



JHU vision lab

# Identification of Hybrid Models Via Generalized Principal Component Analysis

Workshop @ CDC 2007

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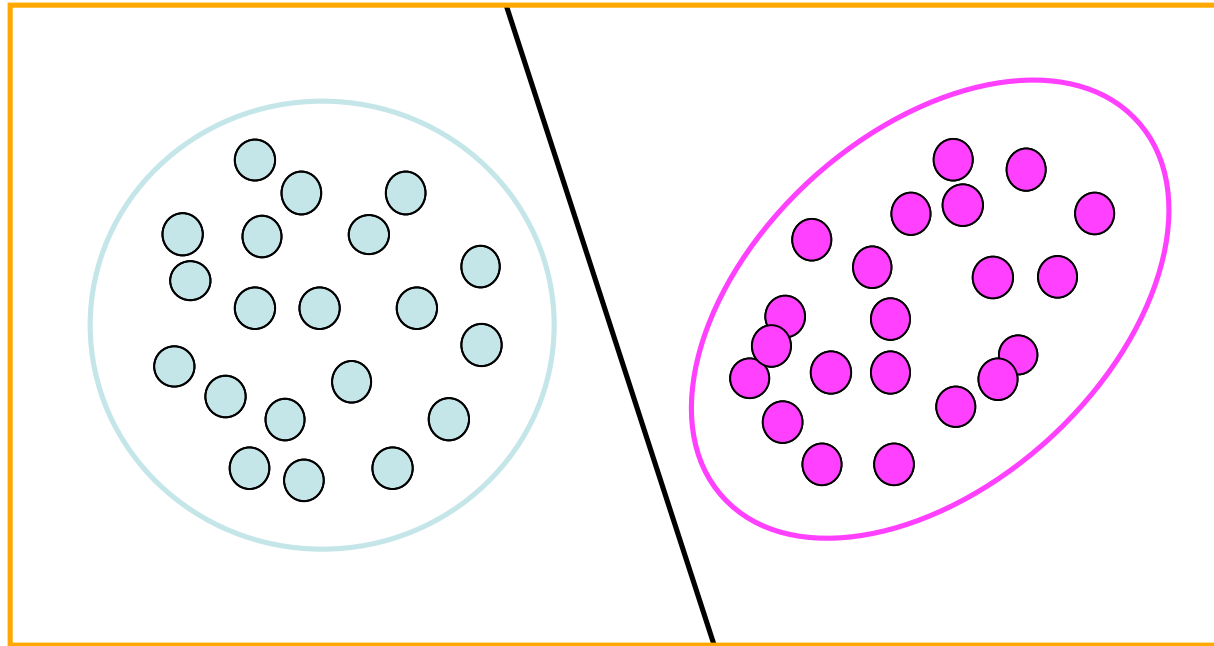
THE DEPARTMENT OF BIOMEDICAL ENGINEERING

The Whitaker Institute at Johns Hopkins



# Data segmentation and clustering

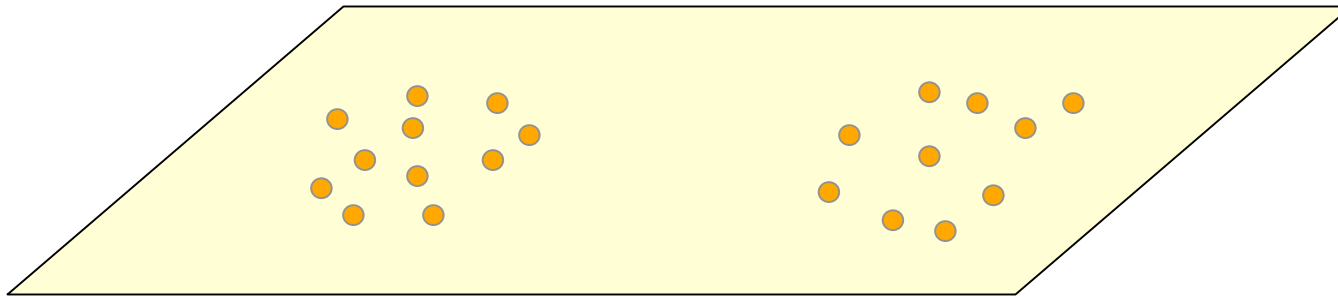
- Given a set of points, separate them into multiple groups



