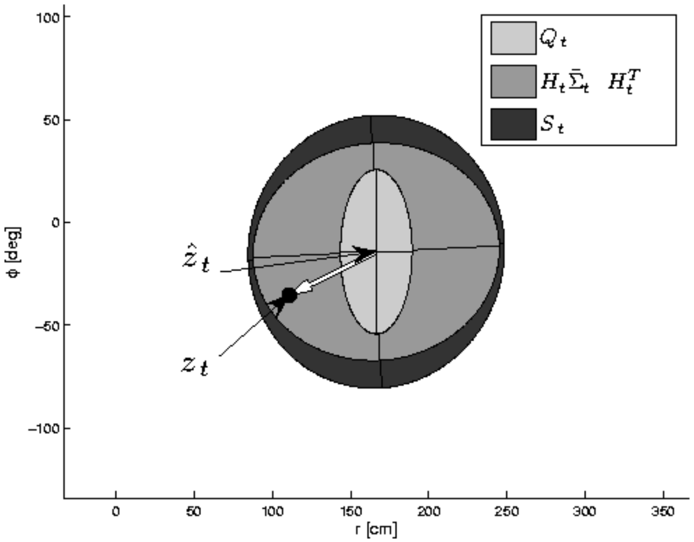
corrected
state mean

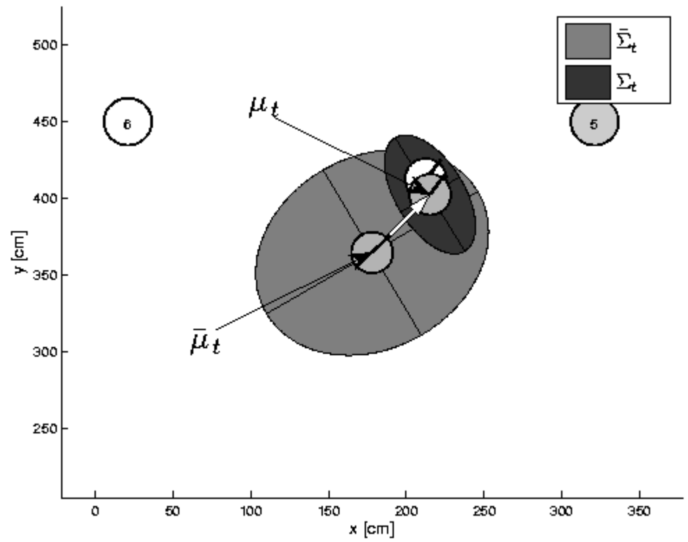
corrected
state
uncertainty



