Subspace methods (for visual learning and recognition)

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Udine; 5, 12 December 2014

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ViCoS visualgnitive ystemslab

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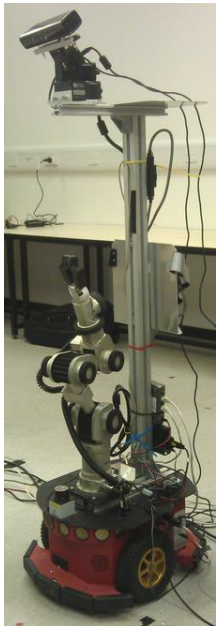
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ViCoS Areas of Research

- Research on intelligent (artificial cognitive) systems
- Focus on visual learning and recognition:
  - recognition and categorisation of objects and places
  - supervised/unsupervised learning
  - learning in interaction with a tutor and a scene
  - visual tracking
- Target platforms: mobile robots, intelligent environments, personal mobile devices















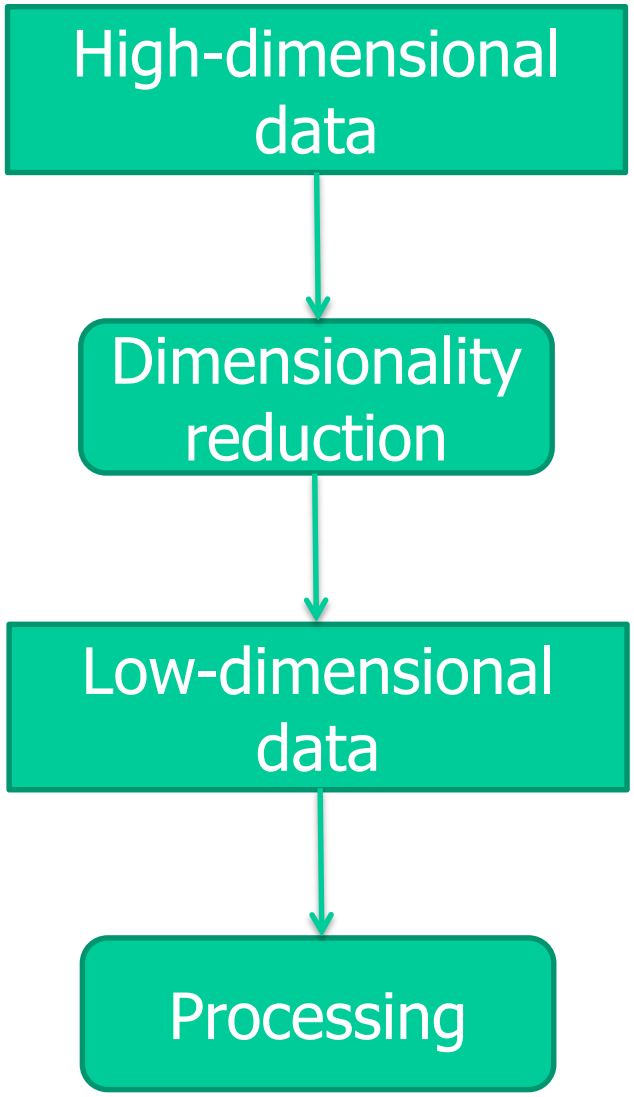








Handling high-dimensional data



Images, attributes, sensor readings,...

