

MCSE 666: Pattern and Speech Recognition



Introduction to Pattern Recognition

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What Is Pattern Recognition?

Pattern recognition (PR) is a **process** by which some **input is measured, analyzed**, and then **classified** as belonging to **one of a set of classes**

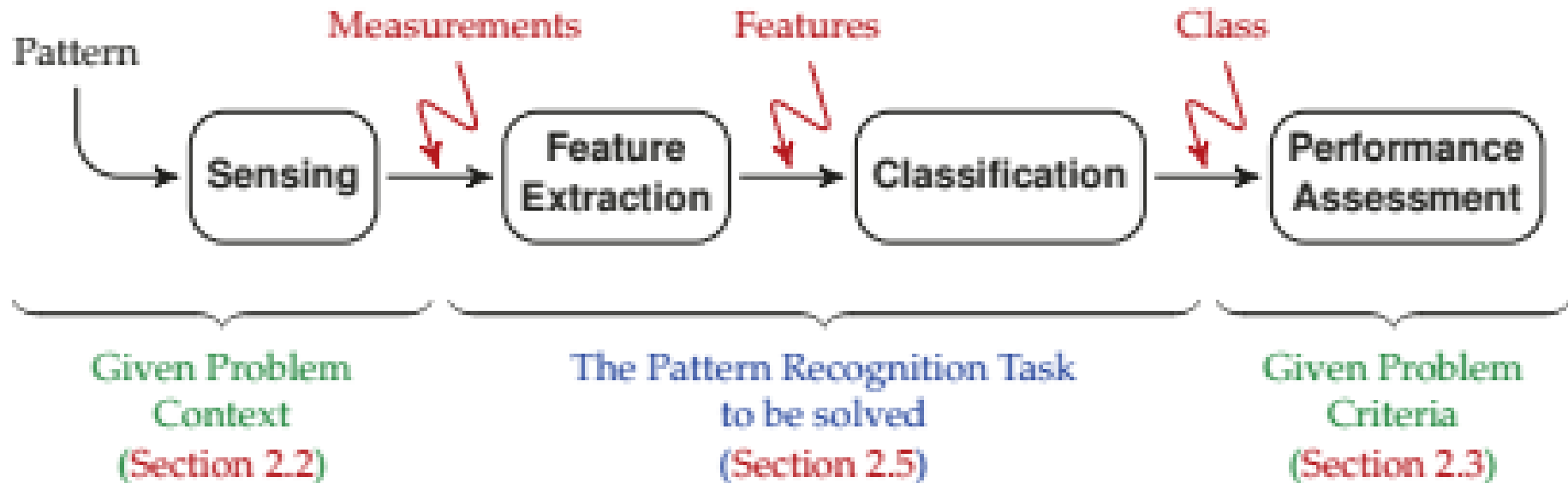
Process of PR and classification is a **continual, never ending aspect** of every-day human existence:

Pattern recognition task	Possible classes
What is in front of you as you walk?	Door vs. Window Sidewalk vs. Road
What music are you listening to?	Familiar or Unfamiliar Genre (Rock, Classical, ...) Name of Composer or Group
Is the traffic intersection safe to cross?	Green vs. Red light Pedestrian Walk vs. Stop Car Present vs. Not Present
Reading a page in a textbook	Letters of the Alphabet Text vs. Graphics Languages
You smell something in your apartment	Cookies finished baking? (Yes/No) Is something burning? (Yes/No)

What Is Pattern Recognition? Cont.

- PR as a human experience refers to a **perceptual process**: some form of sensory input is sensed, analyzed, and recognized (classified), either **subconsciously** (by instinct) or **consciously** (based on previous experience).
- Patterns may be presented in any sensory modality: **vision, hearing, touch, taste, or smell.**
- **PR as a technical discipline**: a process in which an input object is measured, analyzed, and classified by a **machine** as being more or less similar to some class in a set of classes.

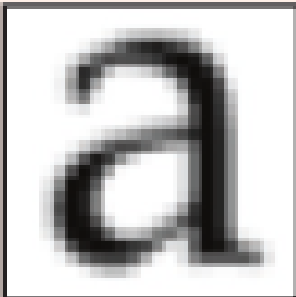
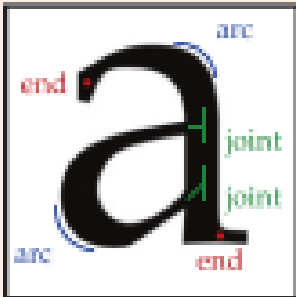
Pattern Recognition Framework



The goal of PR is to provide a machine with a kind of perceptual capability to automatically extract useful information from measured data.

