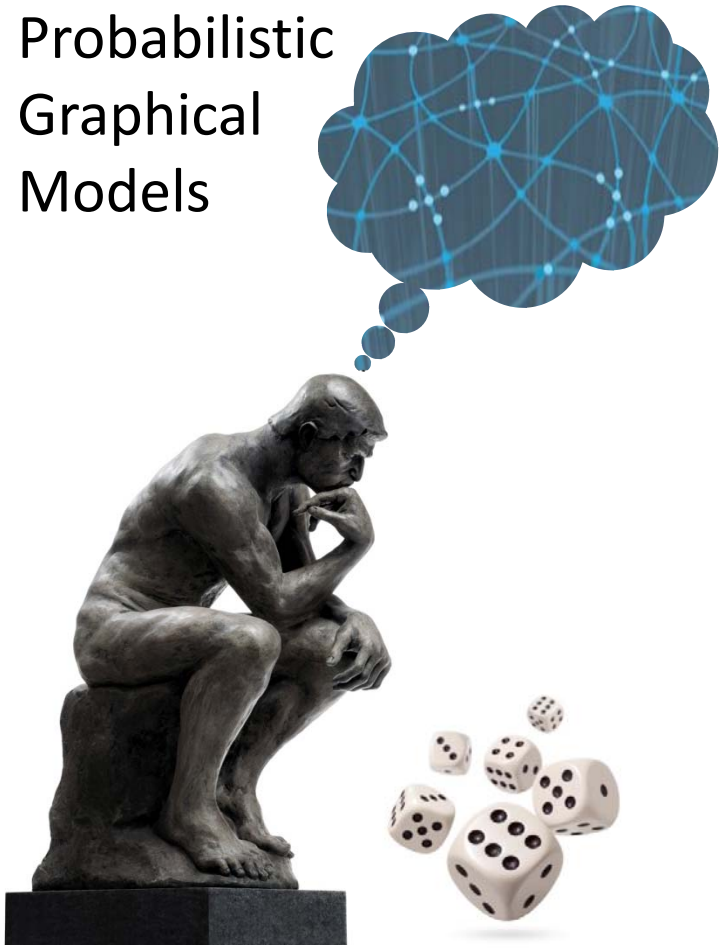
Probabilistic Graphical Models

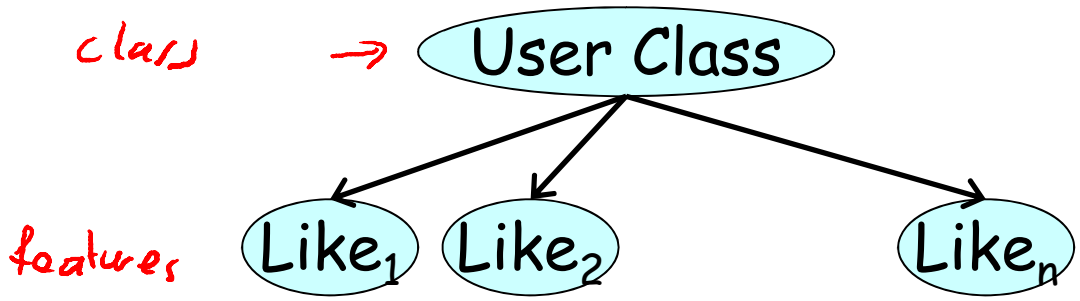


Learning

Incomplete Data

# Learning with Latent Variables

# Discovering User Clusters




segmenting users

J. Breese

# MSNBC Story clusters

Readers of commerce and technology stories (36%):

- E-mail delivery isn't exactly guaranteed
- Should you buy a DVD player?
- Price low, demand high for Nintendo

Sports Readers (19%):

- Umps refusing to work is the right thing
- Cowboys are reborn in win over eagles
- Did Orioles spend money wisely?