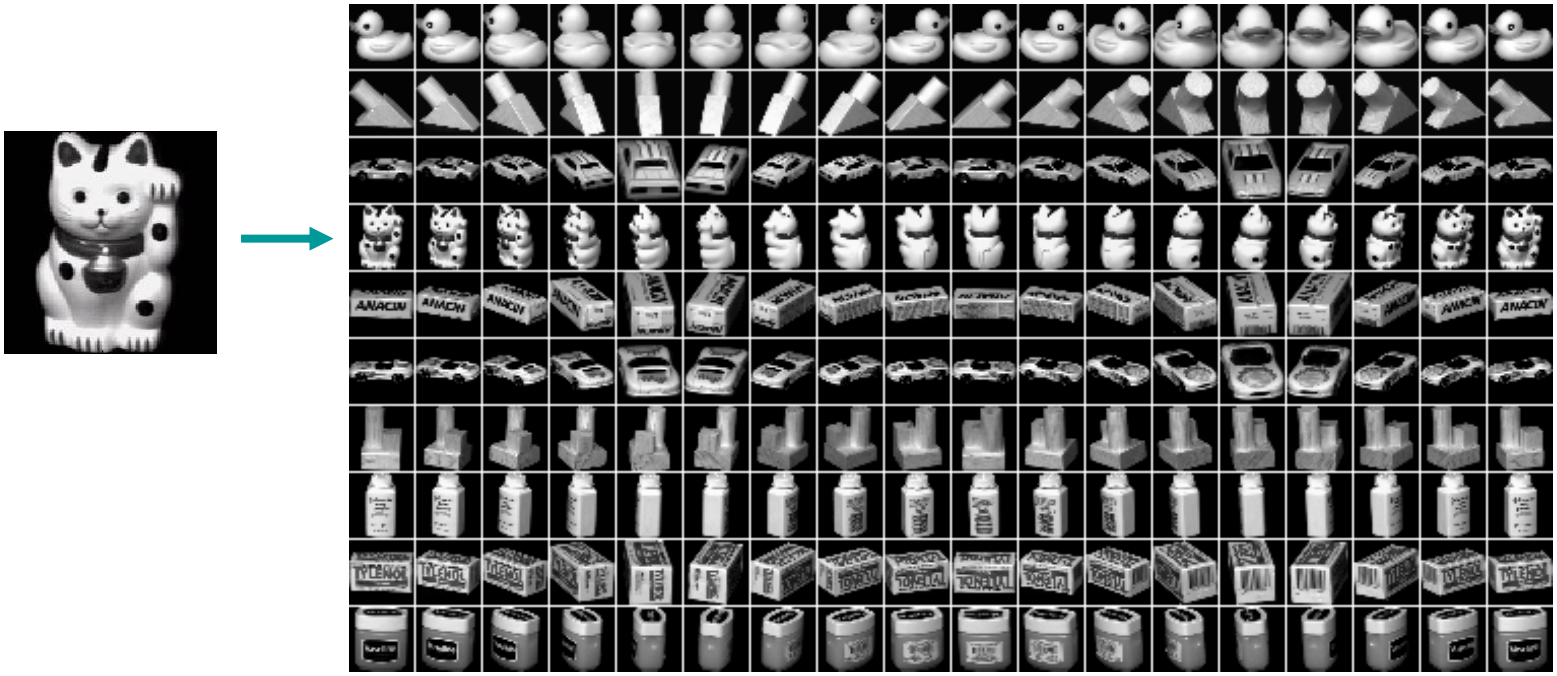
PCA, LDA, CCA, ICA, NMF, ...

Subspace

Visualisation, classification: kNN, SVM

Appearance-based recognition

- An object is represented by a set of images.



- Recognition = searching for the most similar training image.

Appearance-based approach

- Large set of training images ⇨
  we need an efficient representation, which:
  - Is easy to build,
  - does not require a huge amount of memory,
  - enables generalization across views,
  - is suitable for fast recognition (matching).

