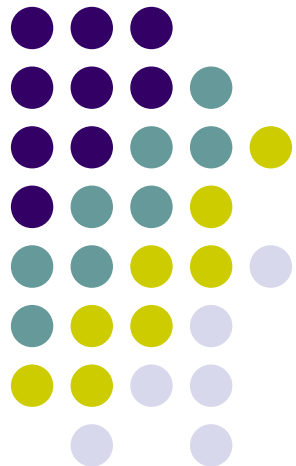
RMIT

Cluster Analysis
K-means



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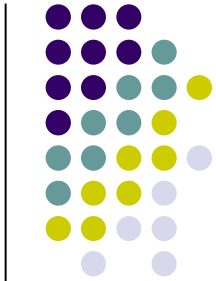
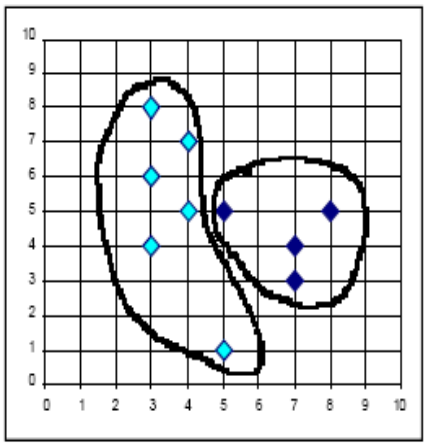
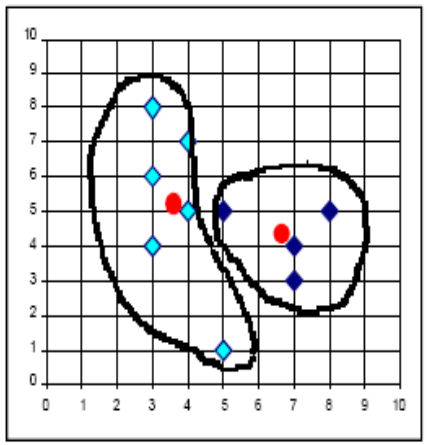
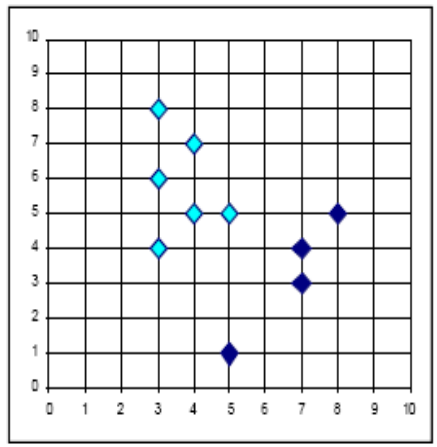
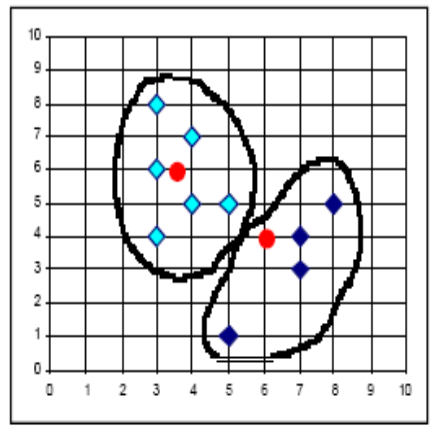
K-means : Overview



- isodata or c-Means
- Partitions the data into K mutually exclusive clusters
- Creates a single level of cluster
- Determine all clusters at once
- Assigns each observation to the cluster whose center is nearest
- The number of clusters (classes) are known a priori

The Algorithm

i. Start with k random clusters
ii. Move each observation to the nearest cluster center (centroids)
iii. Recalculate the new centroids
iv. Repeat until convergence criterion (minimum distance or max iterations) is met

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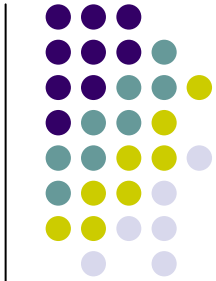
Pros and Cons



