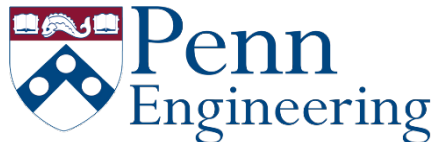


# Robotics

Estimation and Learning  
with Dan Lee

## Week 4. Localization

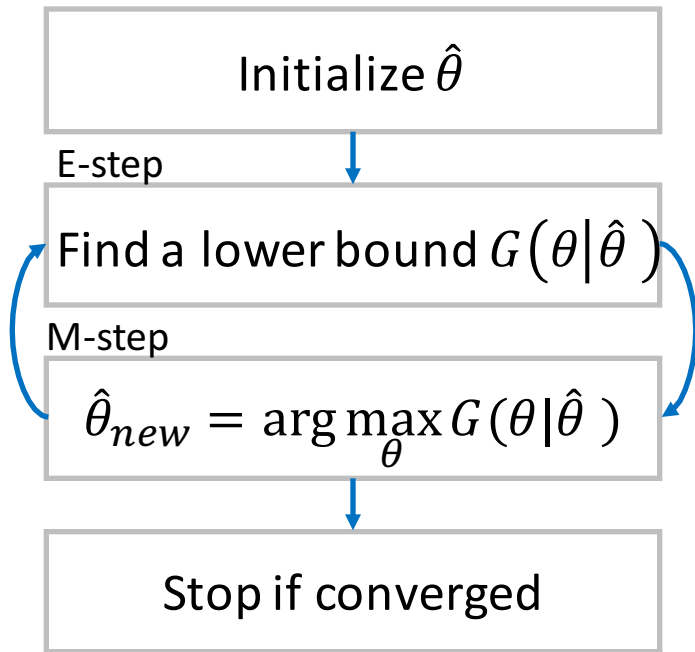
### 4.4 Iterative Closest Point (ICP) Algorithm



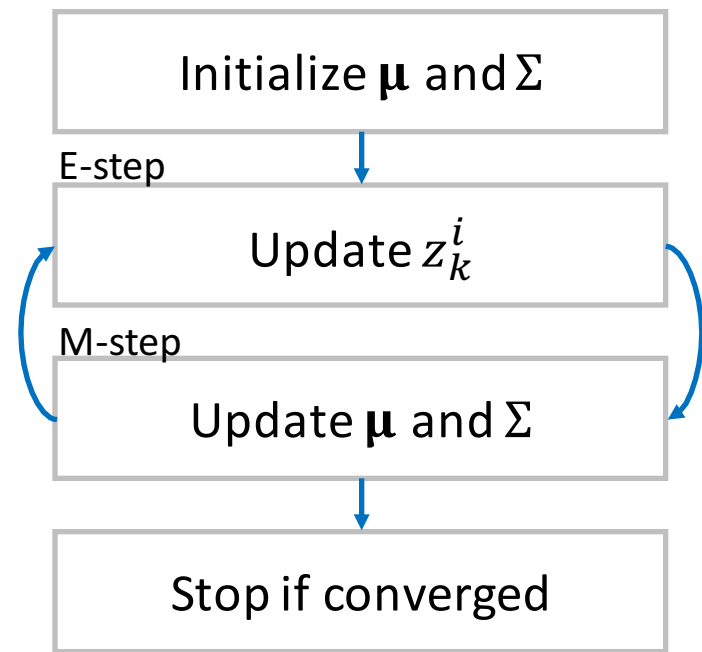
# Review: EM Algorithm

$$\arg \max_{\theta} F(X|\theta)$$

$$\arg \max_{\mu, \Sigma} \sum_{i=1}^N \ln \left\{ \frac{1}{K} \sum_{k=1}^K g_k(\mathbf{x}_i | \mu_k, \Sigma_k) \right\}$$