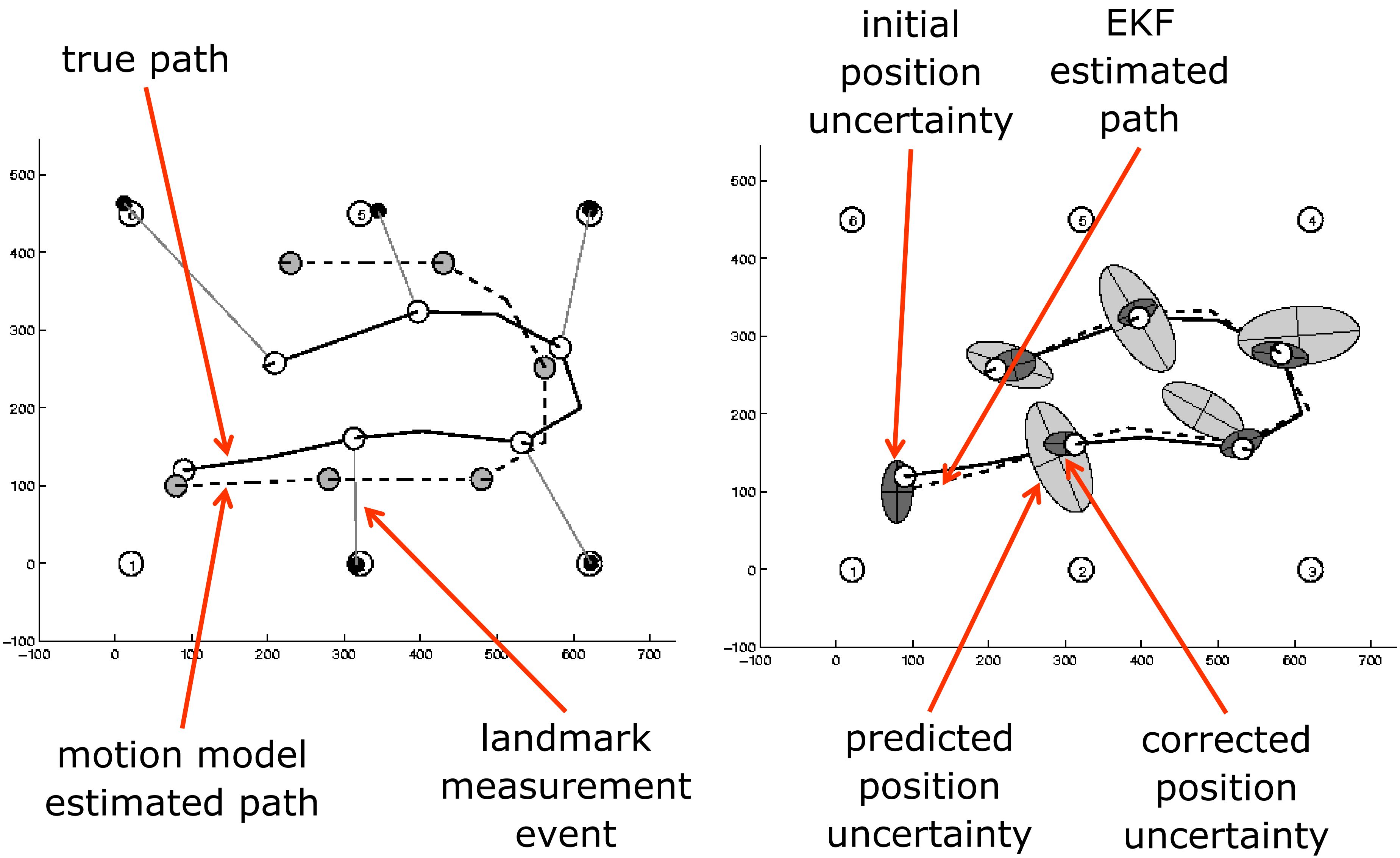


EKF Correction Step

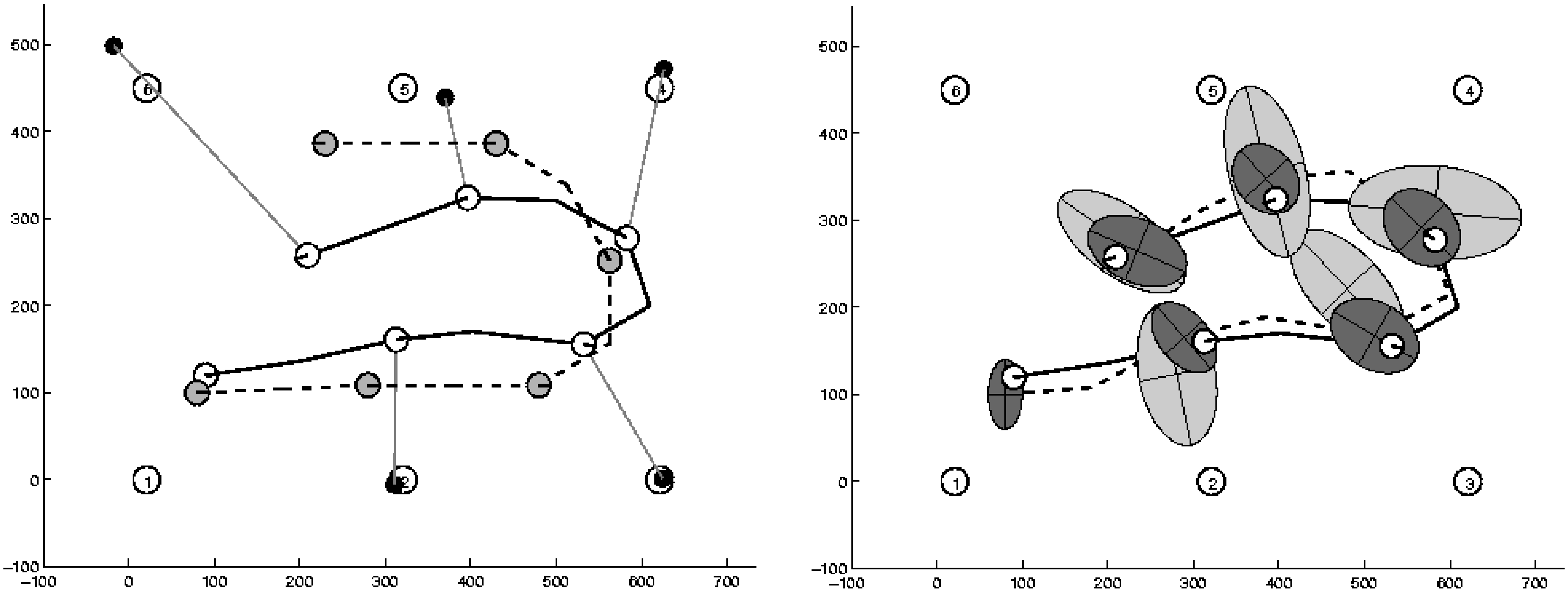




Estimation Sequence (1)

