Understanding Manifolds of Grasping Actions

Javier Romero **Thomas Feix**[1] **Hedvig Kjellström**
Danica Kragic

May 3, 2010

CAS-CVAP/KTH

[1]Otto Bock HealthCare

Grasp Dimensionality

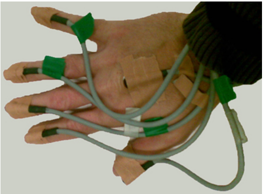
- Effective dimensionality of grasping hand poses is low [1]
- Using a low dimensional representation of grasps sequences is useful
    - Measuring similarities is simpler
    - Modeling hand dynamics in a lower dimensional space is simpler
    - Such a dense representation avoids unnatural/impossible poses

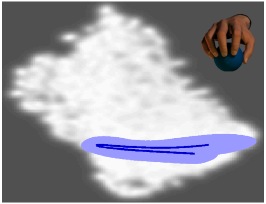
M. Santello et al.
Postural hand synergies for tool use.
In *The Journal of Neuroscience*, 1998.

Methodology

1. Record data from different subjects performing a wide range of grasps [1]
2. Map the data to a lower dimensional space
3. Use it!
    - Model different grasp types in the low dimensional space
    - Create a data-driven grasp taxonomy
    - Compute dynamic models
    - Generate new grasps

T. Feix et al.
A comprehensive grasp taxonomy.
In *RSS Workshop on Understanding the Human Hand for Advancing Robotic Manipulation, Poster Presentation*, 2009.



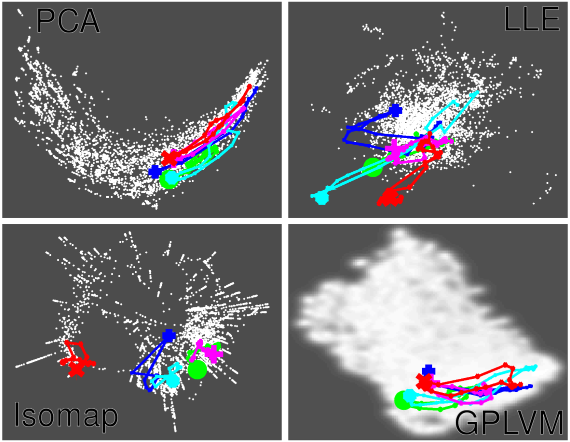


Data

- Polhemus magnetic tracker with 6 sensors [2]
- Orientation (quaternion 4D) and position (xyz 3D) for each sensor
- 5 subjects, 31 grasps with 2 trials per grasp (first used for testing and second for training)
- 30 samples per grasp used
- Data used: relative position/orientation of fingertips wrt the wrist

[2] Thanks to LMU university

Dimensionality reduction methods

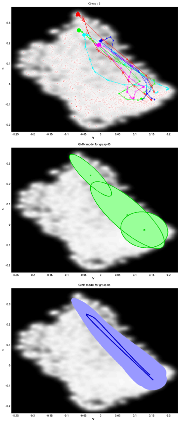


Gaussian Process Latent Variable Models

- Each dimension in the high dimensional space is mapped by a non-linear Gaussian Process
- GPLVM optimizes the mapping parameters and the latent space iteratively to minimize the reconstruction error
- Additional priors can be introduced in the optimization process
  - Discriminative priors favor interclass separation
  - Dynamic priors favor coherent sequential data
- However, none of these priors were used here in order to explore the natural separability and time continuity of the data