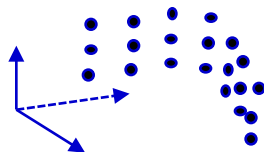
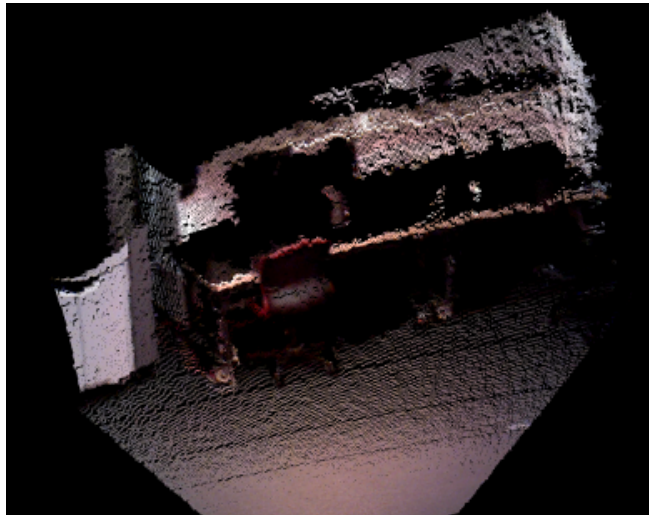
**General EM**



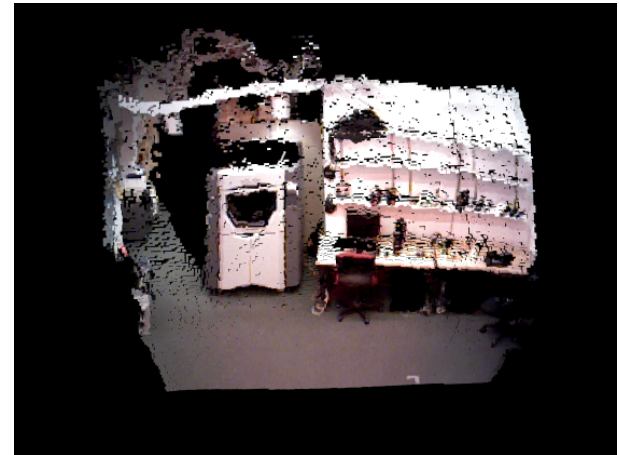
**EM for GMM**

# Review: 3D Map Representation

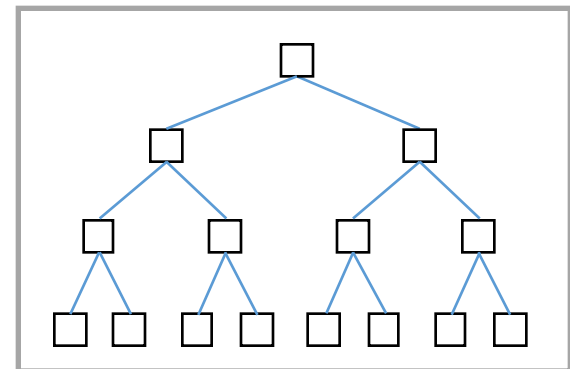
3D point cloud measurement



Map visualized in 3D



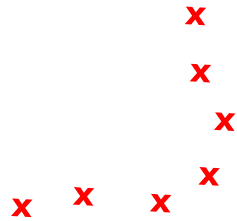
Implementation Example



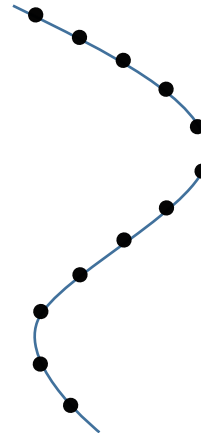
# ICP Algorithm

- Problem: Register two point sets  $X$  and  $Y$ .

Measurement (X)



Model (Y)



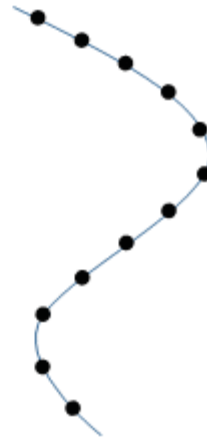
# ICP Algorithm

- Problem 1: Rotation and translation?