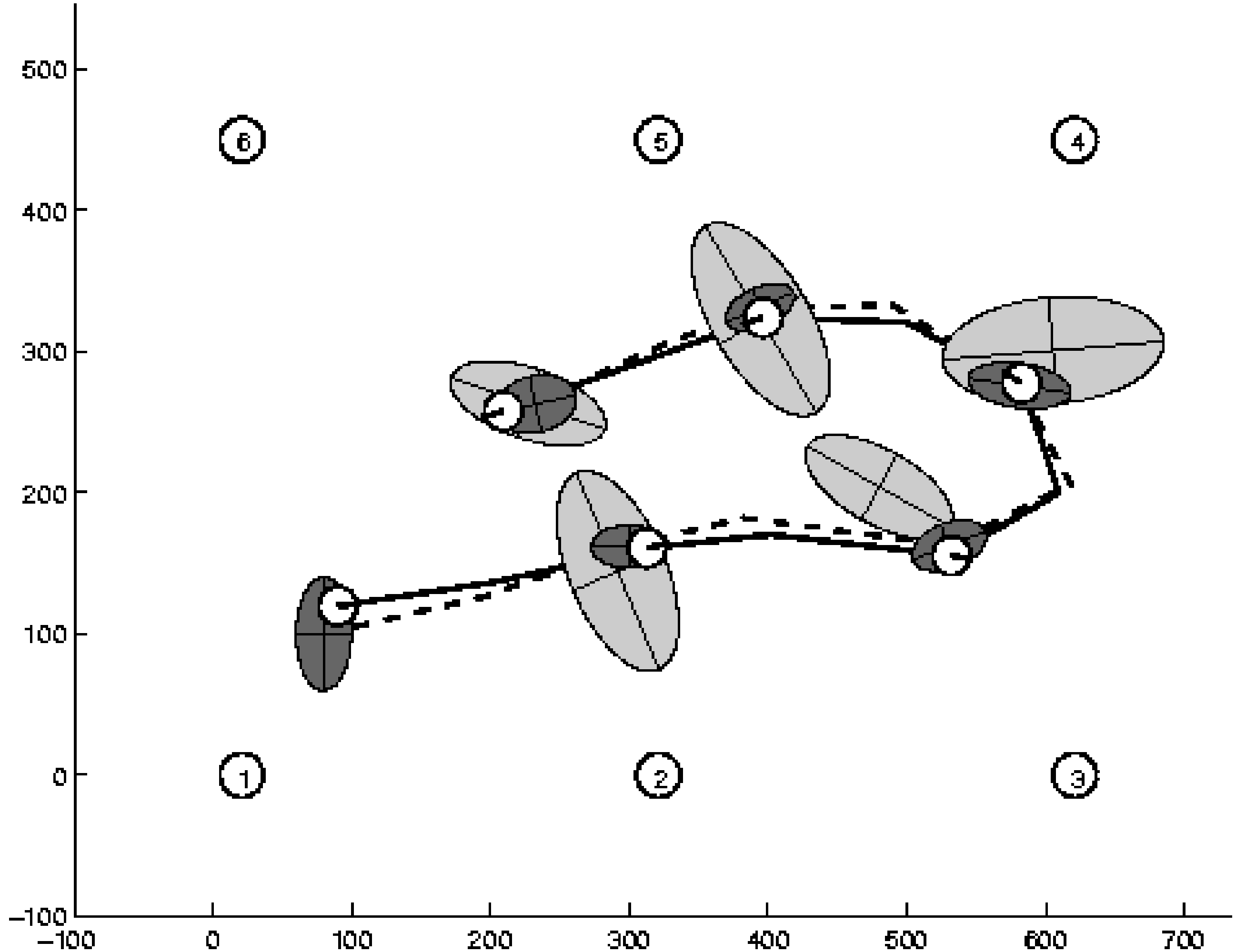


Estimation Sequence (2)



same as previous but with greater measurement uncertainty

Comparison to GroundTruth



EKF Summary

- Highly efficient: Polynomial in measurement dimensionality k and state dimensionality n:
$$O(k^{2.376} + n^2)$$

- Not optimal!
- Can diverge if nonlinearities are large!
- Works surprisingly well even when all assumptions are violated!