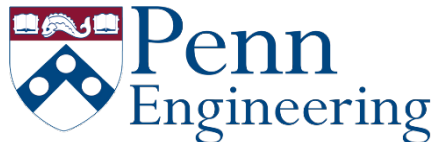# Robotics
Estimation and Learning
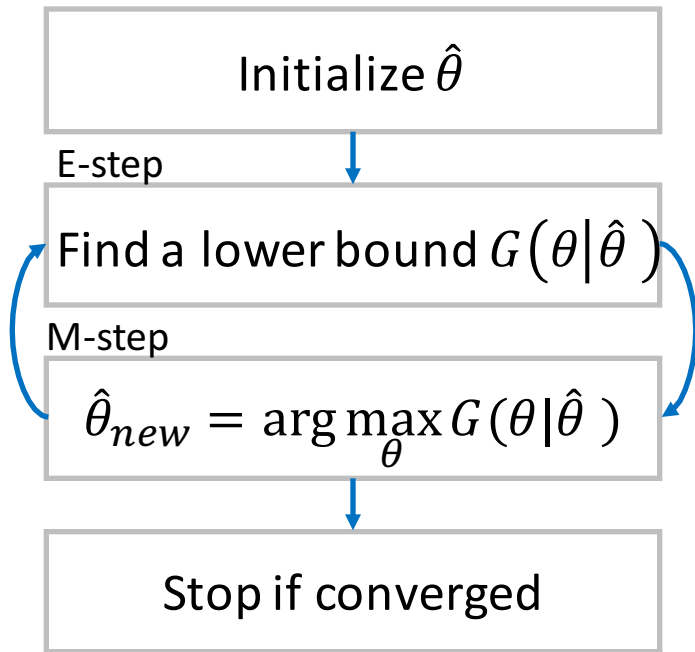## with Dan Lee