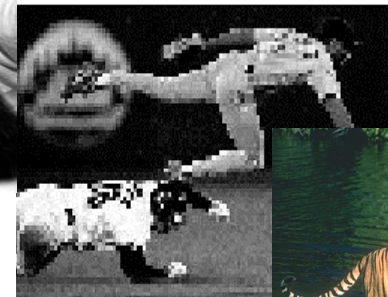
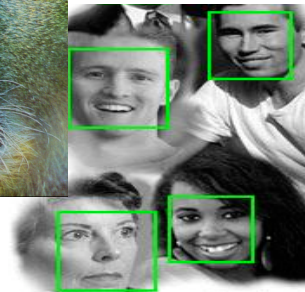
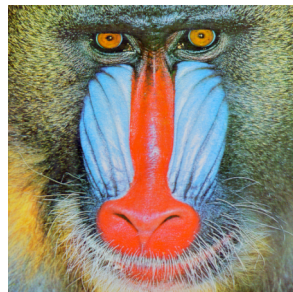
- Discriminative methods: learn boundary
- Generative methods: learn mixture model, using, e.g. Expectation Maximization

# Dimensionality reduction and clustering

- In many problems data is high-dimensional: can reduce dimensionality using, e.g. Principal Component Analysis

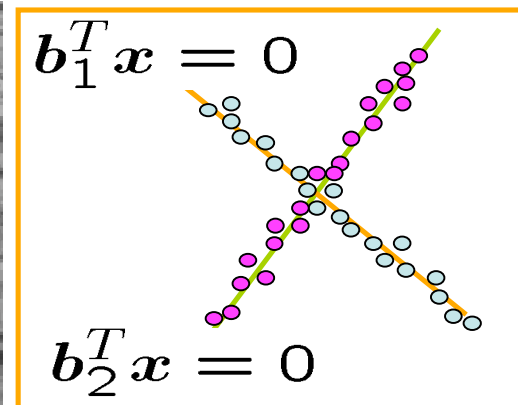


- Image compression
- Recognition
  - Faces (Eigenfaces)
- Image segmentation
  - Intensity (black-white)
  - Texture

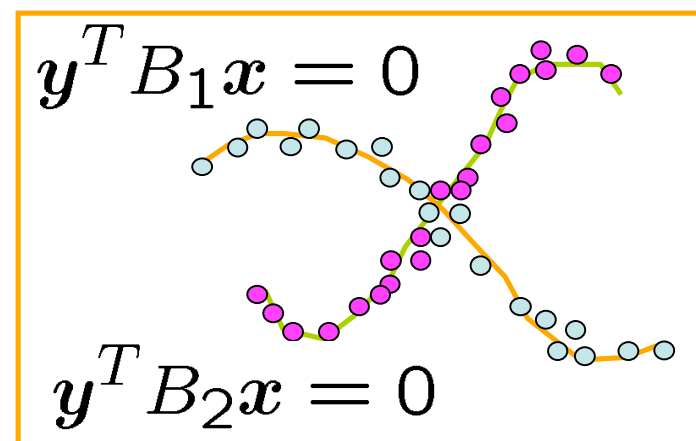
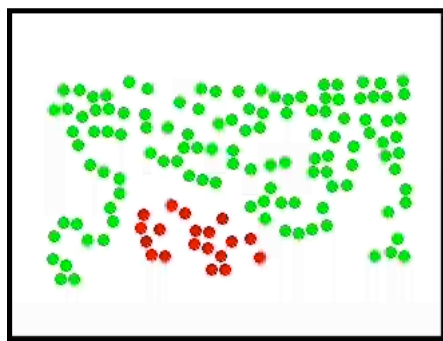