PR Illustration with Example

Pattern Recognition of Text

Pattern	Attributes to Measure	Measurements	Strengths and Weaknesses
"a" →		Vector of pixel values	<p>Fast, easy, explicit</p> <p>Sensitive to changes in font style, size, and rotation</p>
"a" →		Vector of shape properties	<p>Robust to changes in size and rotation</p> <p>Complicated features to extract</p>
"a" →	Complex Nonlinear Algorithm	Vector of values, but with no intuition	<p>Possibly very flexible</p> <p>May be very hard to learn</p> <p>Difficult to analyze</p>

PR Illustration with Example

Pattern Recognition of the Mind

The typesetting may be weird, but for the human brain this is very easy to read.

It doesn't matter in what order the letters in a word are, as long as the first and last letters remain in the right place.

- The retina in the eye is densely packed with light-sensitive cells, so that it may be tempting to think
- Our brain effectively sees and perceives the world as a great many pixels.
- There are many simple mind tricks or optical illusions

PR Illustration with Example

Pattern Recognition of the Mind



There are no black dots in the white circles.



The two eyes are the same colour. There is no blue pigment, at all, in the left eye.



This is a static image, yet try zooming in and scrolling.

- The eye is **not just sending pixellated images** to the brain.
- There is a great deal of **feature extraction** taking place, much already in the retina
- It is very helpful in running through a forest, but perhaps not so useful in staring at deliberately manipulated images on a page.



Features from Patterns

- The word “pattern” may bring to mind texture, fabric, or shape.
- In the context of *pattern recognition*, the notion of pattern is far more broad, and can apply to **any thing that can be distinguished from another thing**.
- Identity view point: **infer the unknown *identity* of an object**
- Type of wildflower, type of songbird, or the name of the person facing a camera — each of these has a **certain identity to determine from measurements**.

A pattern is assumed to have certain ***properties or attributes*** which distinguishes it from other patterns.

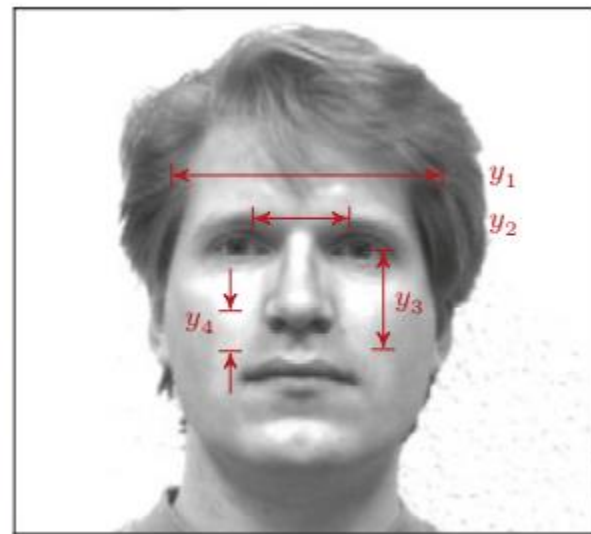


Features from Patterns (Cont.)

One or more measurements are taken of a pattern



Size / weight of a piece



Various dimensions from face

Does all measurements from patterns important to distinguish?



Features from Patterns (Cont.)

- The selection of appropriate measurements is an essential
- Measurements may cost money and/or time, and
- Poor measurements lead to poor performance of the resulting classifier.

The process of **transforming measurements into features** facilitate classification, normally in one or both of the following ways:

1. By reducing the dimensionality of the problem: **$n < m$**
2. By creating features in which **patterns are more clearly distinguished.**

$$\text{Measurements } \underline{y} = \begin{bmatrix} y_1 \\ \vdots \\ y_m \end{bmatrix} \xrightarrow{\underline{x} = f(\underline{y})} \text{Features } \underline{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}$$



Features from Patterns (Cont.)

$$\text{Measurements } \underline{y} = \begin{bmatrix} y_1 \\ \vdots \\ y_m \end{bmatrix} \xrightarrow{\underline{x} = f(\underline{y})} \text{Features } \underline{x} = \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix}$$

- The feature extraction function $f()$ can **focus the information** from x , or it can **remove irrelevant information** from x , but **$f()$ never adds information**.
- Data Processing Theorem: *x can never have more information than was present in y .*
- ❖ An effective feature extraction function $f()$ can make the PR problem **easier**,
- ❖ However, in principle, the **best possible classifier** based on the **measurements y** should perform at least as well as **the best possible classifier based on the features x** .