Week 4.
Localization

4.4 Iterative Closest Point (ICP) Algorithm
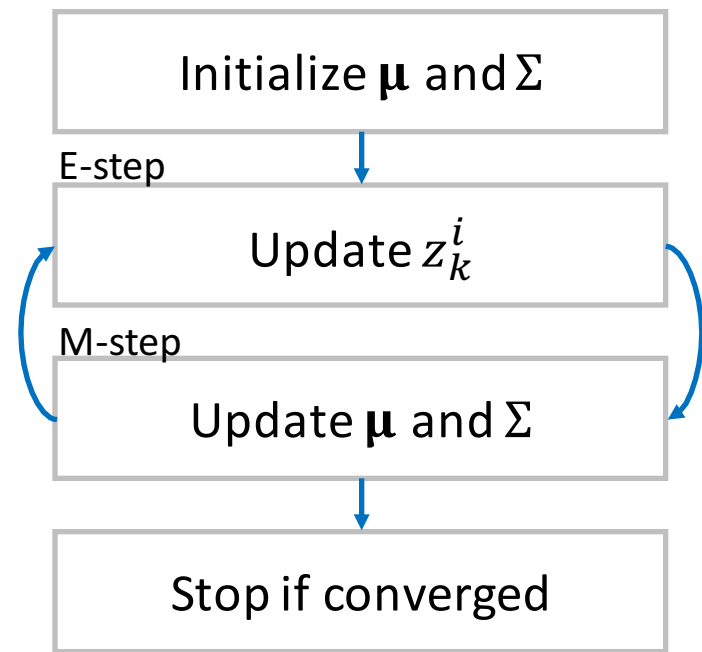
Review: EM Algorithm

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

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

Initialize $\hat{\theta}$

E-step

Find a lower bound $G(\theta|\hat{\theta})$

M-step

$\hat{\theta}_{new} = \arg\max_{\theta} G(\theta|\hat{\theta})$

Stop if converged

General EM

Initialize $\boldsymbol{\mu}$ and Σ

E-step

Update z_k^i

M-step
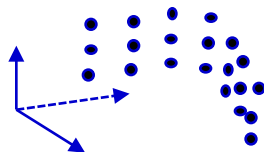
Update $\boldsymbol{\mu}$ and Σ
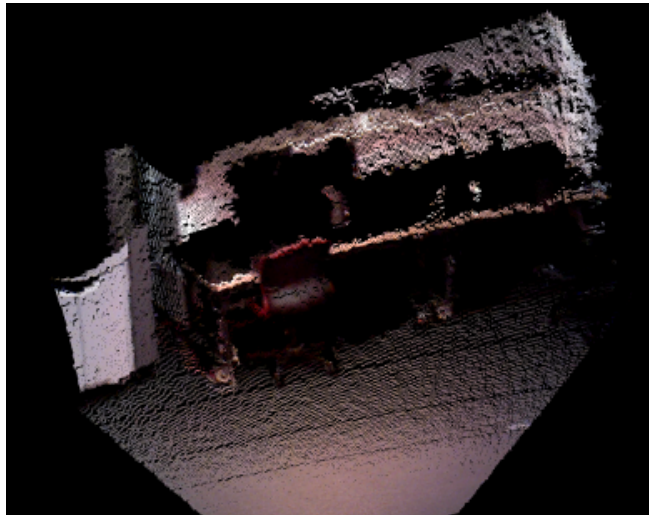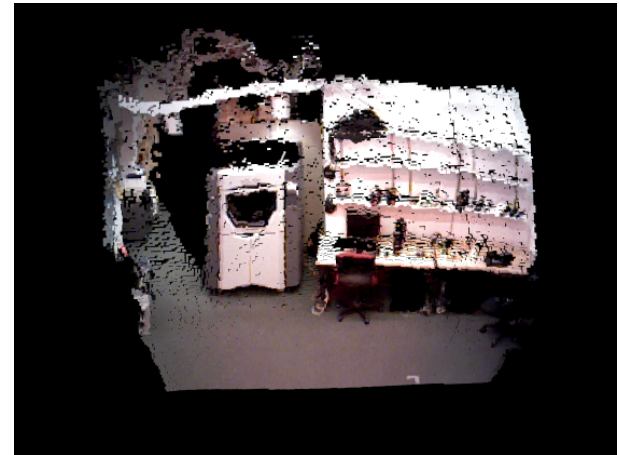
Stop if converged

EM for GMM

Review: 3D Map Representation
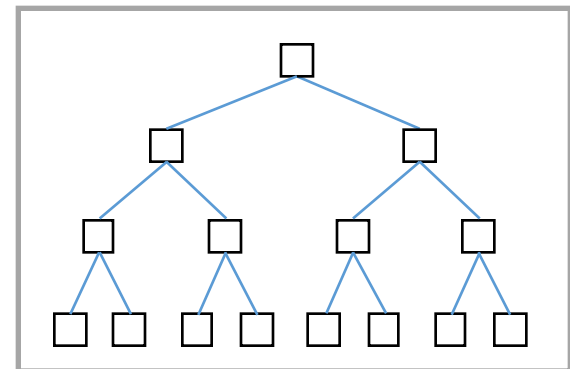
3D point cloud measurement

Map visualized in 3D
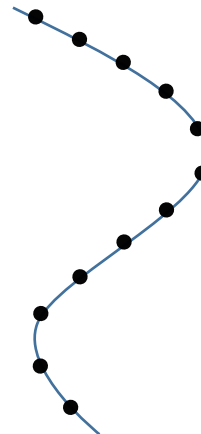
Implementation Example

ICP Algorithm

- Problem: <mark>Register two point sets X and Y.</mark>

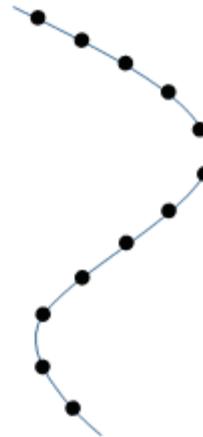Measurement (X)   Model (Y)