# Segmentation problems in dynamic vision

- Segmentation of video and dynamic textures



- Segmentation of rigid-body motions





# Segmentation problems in dynamic vision

- Segmentation of rigid-body motions from dynamic textures



# Clustering data on non Euclidean spaces

- Clustering data on non Euclidean spaces

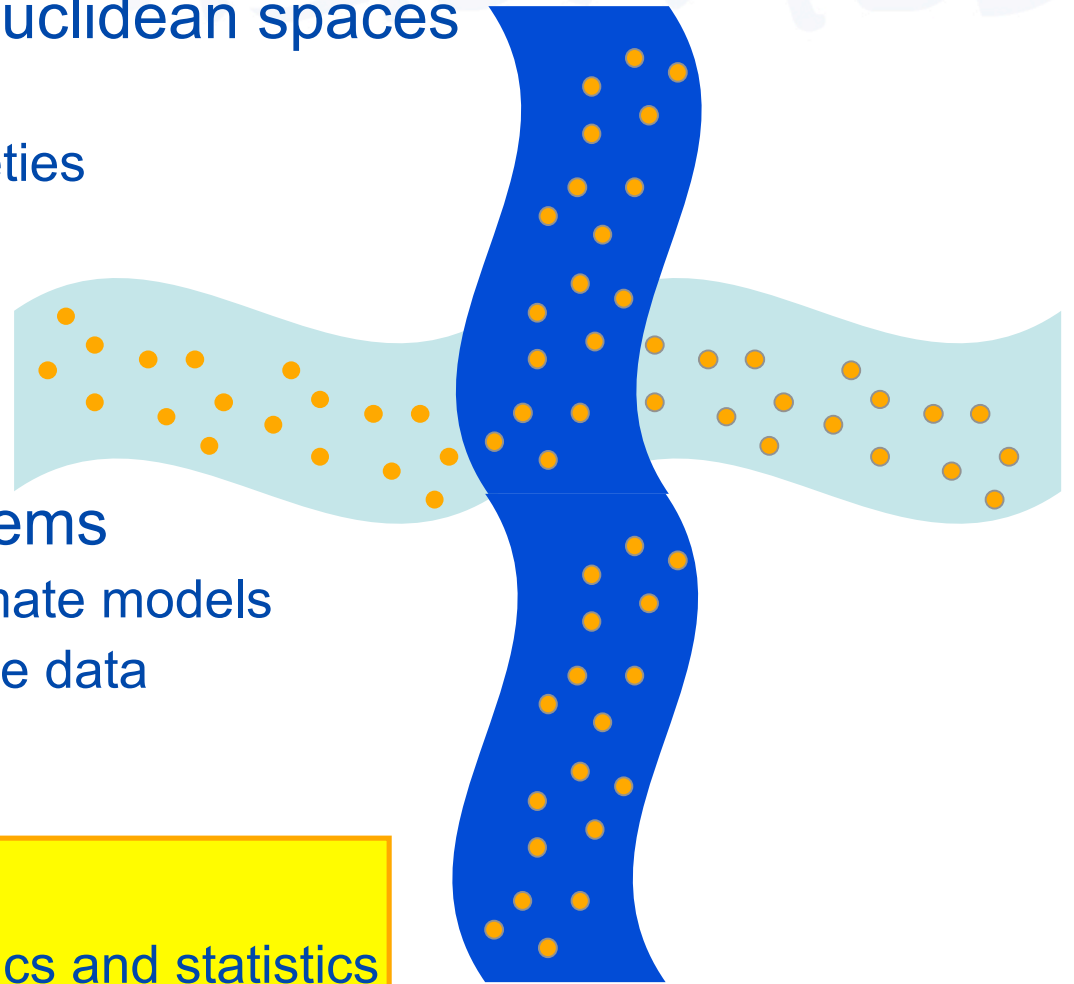
- Mixtures of linear spaces
- Mixtures of algebraic varieties
- Mixtures of Lie groups

- “Chicken-and-egg” problems

- Given segmentation, estimate models
- Given models, segment the data
- Initialization?

