Expert Systems, Pattern Recognition

Expert Systems

- A geologist is effective at discovering mineral deposits because he is able to apply a good deal of theoretical and empirical knowledge about geology to the problem at hand.
- Expert knowledge is a combination of a theoretical understanding of the problem and a collection of heuristic problem-solving rules that experience has shown to be effective in the domain.
- Expert systems constructed by obtaining this knowledge from a human expert and coding it into a form that a computer may apply to similar problems.
- Such programs grow out of a collaboration between a domain expert such as a doctor, chemist, geologist, or engineer and a separate artificial intelligence specialist.
- Once such a program has been written, it is necessary to refine its expertise through a process of giving it example problems to solve, letting the domain expert criticize its behavior, and making any required changes or modifications to the program's knowledge. This process is repeated until the program has achieved the desired level of performance.

Expert Systems

- DENDRAL:
  - Developed at Stanford in the late 1960s (Lindsay et al. 1980).
  - Designed to infer the structure of organic molecules from their chemical formulas and mass spectrographic information about the chemical bonds present in the molecules.
- MYCIN:
  - Uses expert medical knowledge to diagnose and prescribe treatment for spinal meningitis and bacterial infections of the blood.
  - Developed at Stanford in the mid-1970s
- PROSPECTOR:
  - For determining the probable location and type of ore deposits based on geological information about a site (Duda et al. 1979a, 1979b).
- INTERNIST:
  - Program for performing diagnosis in the area of internal medicine
- Dipmeter Advisor:
  - For interpreting the results of oil well drilling logs (Smith and Baker 1983),

Expert Systems

- Written for relatively specialized, expert level domains.
  - These domains are generally well studied and have clearly defined problem-solving strategies.
- Problems that depend on a more loosely defined notion of "common sense" are much more difficult to solve by these means.
- Difficulty in capturing "deep" knowledge of the problem domain.
  - MYCIN, for example, lacks any real knowledge of human physiology. It does not know whatblood does or the function of the spinal cord.
- Lack of robustness and flexibility.
  - If humans are presented with a problem instance that they cannot solve immediately, they can generally return to an examination of first principles and come up with some strategy for attacking the problem.
  - Expert systems generally lack this ability.
- Little learning from experience.
  - Current expert systems are handcrafted; once the system is completed, its performance will not improve without further attention from its programmers, leading to doubts about the intelligence of such systems.

Human Perception

Humans have developed highly sophisticated skills for sensing their environment and taking actions according to what they observe, e.g.,

- recognizing a face,
- understanding spoken words,
- reading handwriting,
- distinguishing fresh food from its smell.

- We would like to give similar capabilities to machines

What is Pattern Recognition?

- A *pattern* is an entity, vaguely defined, that could be given a name, e.g.,
- ◭ fingerprint image,
- ◭ handwritten word,
- ◭ human face,
- ◭ speech signal,
- ◭ DNA sequence,
- ◭ . . .
- ◭ *Pattern recognition* is the study of how machines can
- ◭ observe the environment,
- ◭ learn to distinguish patterns of interest,
  - ◭ make sound and reasonable decisions about the categories
  - of the patterns.

Pattern Recognition

- In a typical pattern recognition application, the raw data is processed and converted into a form that is amenable for a machine to use.
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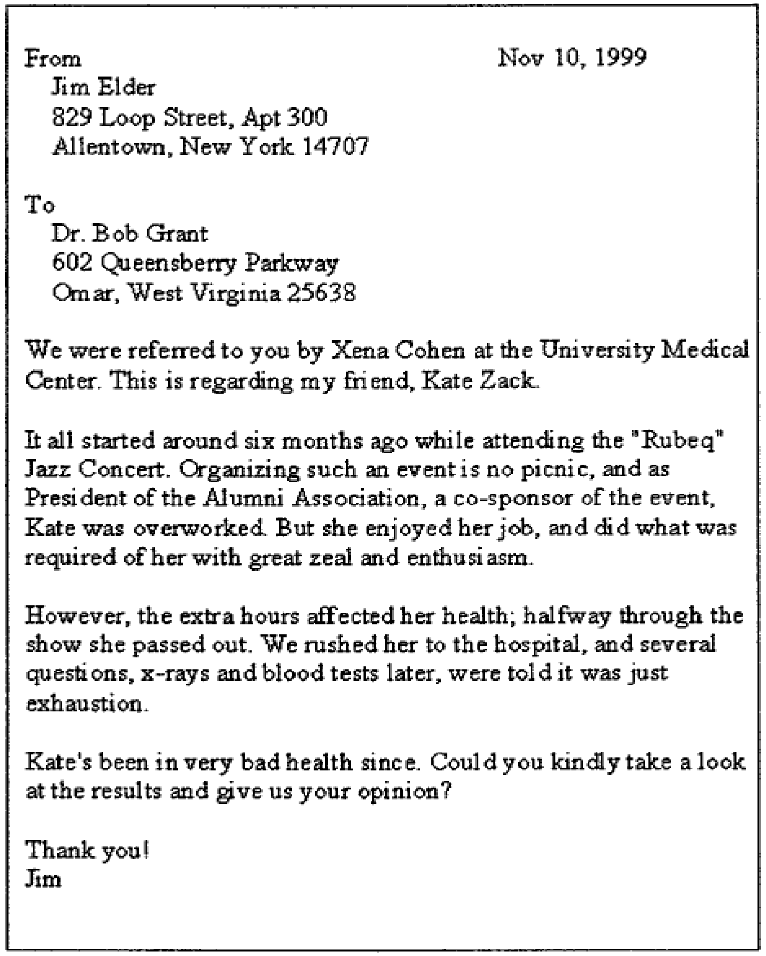
- Pattern recognition involves classification and cluster of patterns.