ICP Algorithm

- Problem 1: Rotation and translation?
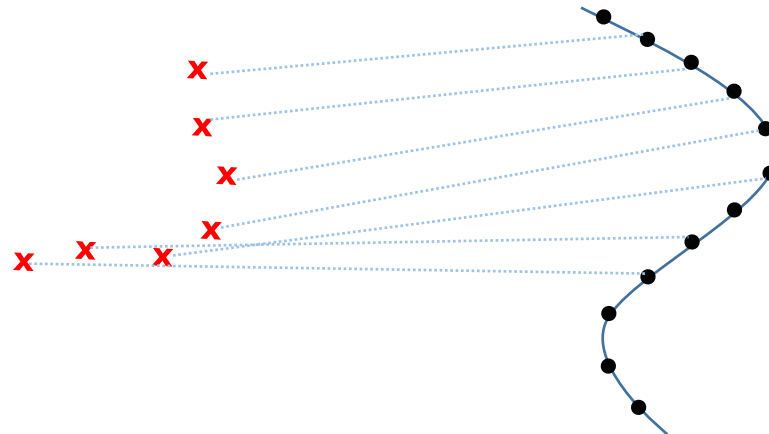
Measurement (X)   Model (Y)

ICP Algorithm

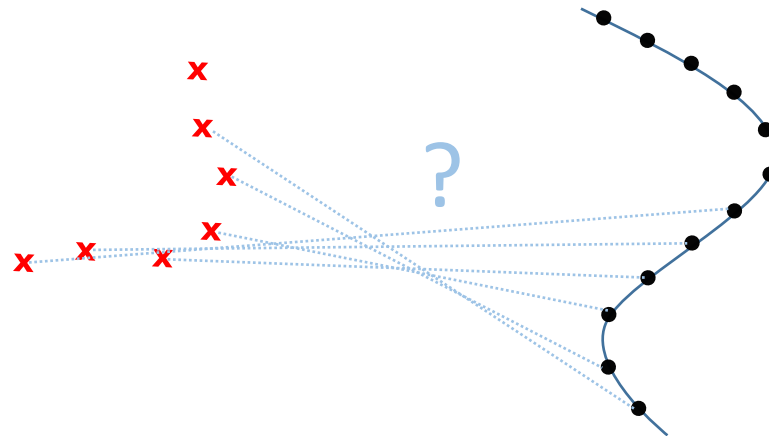- Problem 2: Correspondences?
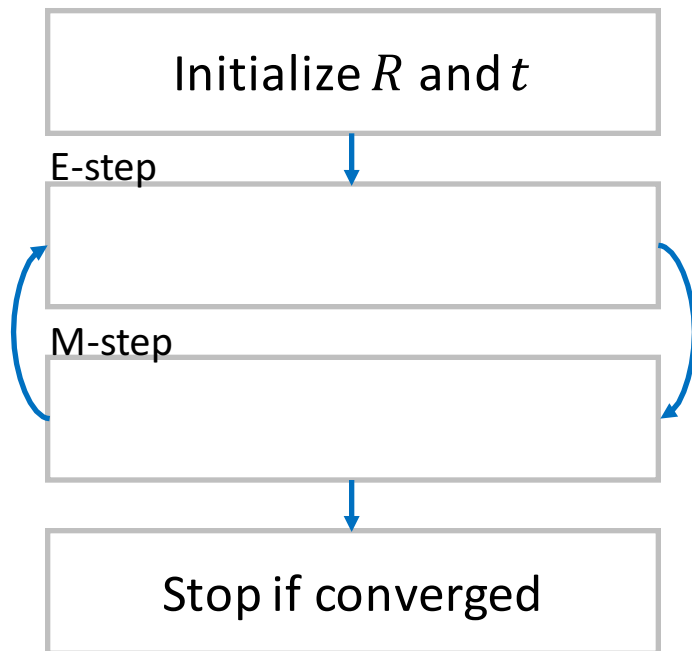
Measurement (X) Model (Y)