- Need to combine

- Algebra/geometry, dynamics and statistics



# Outline of the tutorial

- Part I: Theory (8.30-11.00)
  - Introduction to GPCA (8.30-8.40)
  - Basic GPCA theory and algorithms (8.40-9.30)
  - Coffee Break (09.30-10.00)
  - Advanced statistical and algebraic methods for GPCA (10.00-11.00)
- Part II: Applications (11.00-3.00)
  - Applications to hybrid system identification (11.00-12.00)
  - Lunch Break (12.00-1.30)
  - Applications to motion and video segmentation (1.30-2.30)
  - Applications to image representation & segmentation (2.30-3.30)

# Part I: Theory

- Introduction to GPCA (8.30-8.40)
- Basic GPCA theory and algorithms (8.40-9.30)
  - Review of PCA and extensions
  - Introductory cases: line, plane and hyperplane segmentation
  - Segmentation of a known number of subspaces
  - Segmentation of an unknown number of subspaces
- Advanced statistical and algebraic methods for GPCA (10.00-11.00)
  - Model selection for subspace arrangements
  - Robust sampling techniques for subspace segmentation
  - Voting techniques for subspace segmentation



# Part II: Applications

- Applications to hybrid system identification (11.00-12.00)
  - Identification of switched ARX models in input-output form
  - Identification of switched linear systems
- Applications to motion & video segmentation (1.30-2.30)
  - 2-D and 3-D motion segmentation
  - Temporal video segmentation
  - Dynamic texture segmentation
- Applications to image representation and segmentation (2.30-3.30)
  - Multi-scale hybrid linear models for sparse image representation
  - Hybrid linear models for image segmentation



References: Springer-Verlag 2008

**Generalized Principal Component Analysis**

Estimation & Segmentation of Geometric Models

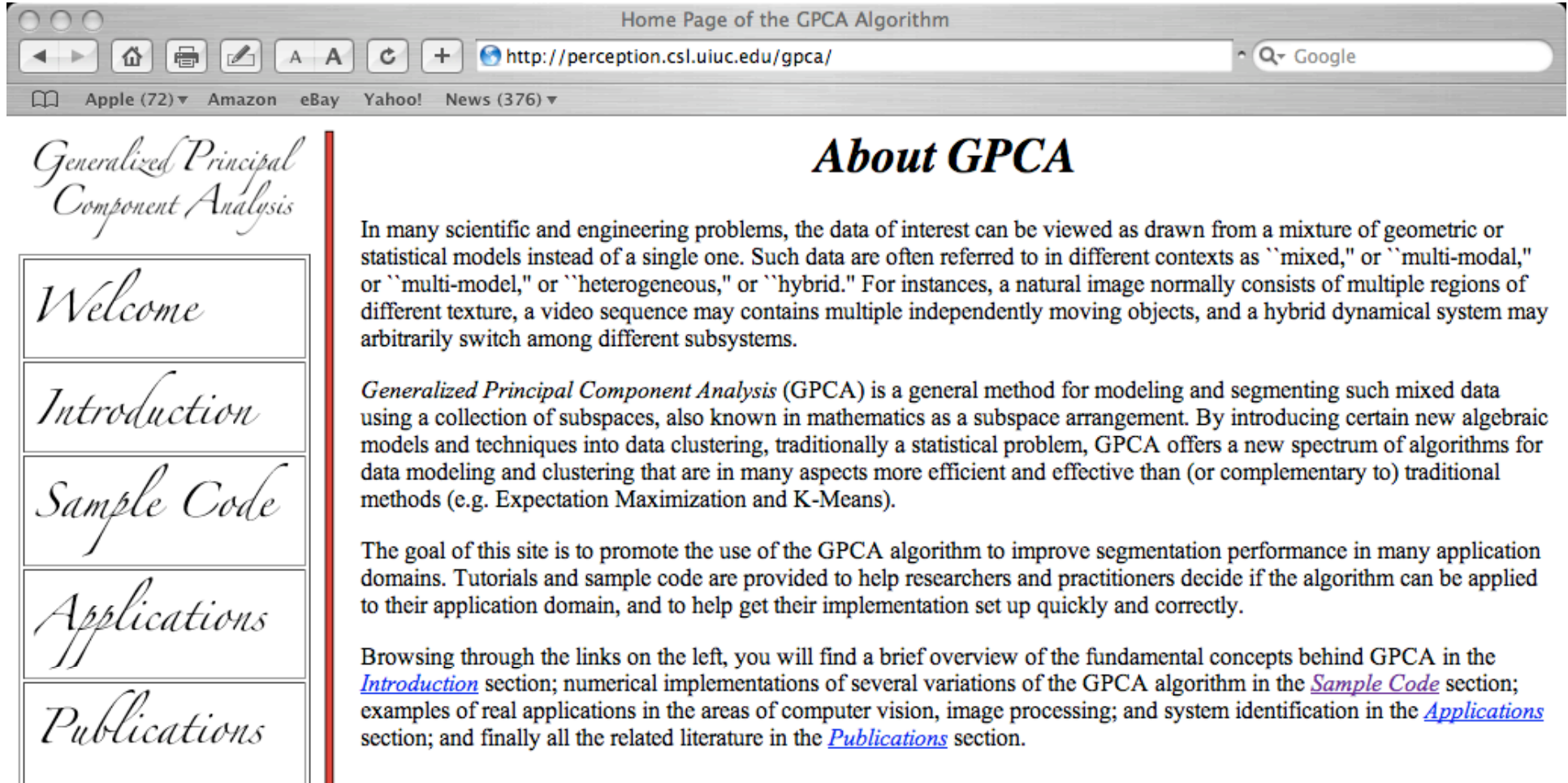
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# Slides, MATLAB code, papers