Measurement (X)



Model (Y)

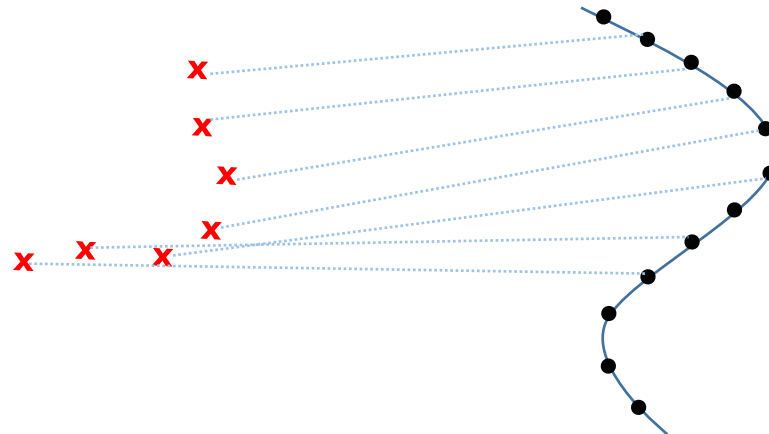


# ICP Algorithm

- Problem 2: Correspondences?

Measurement (X)

Model (Y)

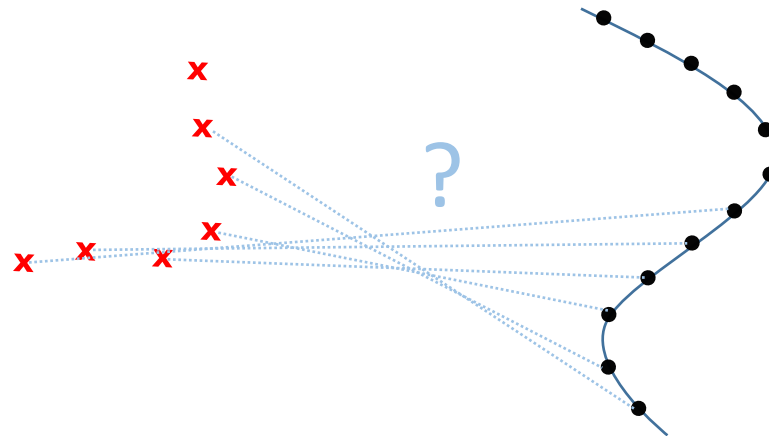


# ICP Algorithm

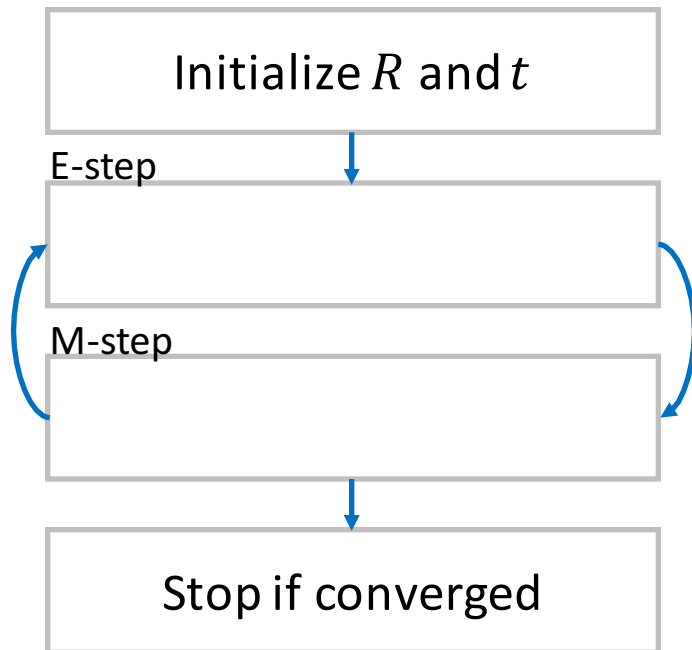
- Problem 2: Correspondence

Measurement (X)

