Advanced Pattern Recognition Techniques

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Lecture 1

What is pattern recognition?
Pattern recognition is the scientific discipline in the field of computer science whose goal is the classification of objects into a number of categories or classes.
Objects – images, signal waveforms or any type of measurement or sensing

Generic term for objects – patterns

In abstract sense, the pattern recognition may be represented as a mapping of patterns from measurement space or world observation space to class membership space.

Pattern recognition is an integral part of most machine intelligent systems

Examples of areas of pattern recognition use:

i) Recognition of visual patterns

- Alphanumeric Character Recognition (OCR systems)
- Mammography, tomography (CT or CAT scan), chromosome classification, cell classification
- Robot/machine vision (machine vision systems in the manufacturing industry – visual inspection, robot manipulation)
- Detection of the objects in a scene
- Interpretation of 3D scene
- Classification of aero and satellite images
- Biometric-based verification/identification

ii) Recognition of sound patterns

- Speech recognition
- Speaker recognition
- Language recognition
- Sound recognition (proper operation of the machine, type of vehicle, recognition of human/animal walk)

iii) Recognition of biomedical patterns (computer-added diagnosis)

- Electrocardiograms (ECGs), electroencephalograms (EEGs)
- Diagnosis

iv) Data mining and knowledge discovery

- Automatic annotation and content-based image retrieval (CBIR)
- Mining for DNA analysis

v) Earthquake and ground vibration patterns

- recognition of earthquake patterns (a natural cause or a nuclear underground experiment)
- recognition of vibration of the ground due to walk (human walk, animal walk)

vi) Human-machine interaction

- Gesture recognition
- Recognition of human emotional states

Basic motives for research in the field of PR

- Intellectual curiosity - how to design a machine whose responses to perceptual stimuli will be similar to the human being?

- Design of system that enables efficient human-machine interaction

- Design of machines that increase intellectual and physical human's power (faster and more accurate operation, work in a hostile environment)

Features, Feature vector, and Classifiers

Pattern – a generic term for an object

A pattern has double role:

i) It is a representation of an object
ii) It is a member of the class or category

An object from the real-world has the number of features that approaches to infinity!
Important – find only the distinguishing features, i.e. features that can distinguish one pattern which belongs to one class from pattern which belongs to the another class
Determination of a complete set of discriminatory features is not possible