Readers of top promoted stories (29%):

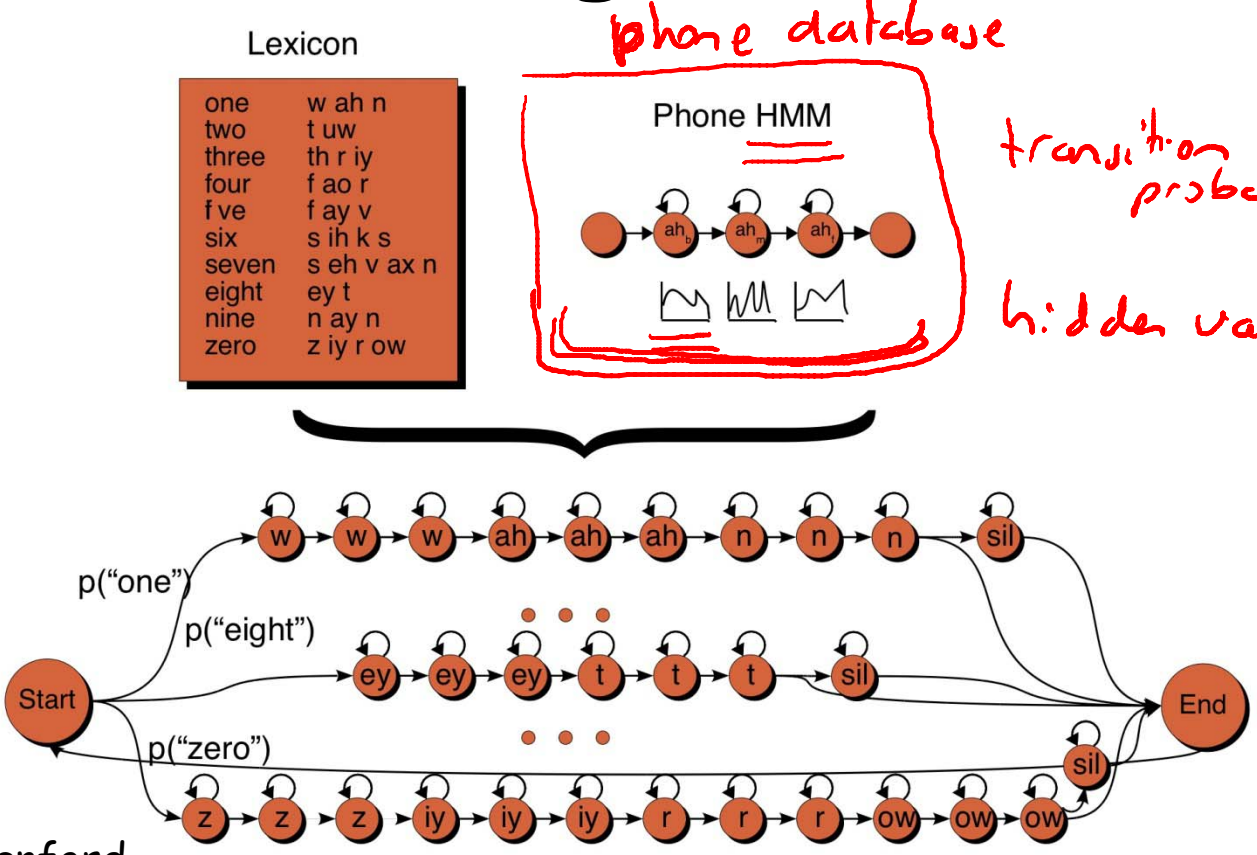
- 757 Crashes At Sea
- Israel, Palestinians Agree To Direct Talks
- Fuhrman Pleads Innocent To Perjury

Readers of "Softer" News (12%):

- The truth about what things cost
- Fuhrman Pleads Innocent To Perjury
- Real Astrology