<http://perception.csl.uiuc.edu/gpca>



The screenshot shows a web browser window titled "Home Page of the GPCA Algorithm". The address bar contains the URL <http://perception.csl.uiuc.edu/gpca/>. The browser's search bar shows "Google". Below the browser window, the page content is displayed. On the left, there is a vertical navigation menu with the title "Generalized Principal Component Analysis" and five links: "Welcome", "Introduction", "Sample Code", "Applications", and "Publications". The main content area is titled "About GPCA" and contains three paragraphs of text. The first paragraph discusses the nature of the data GPCA handles. The second paragraph defines GPCA as a general method for modeling and segmenting mixed data. The third paragraph states the goal of the site. The fourth paragraph provides a brief overview of the site's structure.

Generalized Principal Component Analysis

Welcome

Introduction

Sample Code

Applications

Publications

## About GPCA

In many scientific and engineering problems, the data of interest can be viewed as drawn from a mixture of geometric or statistical models instead of a single one. Such data are often referred to in different contexts as "mixed," or "multi-modal," or "multi-model," or "heterogeneous," or "hybrid." For instances, a natural image normally consists of multiple regions of different texture, a video sequence may contains multiple independently moving objects, and a hybrid dynamical system may arbitrarily switch among different subsystems.

*Generalized Principal Component Analysis* (GPCA) is a general method for modeling and segmenting such mixed data using a collection of subspaces, also known in mathematics as a subspace arrangement. By introducing certain new algebraic models and techniques into data clustering, traditionally a statistical problem, GPCA offers a new spectrum of algorithms for data modeling and clustering that are in many aspects more efficient and effective than (or complementary to) traditional methods (e.g. Expectation Maximization and K-Means).

The goal of this site is to promote the use of the GPCA algorithm to improve segmentation performance in many application domains. Tutorials and sample code are provided to help researchers and practitioners decide if the algorithm can be applied to their application domain, and to help get their implementation set up quickly and correctly.

Browsing through the links on the left, you will find a brief overview of the fundamental concepts behind GPCA in the [Introduction](#) section; numerical implementations of several variations of the GPCA algorithm in the [Sample Code](#) section; examples of real applications in the areas of computer vision, image processing; and system identification in the [Applications](#) section; and finally all the related literature in the [Publications](#) section.