- In classification, an appropriate class label is assigned to a pattern based on an abstraction that is generated using a set of training patterns or domain knowledge. Classification is used in supervised learning.

- Clustering generated a partition of the data which helps decision making, the specific decision making activity of interest to us. Clustering is used in an unsupervised learning.

Pattern Recognition Applications

- English handwriting recognition



From Nov 10, 1999
Jim Elder
829 Loop Street, Apt 300
Allentown, New York 14707

To
Dr. Bob Grant
602 Queensberry Parkway
Omar, West Virginia 25638

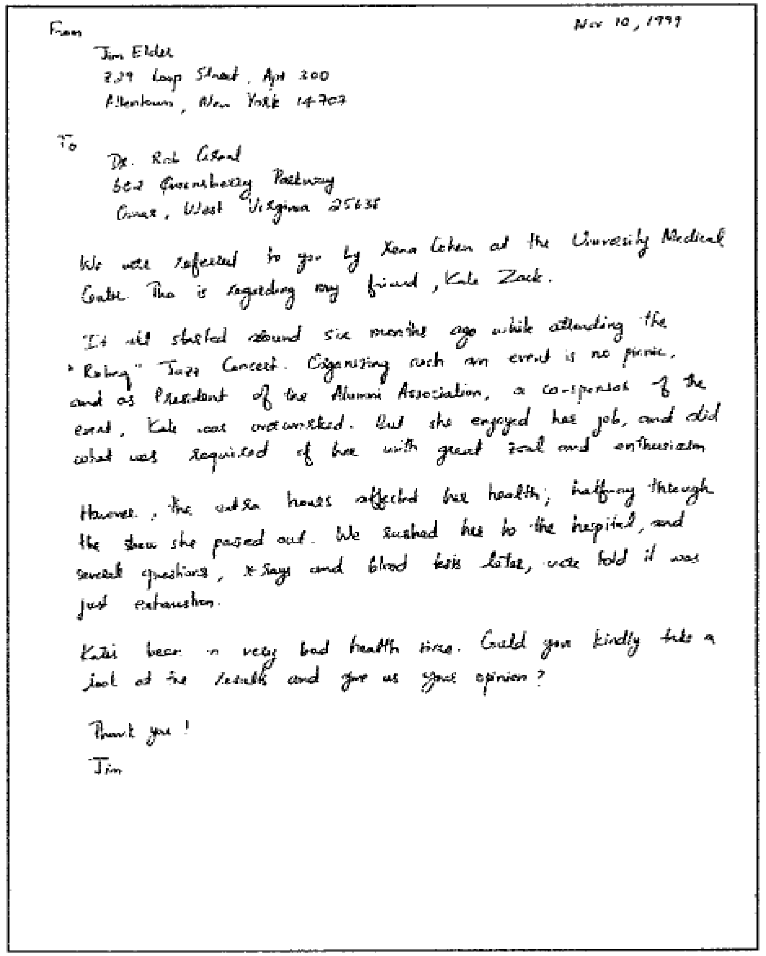
We were referred to you by Xena Cohen at the University Medical Center. This is regarding my friend, Kate Zack.

It all started around six months ago while attending the "Rubeq" Jazz Concert. Organizing such an event is no picnic, and as President of the Alumni Association, a co-sponsor of the event, Kate was overworked. But she enjoyed her job, and did what was required of her with great zeal and enthusiasm.