Daphne Koller

# Speech Recognition HMM




Dan Jurafsky, Stanford

Daphne Koller

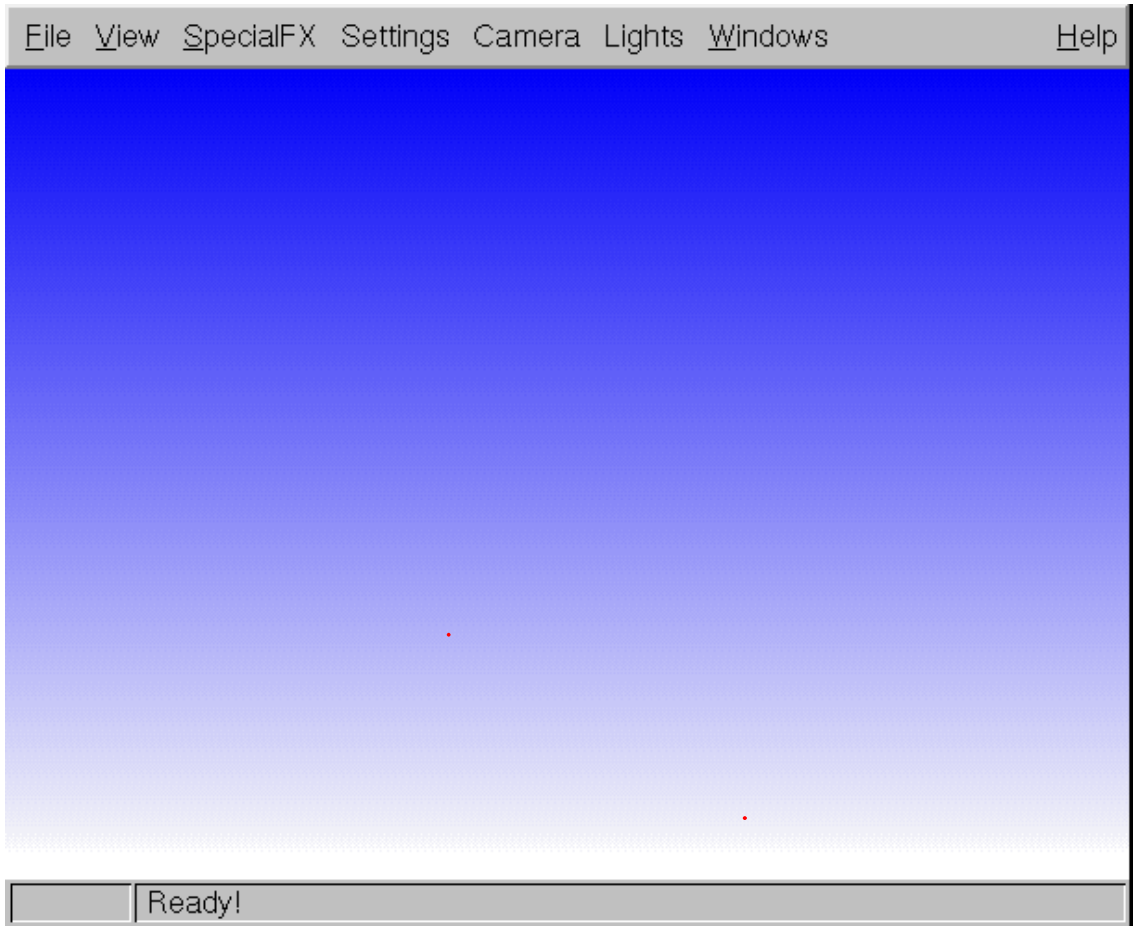
# 3D Robot Mapping

- Input: Point cloud from laser range finder obtained by moving robot
- Output: 3D planar map of environment