Model (Y)

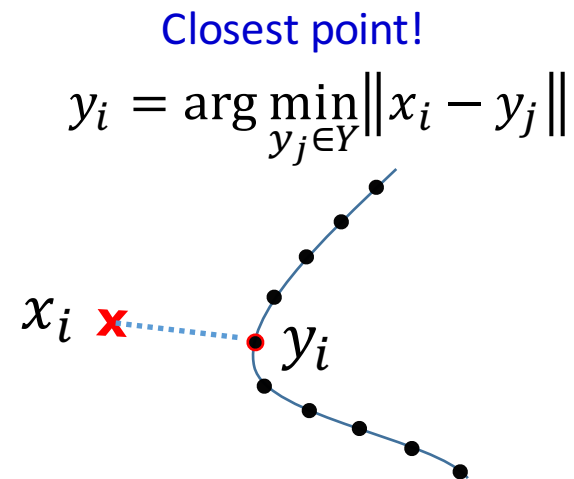
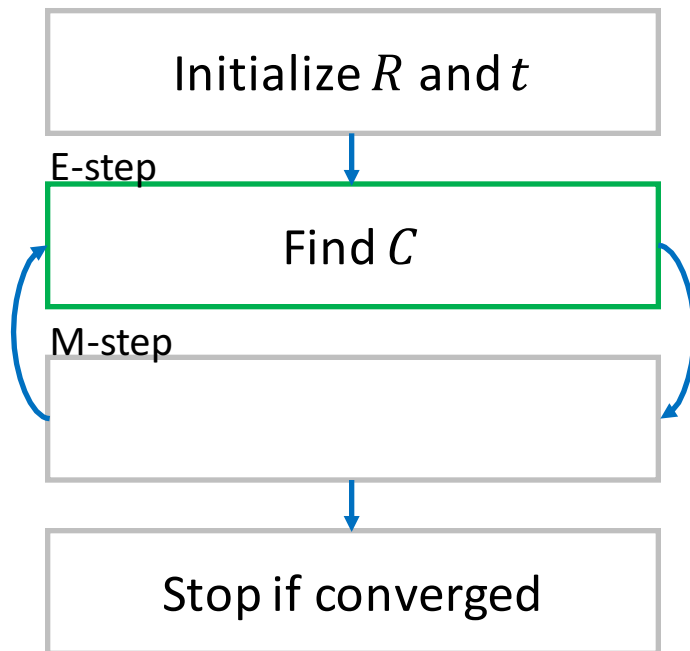