- Advantages:
  - Simple & fast
  - Suitable for large dataset
- Disadvantages:
  - Unable to handle noisy data / outliers
  - Dependent on initial random clusters
    - Different classification results for different runs of the algorithm

K-means Example

- Classification of images extracted from the video of a speaker uttering 2 speech sounds (consonants)
- 40 images for each consonant
- Feature vector for each consonant = 6 values
- Squared Euclidean distance used to partition the data into 2 clusters
- Silhouette plot is shown to indicate the distance between the 2 clusters of features

/g/

/m/

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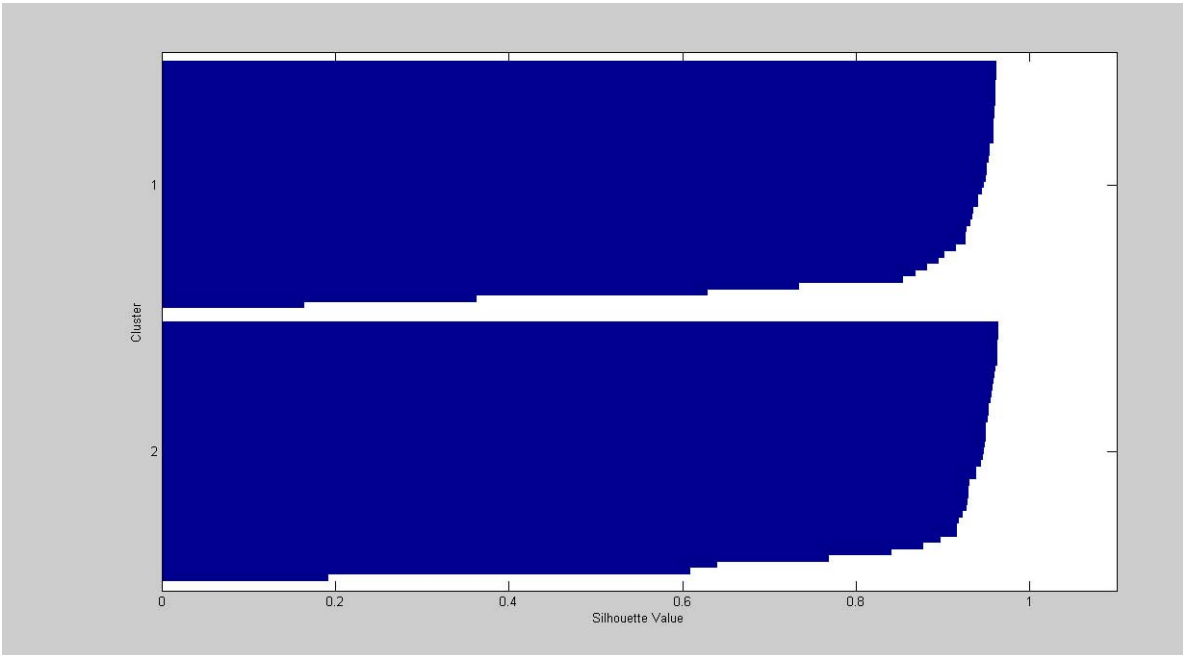
Results – Silhouette Plot

- 79 out of the 80 features are correctly classify into the 2 clusters.
- Recognition rate = 98.75% for the classification of these 2 classes of images
- Silhouette plot for the 2 clusters of data shows that the distance between the two clusters are well separated (the silhouette value is near to 1)



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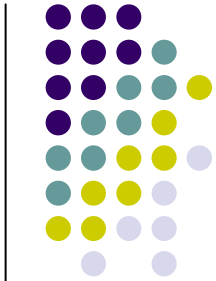

That’s all for clustering

Next topic : Hidden Markov Models

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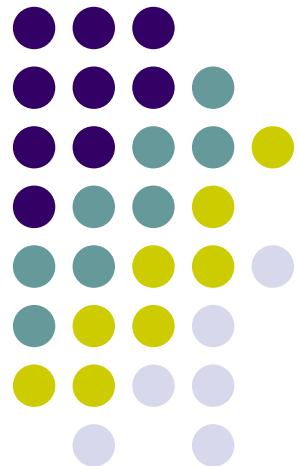
Supervised Classifiers

HIDDEN MARKOV MODELS (HMM)