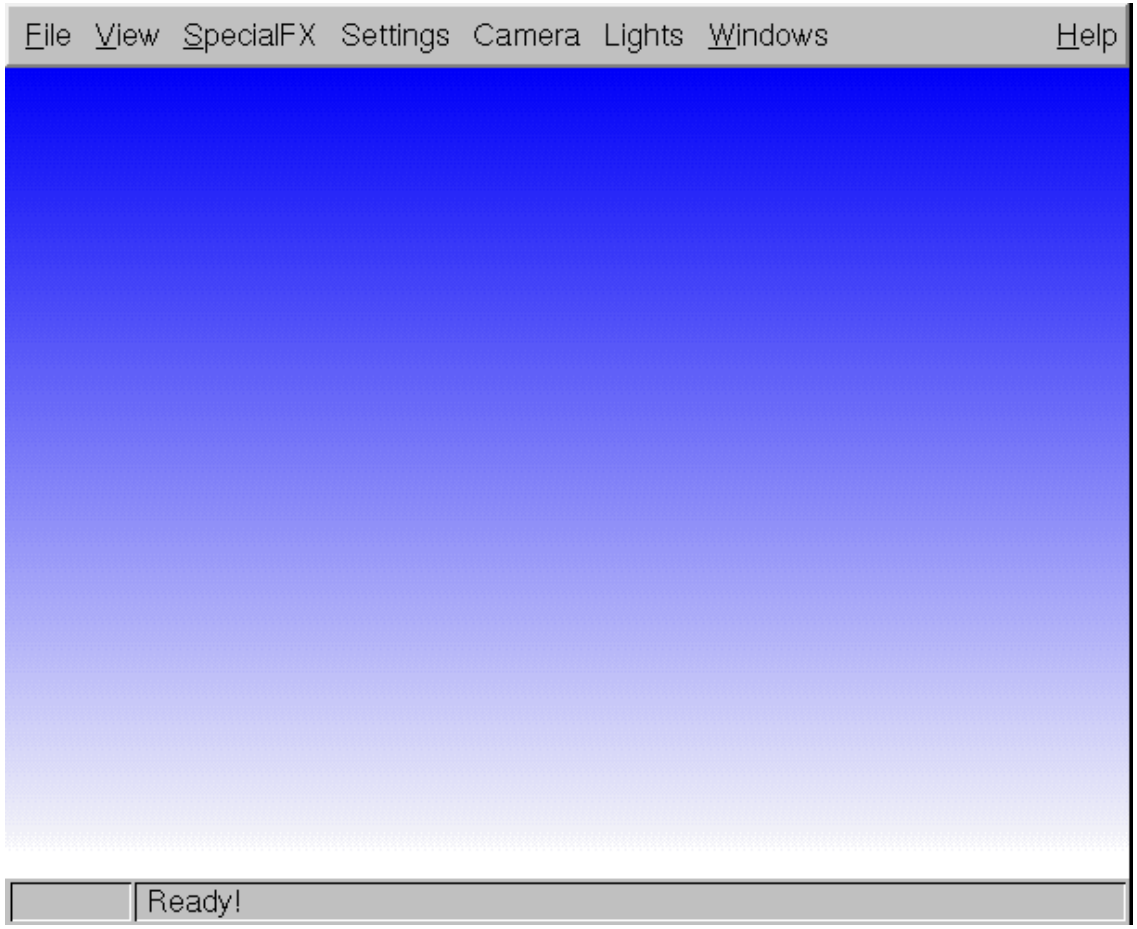
- Parameters: Location & angle of walls (planes)
- Latent variables: Assignment of points to walls

association

Thrun, Martin, Liu, Haehnel, Emery-Montemerlo, Chakrabarti, Burgard,
IEEE Transactions on Robotics, 2004