Features

Interset

Features which represent the differences between pattern classes

Intraset

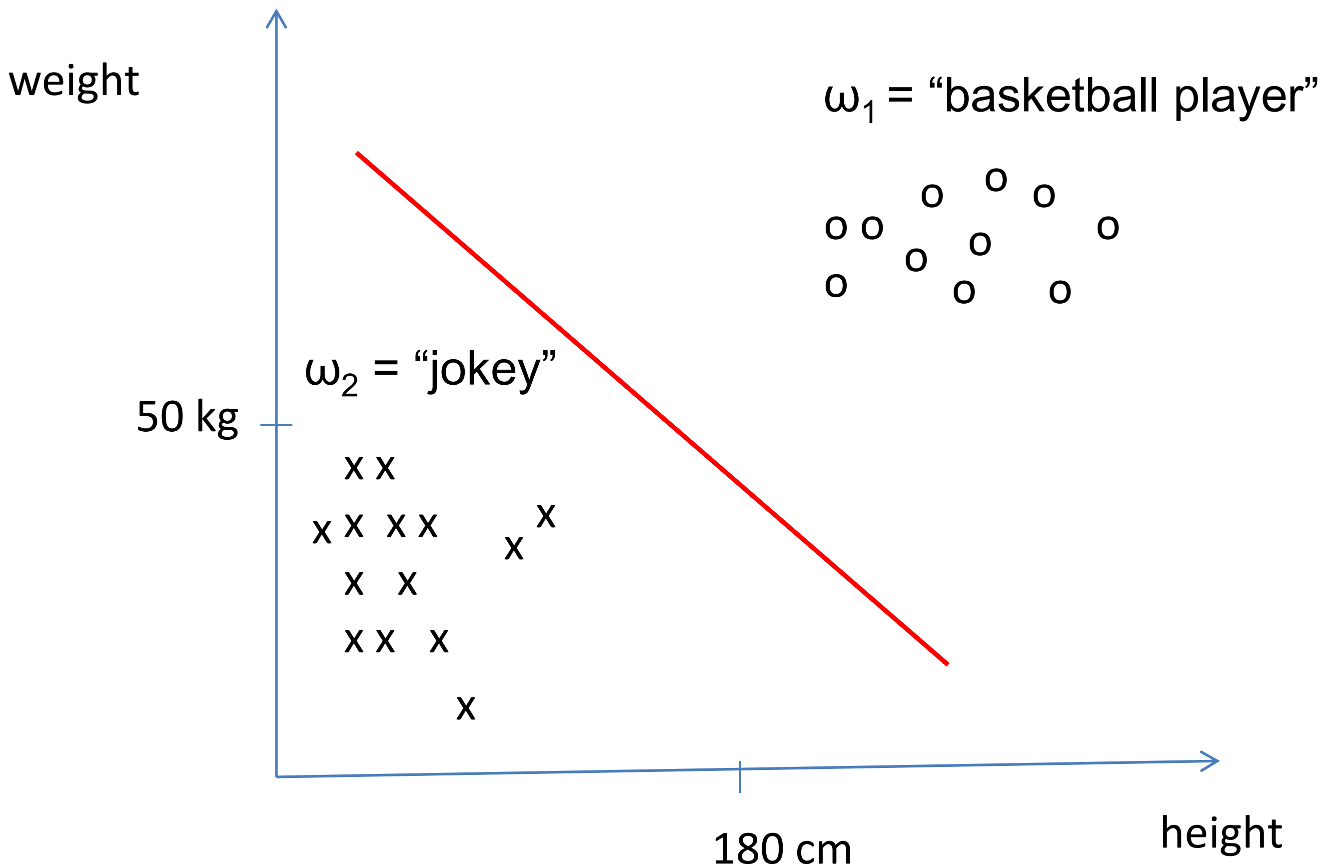
Features common to all pattern classes

Example:

To classify individuals to M = 2 classes: ω_1 = “basketball player”

ω_2 = “jokey”

- interset features: height, weight
- intraset features: eye color, hair color


weight
ω1 = "basketball player"
ω2 = "jokey"
50 kg
180 cm
height

Features: x_i , $i = 1, 2, 3, \ldots, n$ form the feature vector:

$\mathbf{x} = [x_1, x_2, \ldots , x_n]^T$ where T denotes transposition

Each of feature vectors identifies uniquely a single pattern (object)

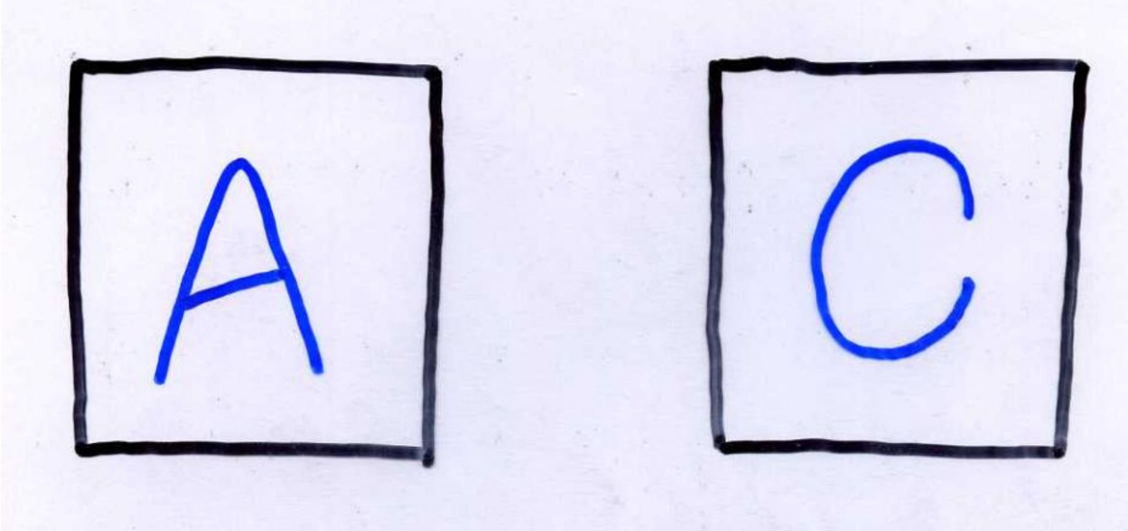
Feature vectors are treated as random variables (random vectors)