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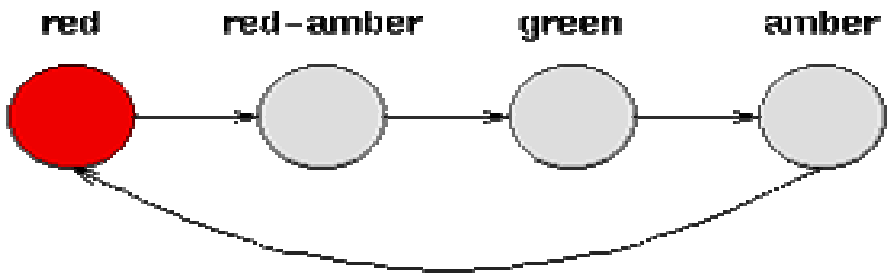
HMM : Introduction

- A type of stochastic model that statistically model a system as Markov process (Markov chain) .
- A simple example of an observable Markov process : traffic light



- Find patterns that appear over a space of time

Animation adopted from http://www.comp.leeds.ac.uk/roger/HiddenMarkovModels/html_dev/main.html

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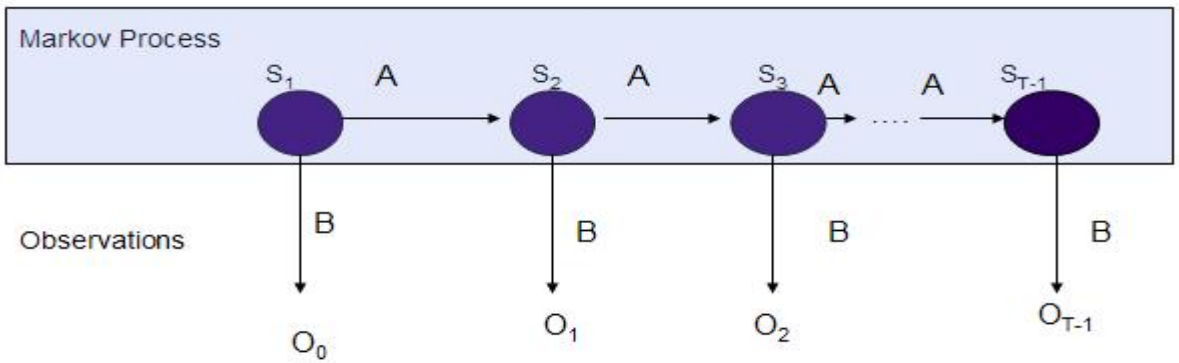
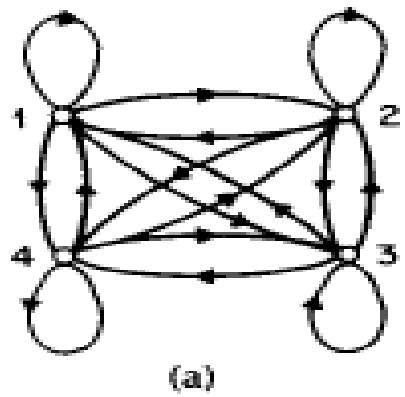
What is Hidden in HMM?

- Process where the states are not observable → Hidden Markov Models
- HMM parameters (λ)
  - number of states
  - state transition probability distribution [A]
  - observation symbol probability distribution [B]
  - probabilities of the initial state
  - Num of observation symbols available (discrete)



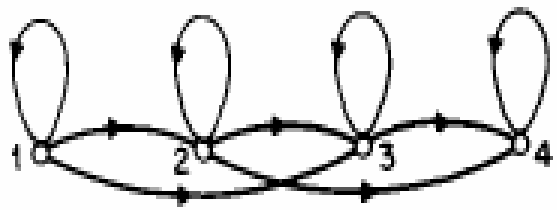
Types of HMM

Fully connected / Ergodic HMM



(a)

Left-right/ Bakis HMM



(b)

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Design of HMM Classifiers

Basic Operations in Design of HMM classifier	Algorithm
Learning /Training: Given an output sequence *or a set* of such sequences ($O=O_1,O_2,\ldots O_T$), find the ***most likely set of HMM parameters λ to generate the training sequences***	**Baum-Welch Algorithm**
Evaluation/ Recognition: Given the parameters of the model λ , compute the probability of a particular observation (test) sequence, O. ***P(O| λ)***	**Forward Algorithm**

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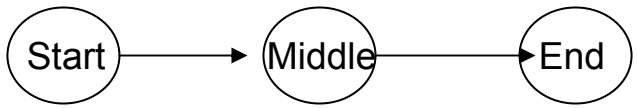
Why HMM?

