Learning Grasp Phases from Human Demonstrations

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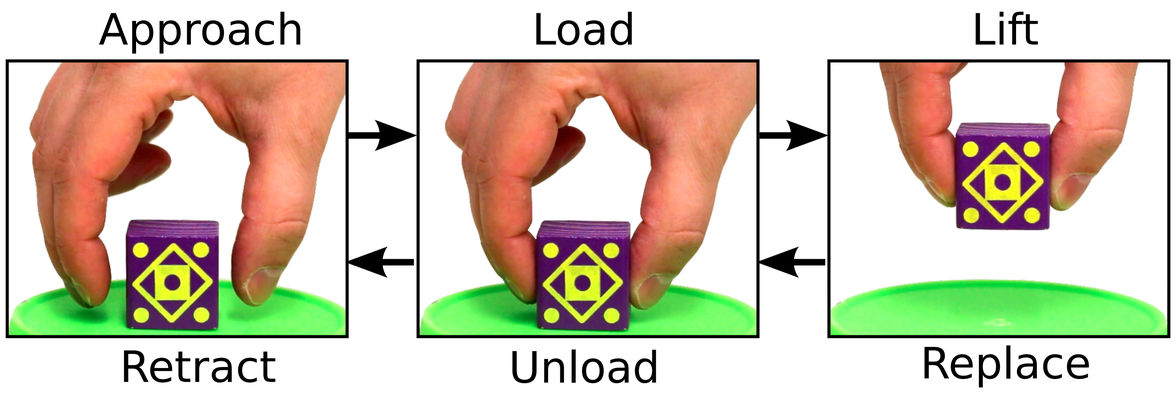
Introduction

- Manipulation tasks can usually be decomposed into phases
- Phase transitions correspond to making and breaking of contacts
- Effects of actions depend on the current phase



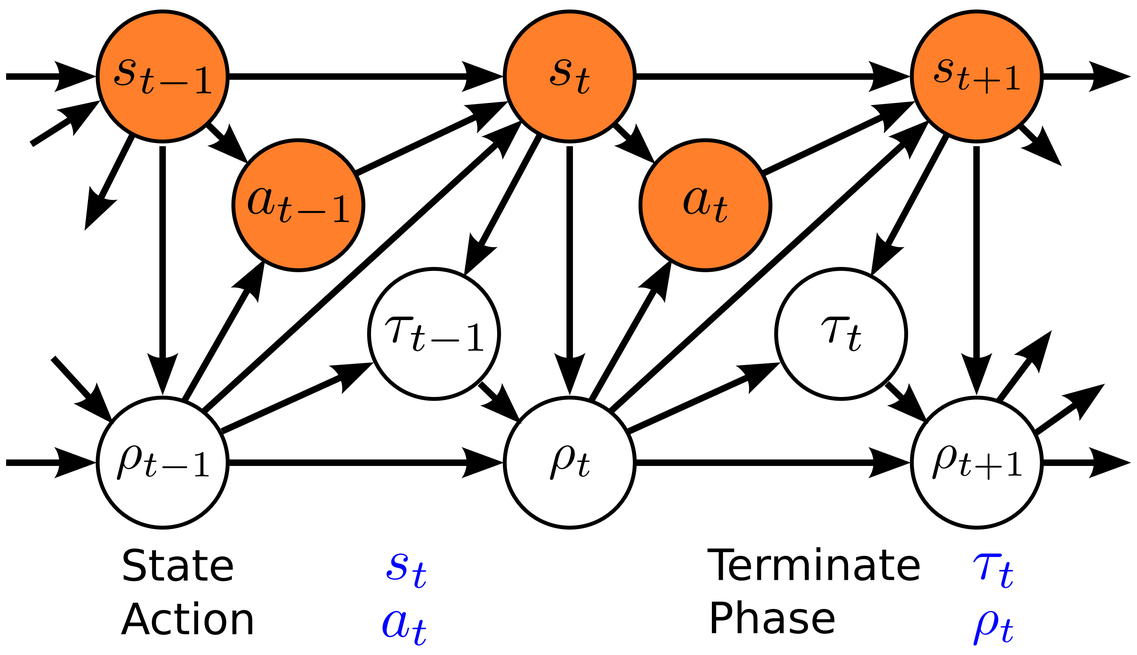
- Phase decomposition can be used to create robust controllers