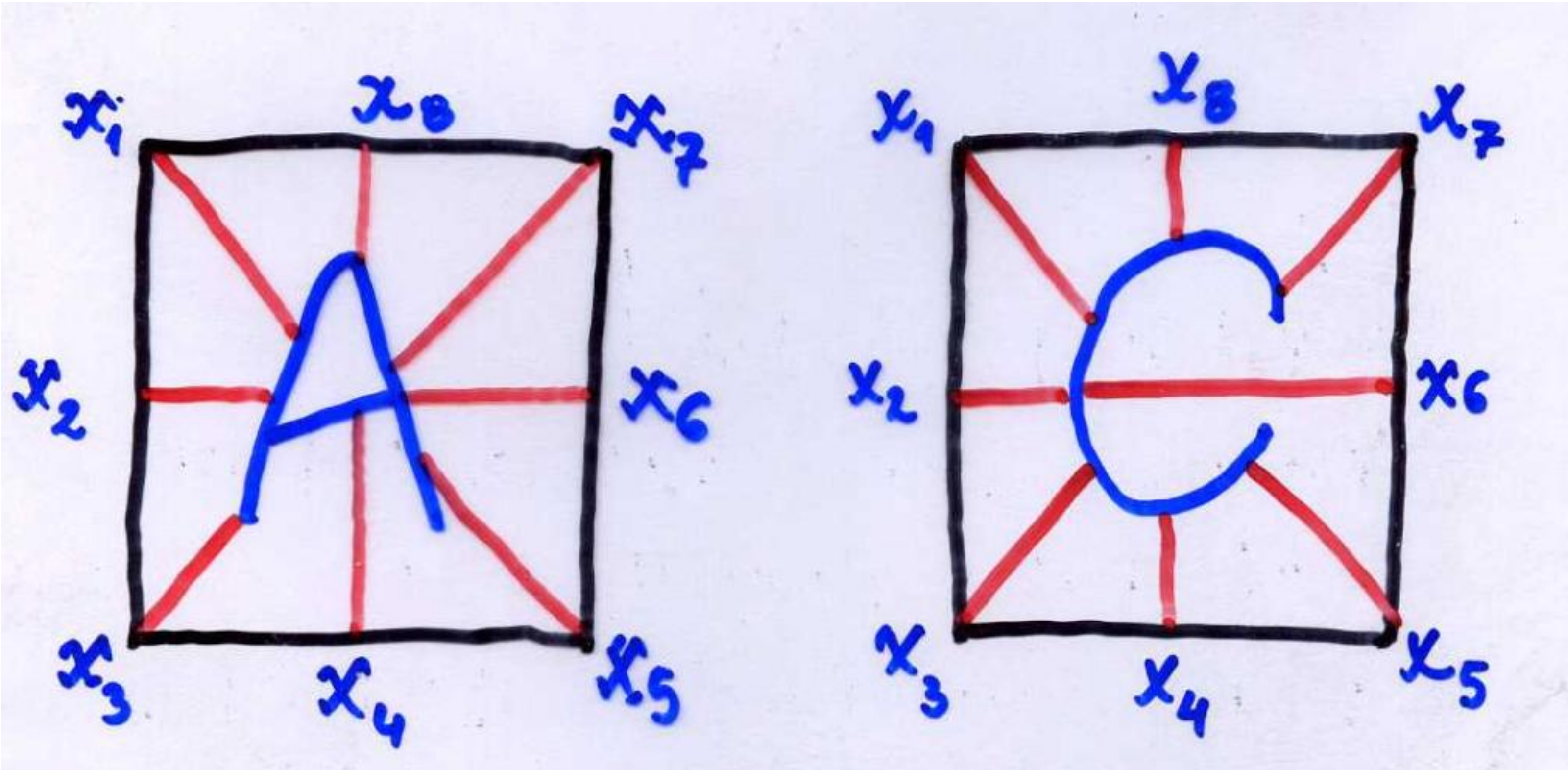
Why?