- Suitable for modelling time-varying signals or classification tasks where patterns exist across a sequence of observations
- Applications:
  - Speech recognition
    - M. T. Chan, "HMM-based Audio Visual Speech Recognition Integrating Geometrics and Appearance-based Visual Features," presented at IEEE Workshop on Multimedia Signal Processing, Cannes, France, 2001
  - Bioinformatics / Genomics
    - Thomas Plötz, Gernot A. Fink,"Pattern recognition methods for advanced stochastic protein sequence analysis using HMMs", Pattern Recognition, Volume 39, 2006
  - Robotics (robot sensing)
    - Sven Koenig and Reid Simmons, *A Robot Navigation Architecture Based on Partially Observable Markov Decision Process Models*," in Artificial Intelligence Based Mobile Robotics:Case Studies of Successful Robot Systems, D. Kortenkamp, R. Bonasso, and R. Murphy, Eds., pp. 91-122. MIT press, 1998.
  - Character recognition
    - Agazzi, O.E., Kuo, S., 1993. *Hidden Markov model based optical character recognition in the present of deterministic transformations*. Pattern Recognition 26 (12), 1813--1826
  - Economics / Finance
    - Rossi, Alessandro & Gallo, Giampiero M., 2006. "Volatility estimation via hidden Markov models," Journal of Empirical Finance, Elsevier, vol. 13(2), pages 203-230,

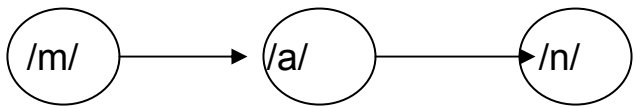
HMM - Speech Recognition

- Speech is a dynamic process (time varying)
- Usually left-right HMMs are used

Modelling Signal →Phones



Modelling Phones → Words



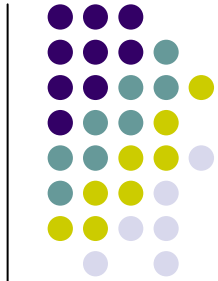
Modelling Words → Sentence

HMM Example

- Classification of the 2 consonants again…
  - But we're using more frames now to model the mouth movement changes across time.
  - 35 videos of each consonant used for training HMM, 5 videos that are not used in training are used in testing the HMM
  - 3 states left-right HMM is used with 1 Gaussian mixture component & diagonal covariance
  - The features of middle frame and end frame forms one sequence of observation for the HMM
  - 1 HMM is created for each consonant (class)
  - Classification of 100% is obtained

Consonants	Start Frame	Middle Frame	End Frame
/m/			
/g/			

References & Toolboxes



1. Lawrence R. Rabiner, A Tutorial on Hidden Markov Models and Selected Applications in Speech Recognition. *Proceedings of the IEEE*, 77 (2), p. 257–286, February 1989.

2. S. Theodoridis and K. Koutroumbas, *Pattern Recognition*: Academic Press, 1999

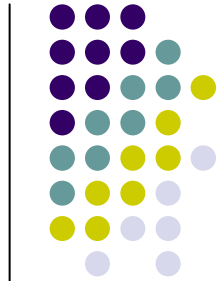
HMM Toolboxes

1. Hidden Markov Models Toolkit (HTK)
   http://htk.eng.cam.ac.uk/

2. BNT- HMM toolbox for MATLAB
   http://www.cs.ubc.ca/~murphyk/Software/HMM/hmm.html

3. gpdsHMM- another HMM toolbox for MATLAB
   http://www.gpds.ulpgc.es/download/index.htm

4. Jahmm- Java based HMM toolbox
   http://www.run.montefiore.ulg.ac.be/~francois/software/jahmm/



Questions?

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