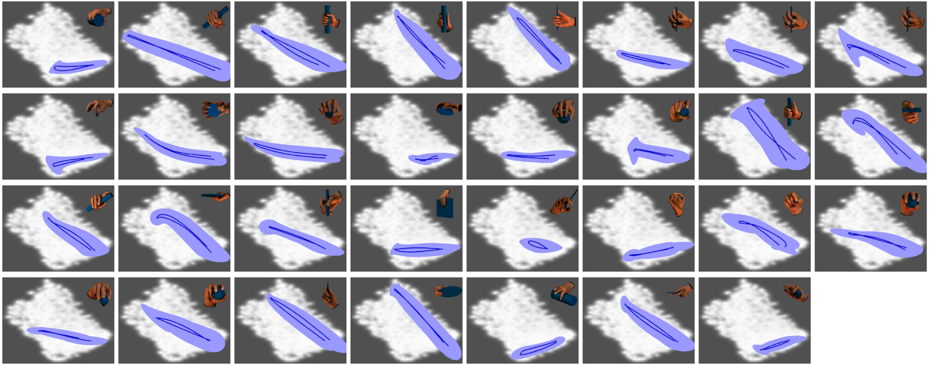
GMM/GMR grasp model

- Goal: Grasp type model that contains temporal information
- Method [1]:
  - Fit a mixture of gaussians (GMM) to each grasp type
  - Apply Gaussian mixture regression (GMR) taking into account the timestamp of each data point



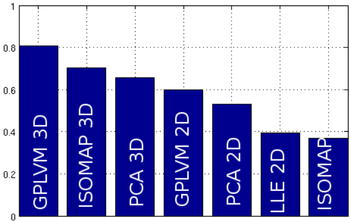
S. Calinon et al.
On learning, representing and generalizing a task in a humanoid robot.
IEEE Transactions on Systems, Man and Cybernetics, Part B, 2007.

GMR results



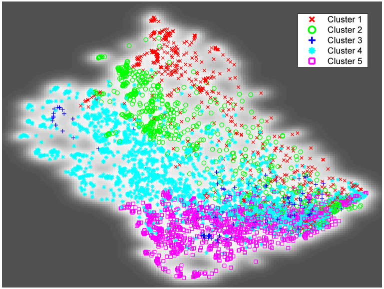
Quantitative evaluation

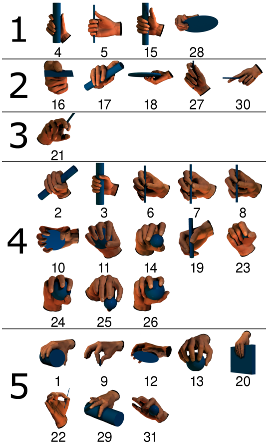
- Evaluation of the discriminative power of the latent space
- Each GMR model is used to classify grasping sequences not included in the training set
- GPLVM outperforms the rest of dimensionality reduction methods with same dimensionality
- Classification error is lower for 3D latent spaces than for 2D



Data-Driven Taxonomy

- Create a similarity matrix based on the GMR grasp models
- Cluster the grasp types based on that similarity matrix





Current Work

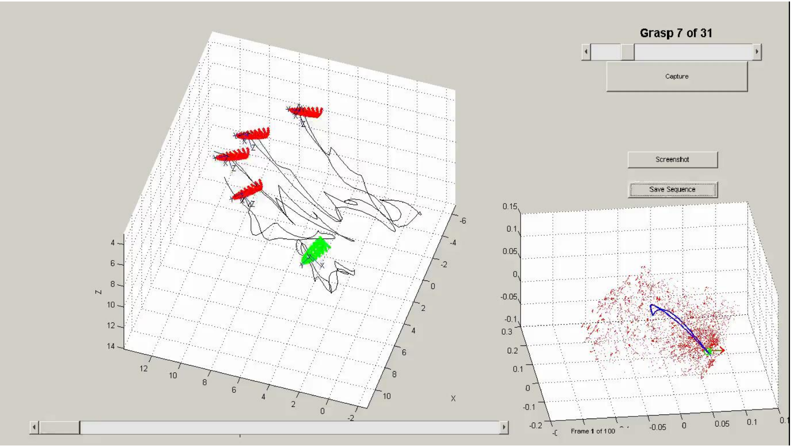
- For our Hand Pose Estimation system [1]
  - Replace Euclidean distance in joint space by distance in low dimensional space
  - Extract dynamic hand behaviour from the low dimensional space
- Generate grasp behaviour subject to kinematic constraints
- Improve Data-driven Grasp Taxonomy

J. Romero et al.
Hands in action, real-time 3d reconstruction of hands in interaction with objects.
In *ICRA 09:00-09:15, Paper TuA12.3*, 2010.

Conclusions

- Modeling grasping actions in latent spaces is useful
- The best results were achieved with GPLVM

Thanks!


Grasp 7 of 31
Capture
Screenshot
Save Sequence
Frame 1 of 100