- Measurements resulting from different pattern exhibit a random variation: due to measurement noise and the distinct characteristics of each pattern

Determination of a complete set of discriminatory features is not possible (and not necessary)

Example (K.S. Fu):





Feature vector: $\mathbf{x} = [x_1, x_2, \dots , x_8]^T$

Three approaches to pattern recognition (S. Watanabe):

i) Paradigm-oriented pattern recognition
ii) Structure oriented pattern recognition
iii) Clustering

Supervised pattern recognition

i) A set of training patterns of known classification is available. Classifier is designed by exploiting this a priori known information by applying machine learning (training) procedure.
ii) Complex patterns are characterized by primitive elements (subpatterns) and their relationships
iii) Training data of known class labels are not available. A set of feature vectors **x** (without known classification) is given and the goal is to ravel the underlying similarities and group “similar” vectors together.

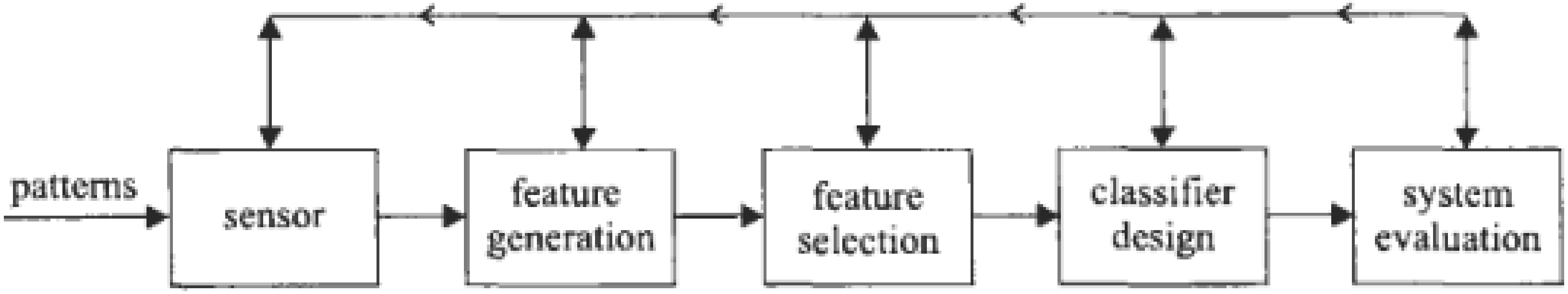
Unsupervised pattern recognition

Semi-supervised pattern recognition – for designing a classification system designer has a set of patterns of unknown class origin, in addition to training patterns whose true class is known.

patterns of unknown class origin – unlabeled data
patterns whose true class is known – labeled data

Reinforcement learning (learning with critic) – no desired category signal is given; instead only teaching feedback is that the tentative category (class) is right or wrong.

Basic stages involved in the design of pattern recognition system



(S. Theodoridis, K. Koutrumbas, Pattern recognition, 2009)

Phases:

-Data collection – how do we know when we have collected an adequately large and representation set of examples for training and testing the system?

Feature choice – the choice of the interset features is a critical step; What is the best number *n* of features to use?

- Classifier design – How does one design the classifier?
- System evaluation – How can one assess the performance of the designed system; What is the classification error rate?