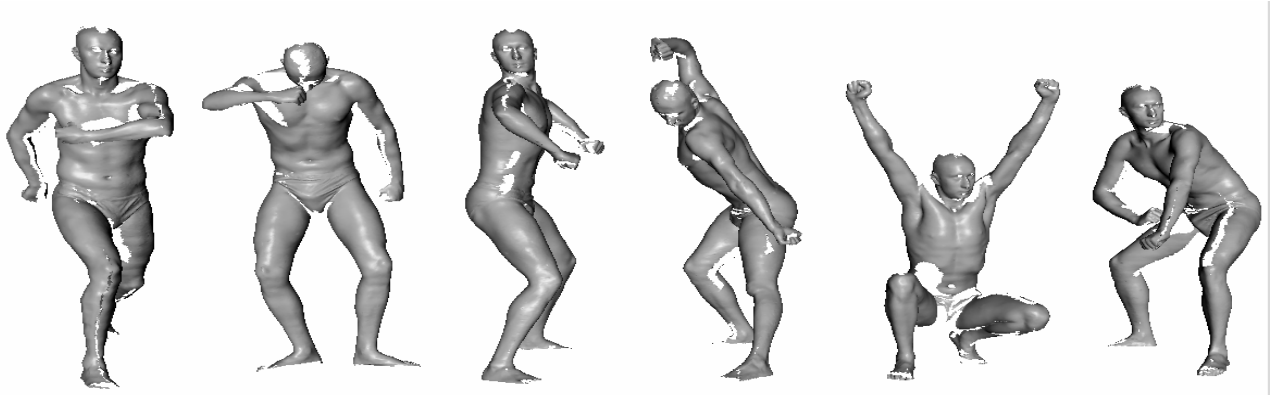


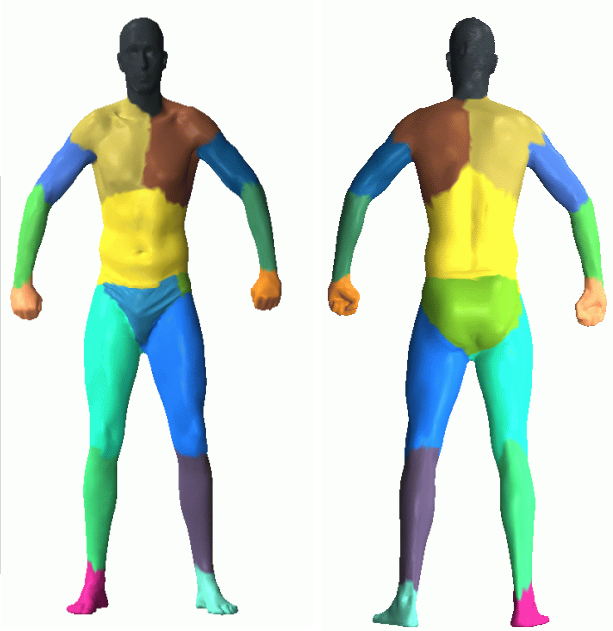

Thrun, Martin, Liu, Haehnel, Emery-Montemerlo, Chakrabarti, Burgard,
IEEE Transactions on Robotics, 2004




Thrun, Martin, Liu, Haehnel, Emery-Montemerlo, Chakrabarti, Burgard,
IEEE Transactions on Robotics, 2004