- Humans perform different actions depending on the phase
- Learn task phases of manipulations from human demonstrations

[Johansson and Flanagan NatRevNeuro 2009] [Romano et al. TRO 2011]

Model of Phases

- Model phases using a dynamic Bayesian network
- States and actions are observed variables (orange circles)
- Phases are latent variables (white circles)



Model Components

- Model phases' state transitions as linear systems and controllers

$$\boldsymbol{s}_{t+1} = \boldsymbol{A}_\rho \boldsymbol{s}_t + \boldsymbol{B}_\rho \boldsymbol{a}_t + \boldsymbol{\epsilon}_\rho \qquad \boldsymbol{a}_t = \boldsymbol{C}_\rho \boldsymbol{s}_t + \boldsymbol{\varepsilon}_\rho$$

- The phase can only change when the previous phase terminates
- Phase terminations are modeled by sigmoidal functions

$$p(\tau_{t-1} = 1 | \boldsymbol{s}_t, \rho_{t-1} = i) = (1 + \exp(-\boldsymbol{\omega}_i^T \boldsymbol{\phi}(\boldsymbol{s}_t))^{-1}$$

- Otherwise, the distribution over next phases is given by:

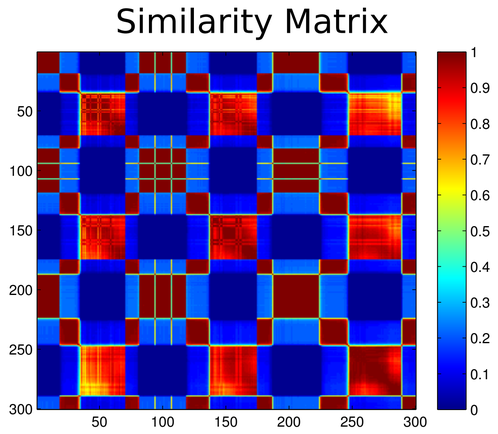
$$p(\rho_t = i | \boldsymbol{s}_t, \tau_{t-1} = 1) = \frac{\exp(-\boldsymbol{w}_i^T \boldsymbol{\phi}(\boldsymbol{s}_t))}{\sum_j \exp(-\boldsymbol{w}_j^T \boldsymbol{\phi}(\boldsymbol{s}_t))}$$

- Model parameters are learned using EM algorithm
- Use message passing to compute latent variable distributions

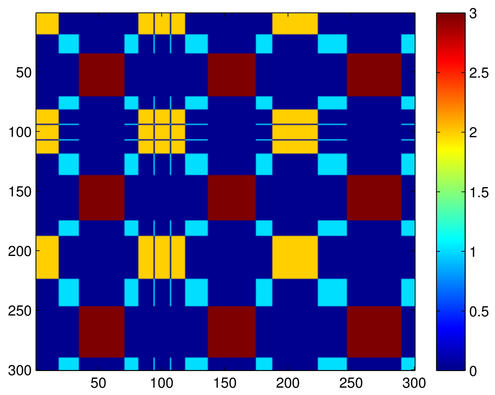
Initialization Based on Contacts

- Expectation Maximization algorithm converges to local optimum
- Need a suitable set of initial parameters for model
- Compute similarty between samples' contact points distributions
- Cluster samples using spectral clustering