- Principal Component Analysis – PCA

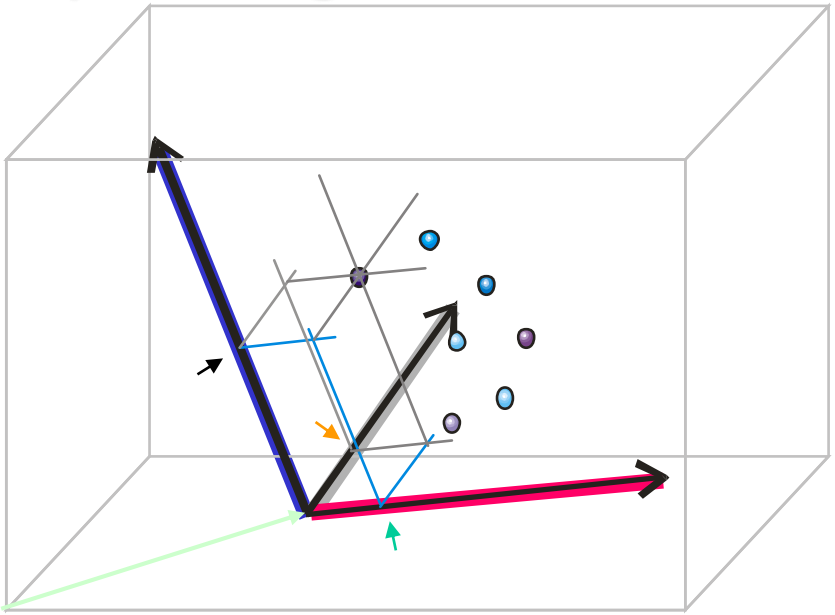
Subspace representation

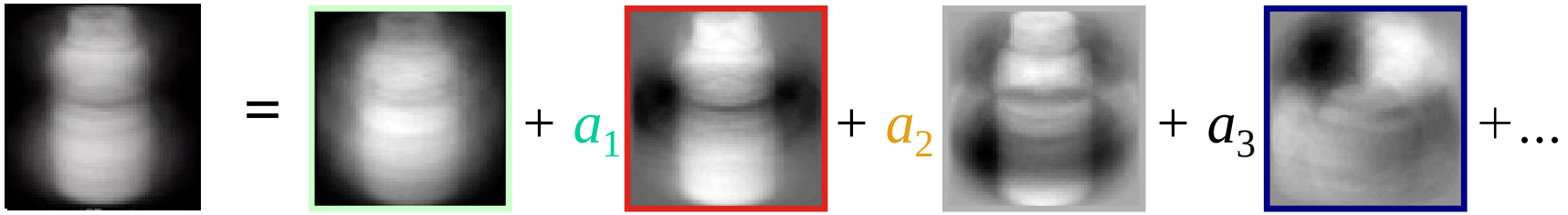
- An image is represented by a linear combination of principal images.
- Projection:

$$\mathbf{a} = \mathbf{U}^{\top}(\mathbf{x} - \boldsymbol{\mu})$$

- Reconstruction:

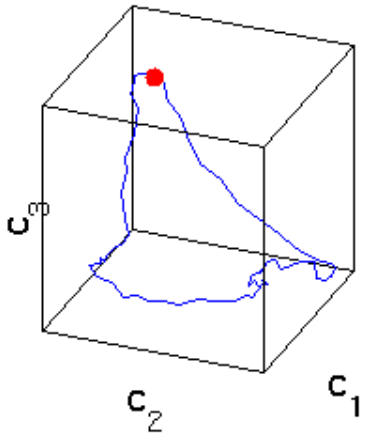
$$\mathbf{x} \approx \mathbf{U}\mathbf{a} + \boldsymbol{\mu}$$





Object recognition and pose estimation





new image:



Recognition:



An object is represented as
a manifold in the principal subspace.

Pose estimation:



Subspace methods

- PCA – Principal Component Analysis
  - maximizes variance of projected input vectors
  - minimizes reconstruction error
- LDA – Linear Discriminative Analysis
  - maximizes between class scatter
  - minimizes within class scatter
- CCA – Canonical Corelation Analysis
  - maximizes correlation between projections
- ...

Other subspace methods

- KPCA - Kernel Principal Component Analysis
- KLDA – Kernel Linear Discriminant Analysis
- KCCA – Kernel Canonical Correlation Analysis
- PPCA – Probabilistic Principal Component Analysis
- ICA – Independent Component Analysis
- NMF - Non-negative matrix factorization
- LLE - Locally Linear Embedding
- LSH - Locality-sensitive hashing
- ISOMAP - A Global Geometric Framework for Nonlinear Dim. Reduction
- GPLVM - Gaussian Process Latent Variable Models
- RP – Random projection
- LTSA - Local tangent space alignment
- LPP – Locality preserving projections
- SC – Spectral Clustering
- SOM - Self-organizing map
- ...

Outline

- Standard PCA
  - Principle and properties
  - Derivation of PCA
  - Algorithm
  - PCA for visual learning and recognition
  - Applications
- Incremental PCA
  - Derivation of IPCA
  - Algorithm
- Standard LDA
- Standard CCA

Outline

- Augmenting LDA and CCA in PCA subspace
- Incremental LDA
- Robust recognition
  - PCA
  - LDA
  - CCA
- Robust learning
  - Weighted PCA
  - Temporaly weighted IPCA
  - Robust PCA

Goals

- To learn several standard subspace methods
  - PCA, LDA, CCA
  - Derivation, application
- To learn how to formulate problems
- To learn how to extend the standard subspace methods to overcome shortcomings
  - Incrementality
  - Robustness

Software available

- **Robust estimation of subspace coefficients**
- This package contains Matlab functions, which perform robust estimation of subspace coefficients in
PCA, CCA and LDA methods. It contains the following files (Matlab functions):
- PCA Principal Component Analysis. Creates the principal subspace.
- IS2FS Maps images from image space to feature space.
- FS2IS Maps vectors of subspace coefficients from feature space to image space.
- IS2FSROB Maps vectors of subspace coefficients from feature space to image space in a robust manner.
- CCA Canonical Correlation Analysis. Computes canonical correlation vectors.
- CCAAPCA CCA-after-PCA. Calculates CCA of augmented PCA coefficient vectors.
- LDA Linear Discriminant Analysis. Computes LDA eigenvectors.
- LDAAPCA LDA-after-PCA. Calculates LDA of augmented PCA coefficient vectors.
- DISPIMGS Displays images.
- DEMOPCA Demo of robust estimation of principal components.
- DEMOCCA Demo of robust estimation of canonical correlation coefficients.

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