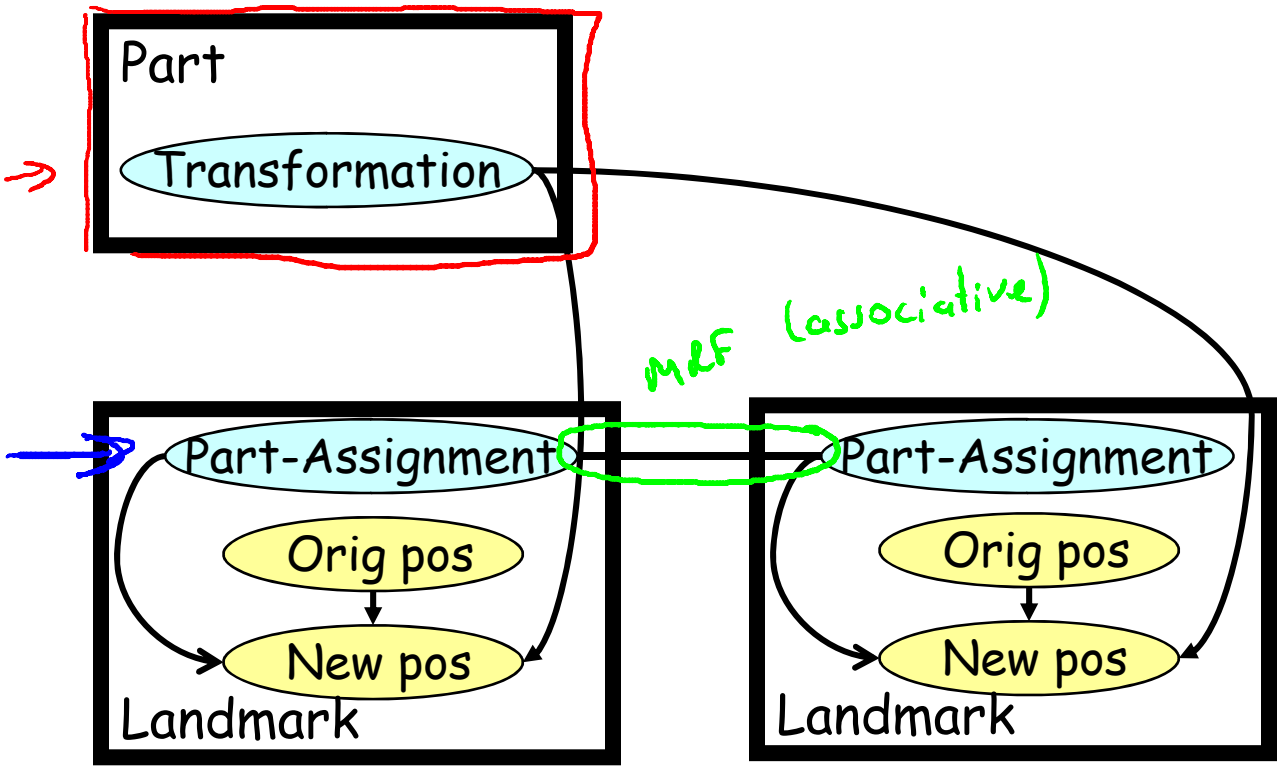
# Body Parts from Point Cloud Scans

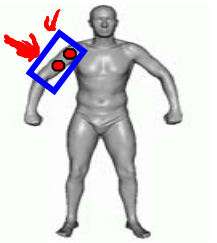


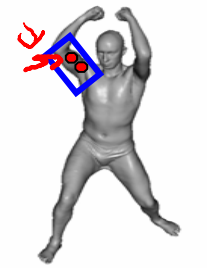


Anguelov, Koller, Pang, Srinivasan, Thrun UAI 2004

# Collective Clustering Model





Anguelov, Koller, Pang, Srinivasan, Thrun UAI 2004

Anguelov, Koller, Pang, Srinivasan, Thrun UAI 2004

# Helicopter Demo Alignment

- Input: Multiple sample trajectories by different pilots flying same sequence
- Output:
  - Aligned trajectories
  - Model of "template" trajectory