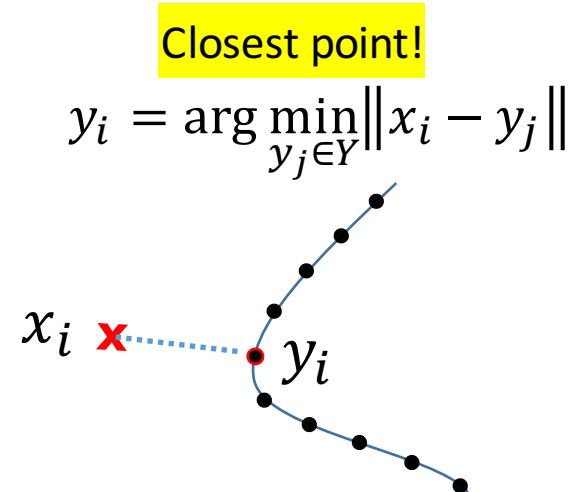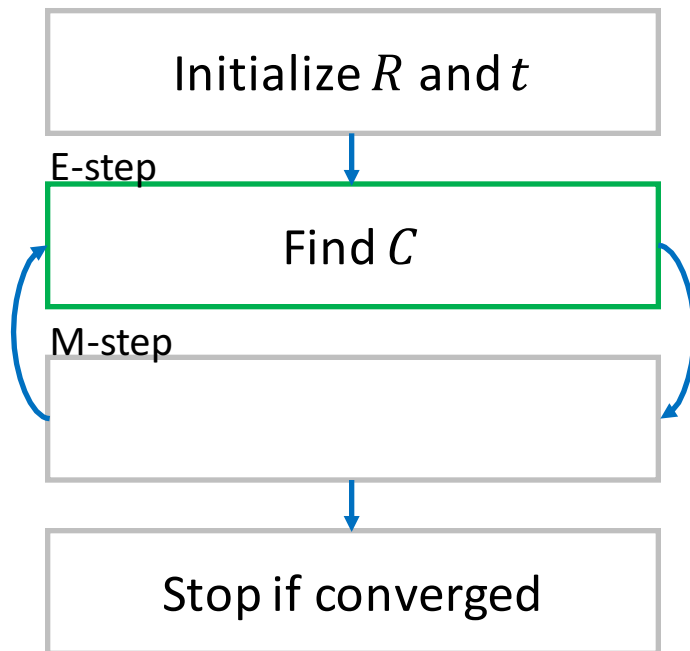# ICP Algorithm