# ICP Algorithm

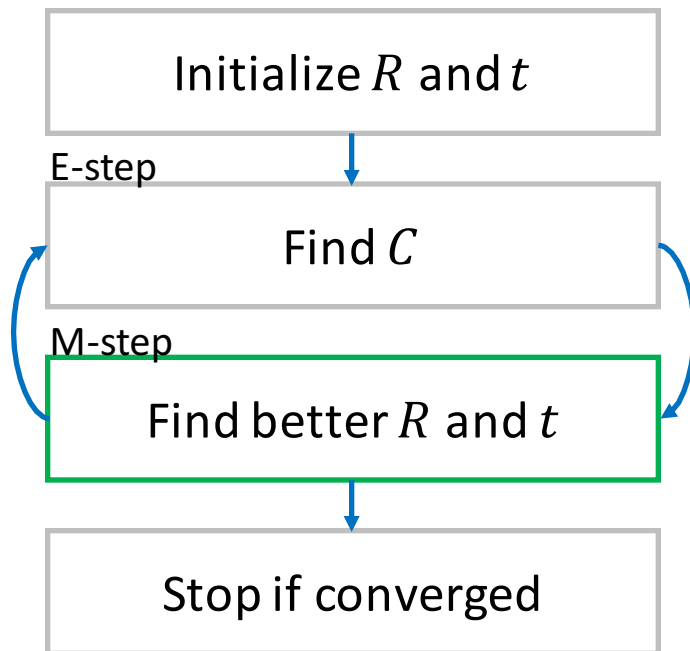




# ICP Algorithm



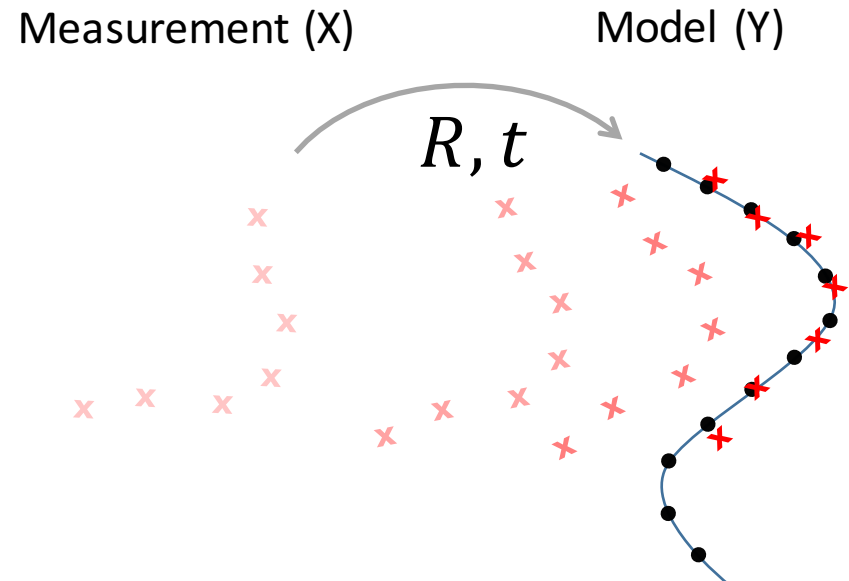
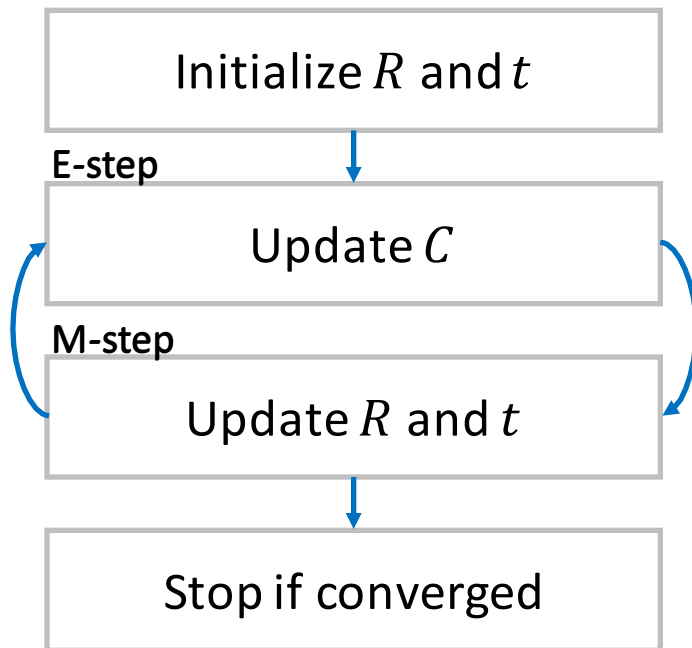
# ICP Algorithm