Features from Patterns (Cont.)

Features may be **intuitive** or they may be **quite abstract**.

Consider, the measurements of an electric motor:

$$\text{Measurements } \underline{y} = \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \\ y_5 \end{bmatrix} = \begin{bmatrix} \text{Motor voltage (Volts)} \\ \text{Motor current (Amperes)} \\ \text{Motor speed (RPM)} \\ \text{Motor winding temperature (°C)} \\ \text{Surrounding air temperature (°C)} \end{bmatrix}$$

$$x = f(\underline{y}) = y_1 \cdot y_2$$

Power as Feature: Understandable

$$x = f(\underline{y}) = \sqrt{y_1 - y_2} - \frac{y_3}{y_4}$$

- **Uninterpretable feature** do not make any physical sense,
- But **perhaps be effective** as a feature for **classification**.

Classes and Classification

- The whole purpose of **PR or classification** consists of **assigning an object to a class**.
- A class is a particular pattern, or possibly a group of patterns which are similar or equivalent in some sense.

In a given problem, the set of classes C is defined as

$$C = \{C_1; C_2; \dots; C_K\};$$

Have to choose one class from K different classes.

Members of a class share some common properties or attributes

In PR problems the class set C is predefined and has been specified as part of the problem to be solved.

Classes and Classification

So, for example, in a face recognition problem each person is their own class, so the set of classes would be defined as

$$\mathcal{C} = \{ \text{"Paul Fieguth"}, \text{"Bob"}, \text{"Jane"}, \text{"Ali"}, \dots \}$$

so that I would be a member of the "Paul Fieguth" class:



∈ "Paul Fieguth"

At a university we might define a different set of classes

$$\mathcal{C} = \{ \text{"Professors"}, \text{"Staff"}, \text{"Undergraduate Students"}, \text{"Graduate Students"} \}$$

such that

$$\text{"Paul Fieguth"} \in \text{"Professor"}$$

One *could* use pattern recognition to estimate age, in which case one might have classes like

$$\mathcal{C} = \{ \text{"0-10 years"}, \text{"10-20 years"}, \text{"20-30 years"}, \dots \}$$

such that now I appear in a class as

$$\text{"Paul Fieguth"} \in \text{"50-60 years"}$$

Classes and Classification

Way of Describing Classes

Via Prototype Idealized representation or notion of the “essence” of the class. Pros: each class is unambiguously defined, Cons: no scope for variability.

Via Parameterized Shape: A generalization of the prototype; the class has a known shape (e.g., rectangular or elliptical), the shape is described in some number of parameters (e.g., ellipse centre, rotation, and axis lengths). Pros. more flexible than that of a single prototype, Cons: still requires the type of shape to be assumed or known.

Via Statistical Distribution: Some description of the **likelihood or probability** of a class member having **a particular set of measurements or features**. Pros.: very comprehensive, Cons: There will be circumstances when the statistics are not known and may be difficult to infer.

Via Samples: A set of given samples (many apples, or tigers, or bicycles) directly characterizes the class. Pros: Highly convenient, since nothing further needs to be done to describe the class Cons: Storage and computational challenges, since all of the data need to be saved.

Classes and Classification

Variability in a Class

Patterns do not need to be identical to belong to the same class: not all pictures of a person the same, or of tigers, or of apples.

There are at least two sources of variability present in the measurements associated with a single class:

1. The inherent variability within a class: Every class will consist of members which differ in some way. The degree and nature of the inherent variability will depend greatly on the class definition.

“Fruit” class contains all manners of variability in colour, size, and shape; “Apple” class is much more specific, but apples do come in different colours and patterning; the “Granny Smith Apple” class is even more specific, but still will have apples of different sizes or with more or fewer blemishes.

2. Noise or random variations in measurement: Every measurement involves some sort of physical process which will be subject to error, such as thermal noise in electronics, or quantization noise in converting an analogue signal to a digital representation.



Open Discussion on Course Conduction