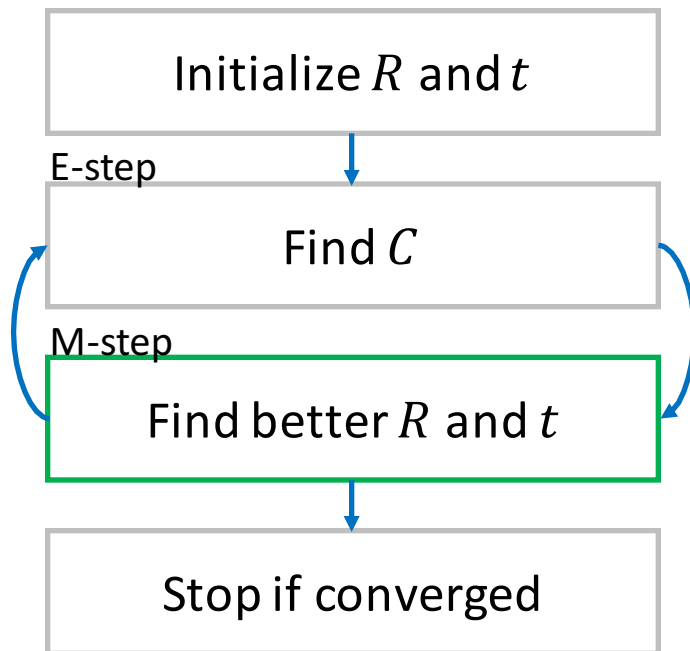- Problem 2: Correspondence

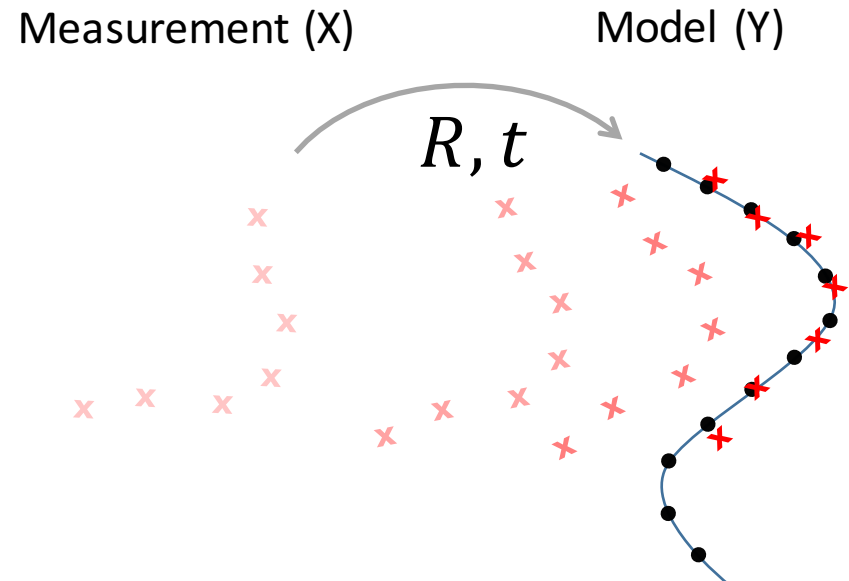Measurement (X)   Model (Y)

?

ICP Algorithm

Initialize R and t

E-step

M-step

Stop if converged

ICP Algorithm

Initialize R and t

E-step

Find C

M-step

Stop if converged

$$y_i = \arg\min_{y_j \in Y} \lVert x_i - y_j \rVert$$

x_i

y_i

ICP Algorithm

Initialize R and t

E-step

Find C

M-step

Find better R and t

Stop if converged

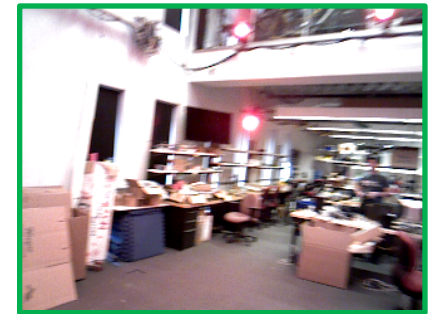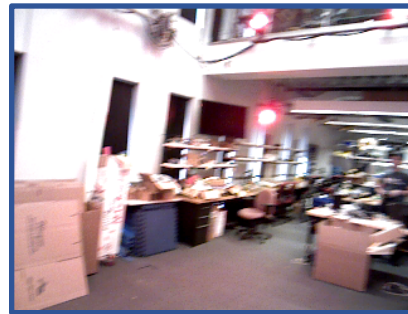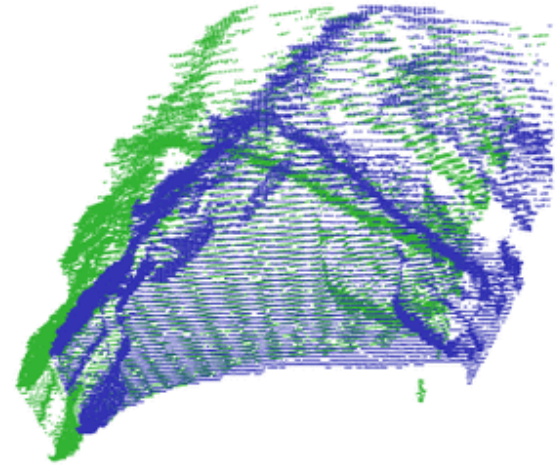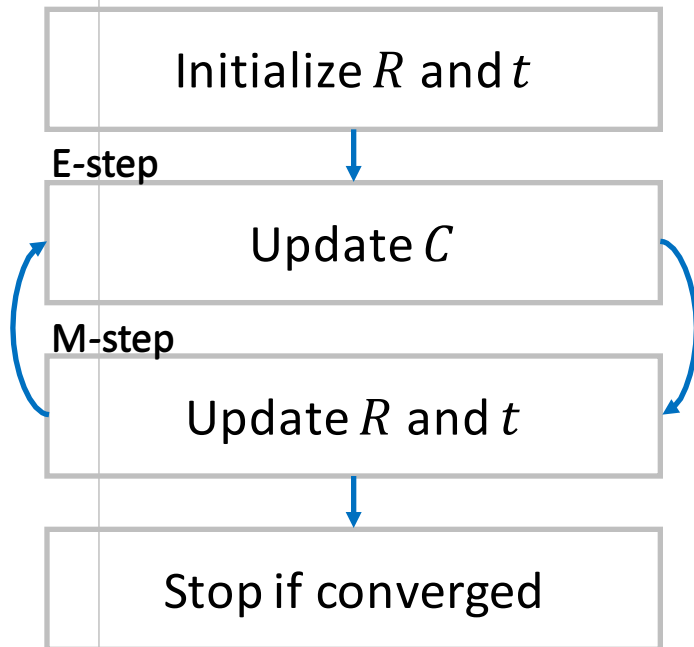$$R, t = \arg\min \sum_{x_i, y_i \in C} \|d(x_i, y_i)\|^2$$