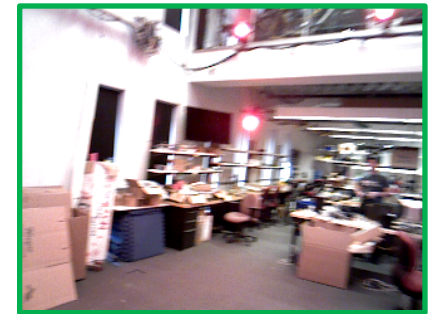
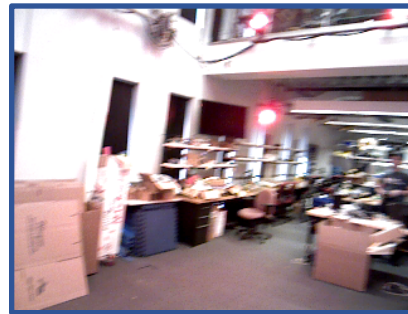
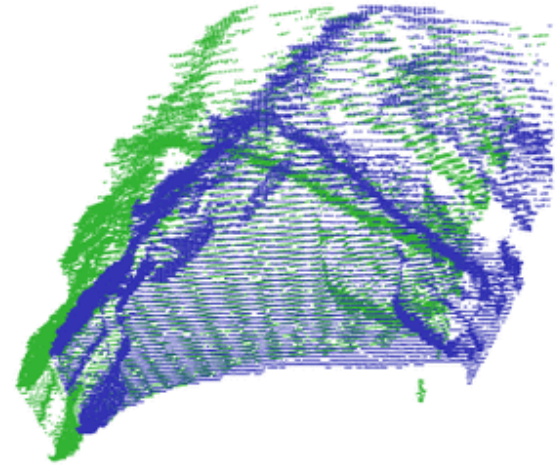
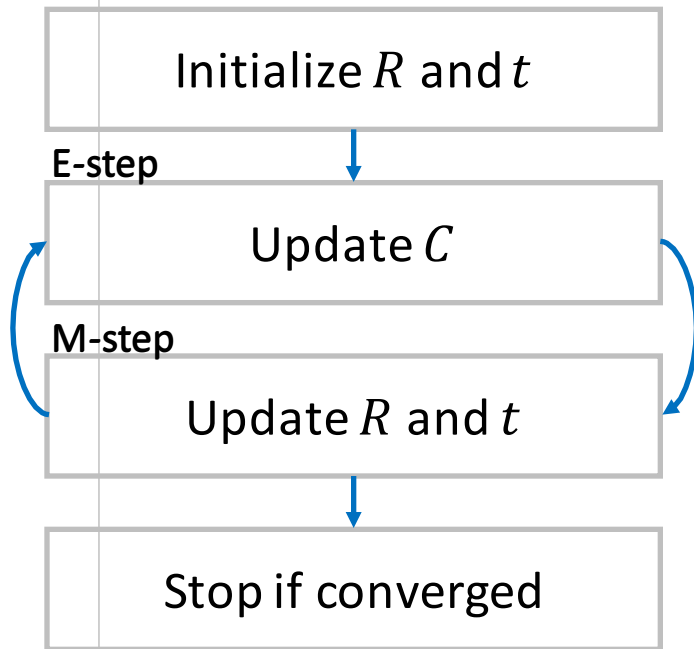
$$R, t = \arg \min \sum_{x_i, y_i \in C} \|d(x_i, y_i)\|^2$$

[SOLUTION] K. Arun, T. Huang, and S. Blostein, "Least-squares fitting of two 3D point set", *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 9(5), pp. 698–700, 1987.

# ICP Algorithm

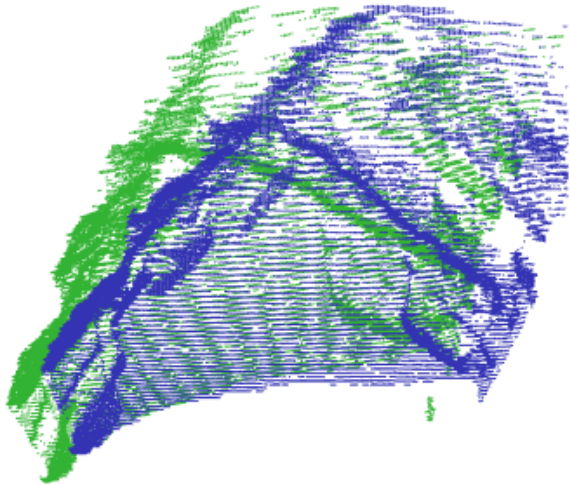


# ICP: Example



# ICP: Motion Increment

Raw measurements are in the local coordinate frame.



Registration gives the motion increment of the body w.r.t the model