- Feature vectors as a points in an *n*-dimensional feature space
- There are M different pattern classes: $\omega_1, \omega_2, \ldots, \omega_M$

- The recognition problem can be viewed as a process of generating the decision boundaries which separate the M pattern classes

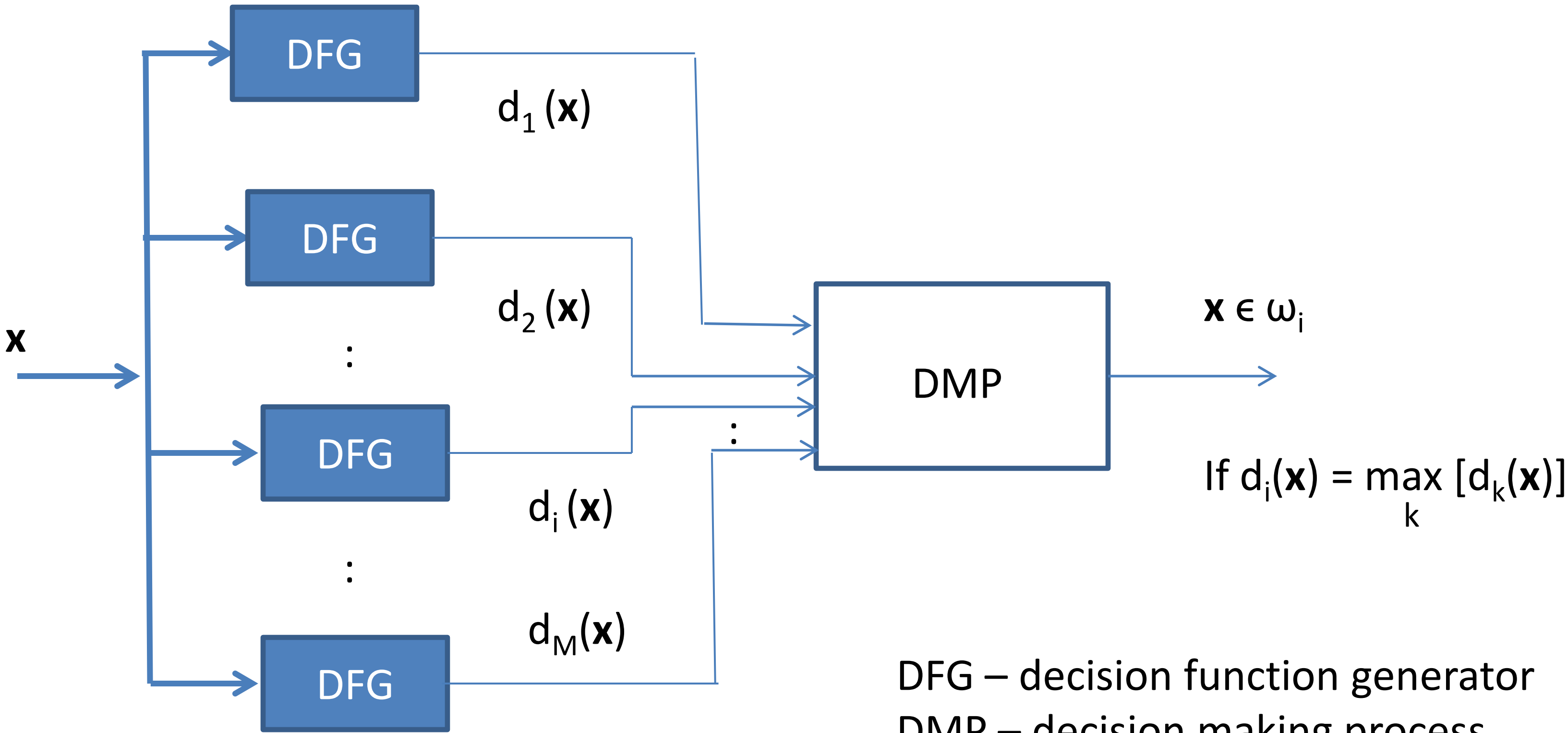
- The *n*-dimensional feature space is divided by decision boundaries into M *n*-dimensional subspaces – each corresponds to one of the class

- Boundaries are defined by decision functions $d_1(\mathbf{x})$ $d_2(\mathbf{x}), \ldots, d_M(\mathbf{x})$

Note that decision functions are scalar and single valued functions of patterns **x**

Classification rule:

If $d_i(\mathbf{x}) > d_j(\mathbf{x})$ for i, j = 1, 2, … , M, the pattern **x** belongs to pattern class ω_i



DFG – decision function generator

DMP – decision making process

An example of pattern recognition system

- System for verification/identification based on palmprint