[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

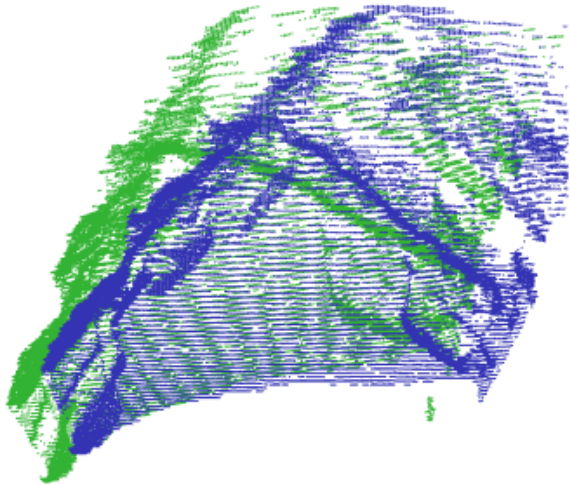Initialize R and t

E-step

Update C

M-step

Update R and t

Stop if converged

Measurement (X)

Model (Y)

R, t

ICP: Example

Initialize R and t

E-step

Update C

M-step

Update R and t

Stop if converged
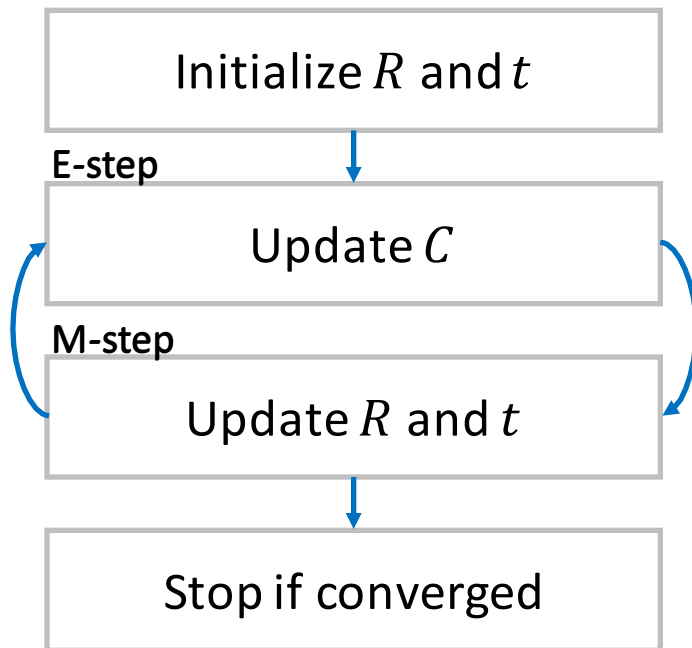
ICP: Motion Increment

Raw measurements are
in the local coordinate frame.

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