Coates, Abbeel, Ng, ICML 2008

# Graphical model

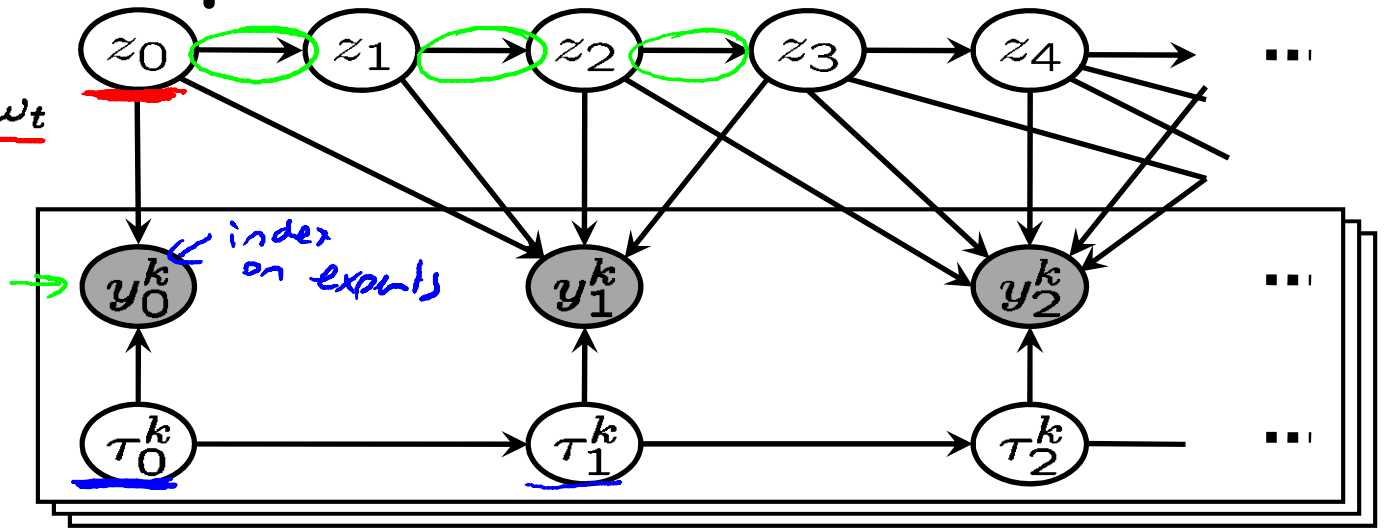
Intended trajectory

$z_{t+1} = f(z_t) + \omega_t$

Expert demonstrations

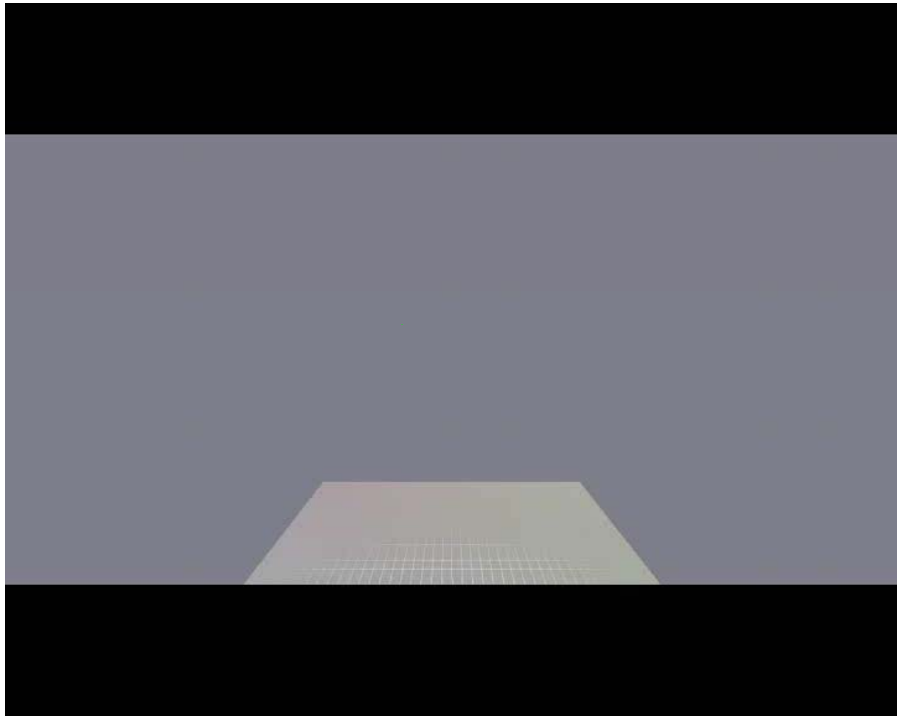
$y_j = z_{\tau_j} + \nu_j$

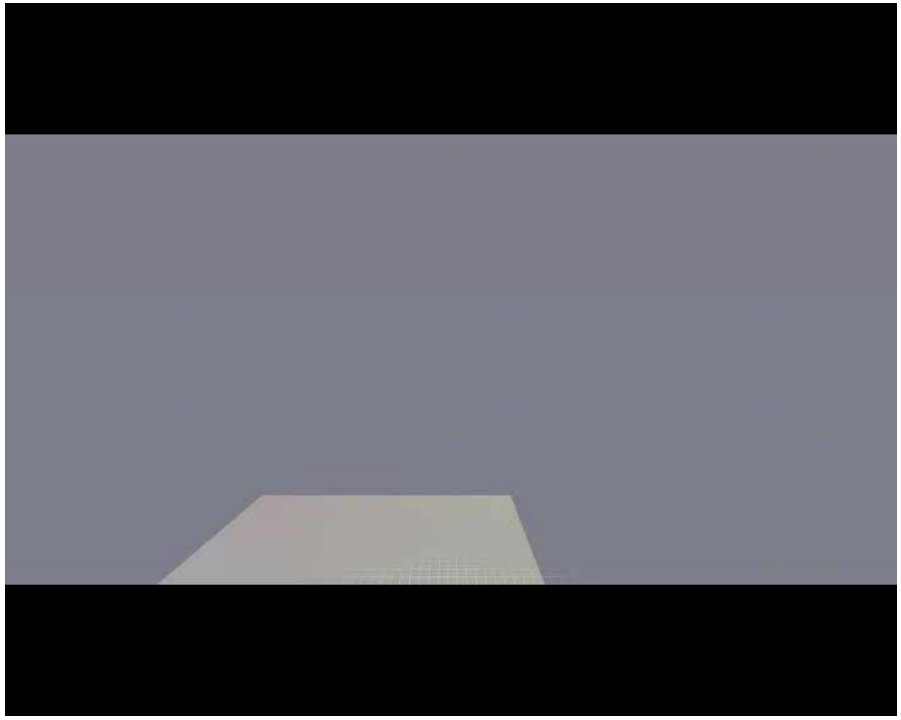
Time indices




Coates, Abbeel, Ng, ICML 2008

# All Expert Demos





Coates, Abbeel, Ng, ICML 2008

# Picking Latent Variable Cardinality

- If we use likelihood for evaluation, more values is always better
- Can use score that penalizes complexity
  - BIC – tends to underfit
  - Extensions of BDe to incomplete data (approximations)
- Can use metrics of cluster coherence to decide whether to add/remove clusters
- Bayesian methods (Dirichlet processes) can average over different cardinalities (MCMC) distribution over cardinality

# Summary

- Latent variables are perhaps the most common scenario for incomplete data
  - often a critical component in constructing models for richly structured domains
- Latent variables satisfy MAR, so can use EM
- Serious issues with unidentifiability & multiple optima necessitate good initialization
- Picking variable cardinality is a key question