Contact Kernel Similarity Matrix



Resulting Clusters

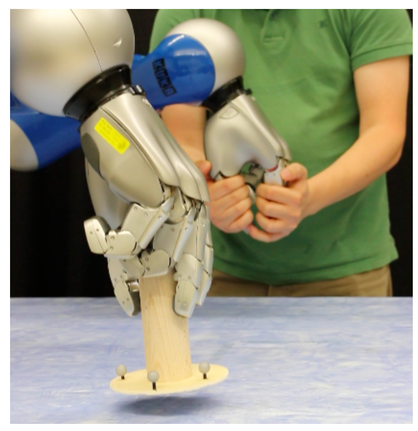


- Clusters coarsely capture structure of phases over time
- Initialize model parameters according to each cluster's samples

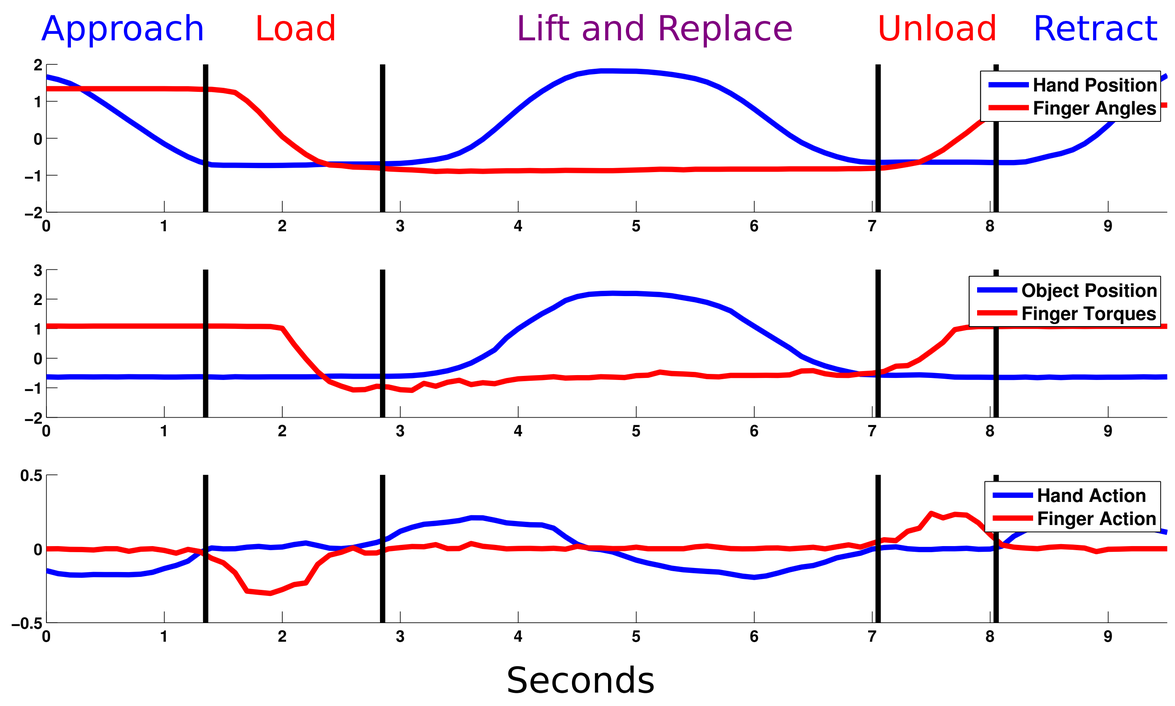
[Chebotar et al. IROS 2014] [Kroemer and Peters IROS 2014]

Learning Grasp Phases

- Demonstrate grasps using teleoperation
- Apply PCA to recorded data
- Learn model from ten demonstrations
- Use model to segment test data



- Example of three-phase segmentation:



Conclusion

- Proposed a probabilistic model for representing grasping phases
- Demonstations were used to help decompose task into phases
- Successfully tested proposed approach on real robot data

Future Work

- Investigate generalizing model between different objects
- Use model of phases to learn controllers for grasping

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