However, the extra hours affected her health; halfway through the show she passed out. We rushed her to the hospital, and several questions, x-rays and blood tests later, were told it was just exhaustion.

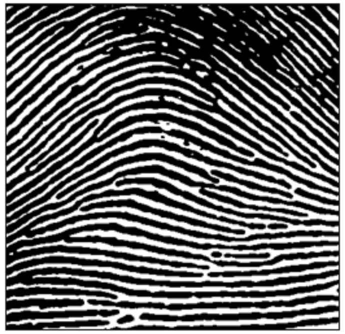
Kate's been in very bad health since. Could you kindly take a look at the results and give us your opinion?

Thank you!
Jim



Pattern Recognition Applications

- Fingerprint Recognition


Plain Arch


Tented Arch


Right Loop


Left Loop


Accidental

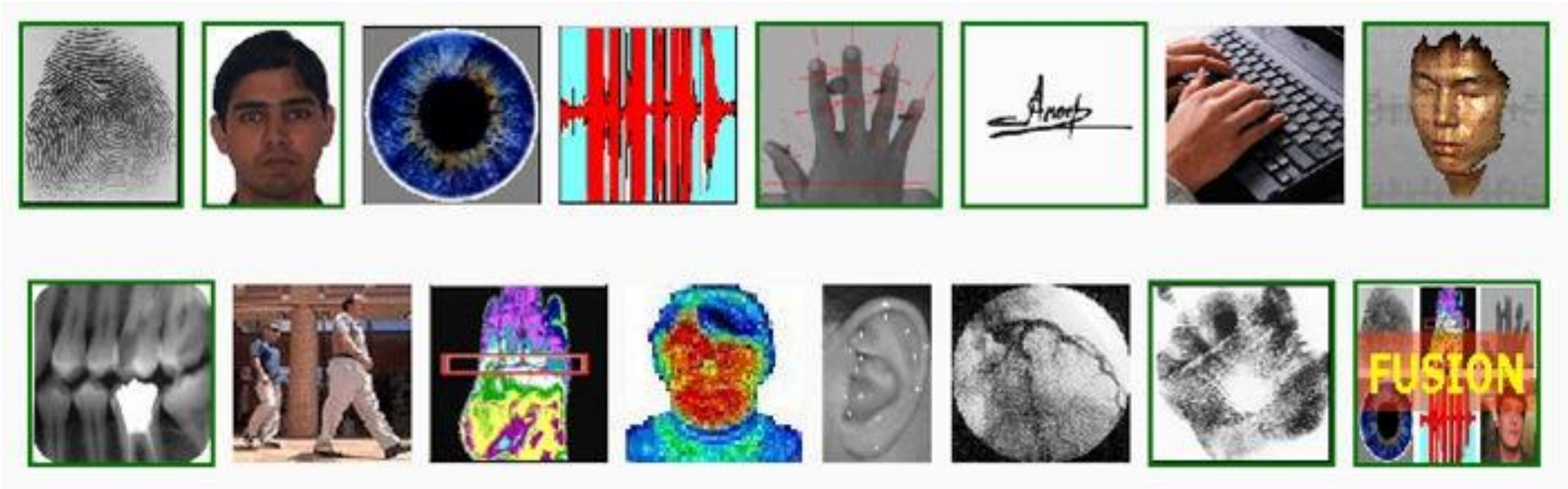

Pocket Whorl


Plain Whorl


Double Loop

Pattern Recognition Applications

- Biometric Recognition



Pattern Recognition Applications

- **Landcover classification using satellite data**

Pattern Recognition Applications

- Number plate recognition

An Example

- Problem: Sorting incoming fish on a conveyor belt according to species.

- Assume that we have only two kinds of fish:
  - sea bass,
  - salmon.

Figure: Picture taken from a camera.

An Example: Decision Process

What kind of information can distinguish one species from the other?

- length, width, weight, number and shape of fins, tail shape, etc.
- What can cause problems during sensing?
  - lighting conditions, position of fish on the conveyor belt, camera noise, etc.
- What are the steps in the process?
  - capture image → isolate fish → take measurements → make decision

An Example: Selecting Features

Assume a fisherman told us that a sea bass is generally longer than a salmon.

- We can use length as a *feature* and decide between sea bass and salmon according to a threshold on length.
- How can we choose this threshold?

An Example: Selecting Features

Even though sea bass is longer than salmon on the average, there are many examples of fish where this observation does not hold.

- Try another feature: average lightness of the fish scales

An Example: Cost of Error

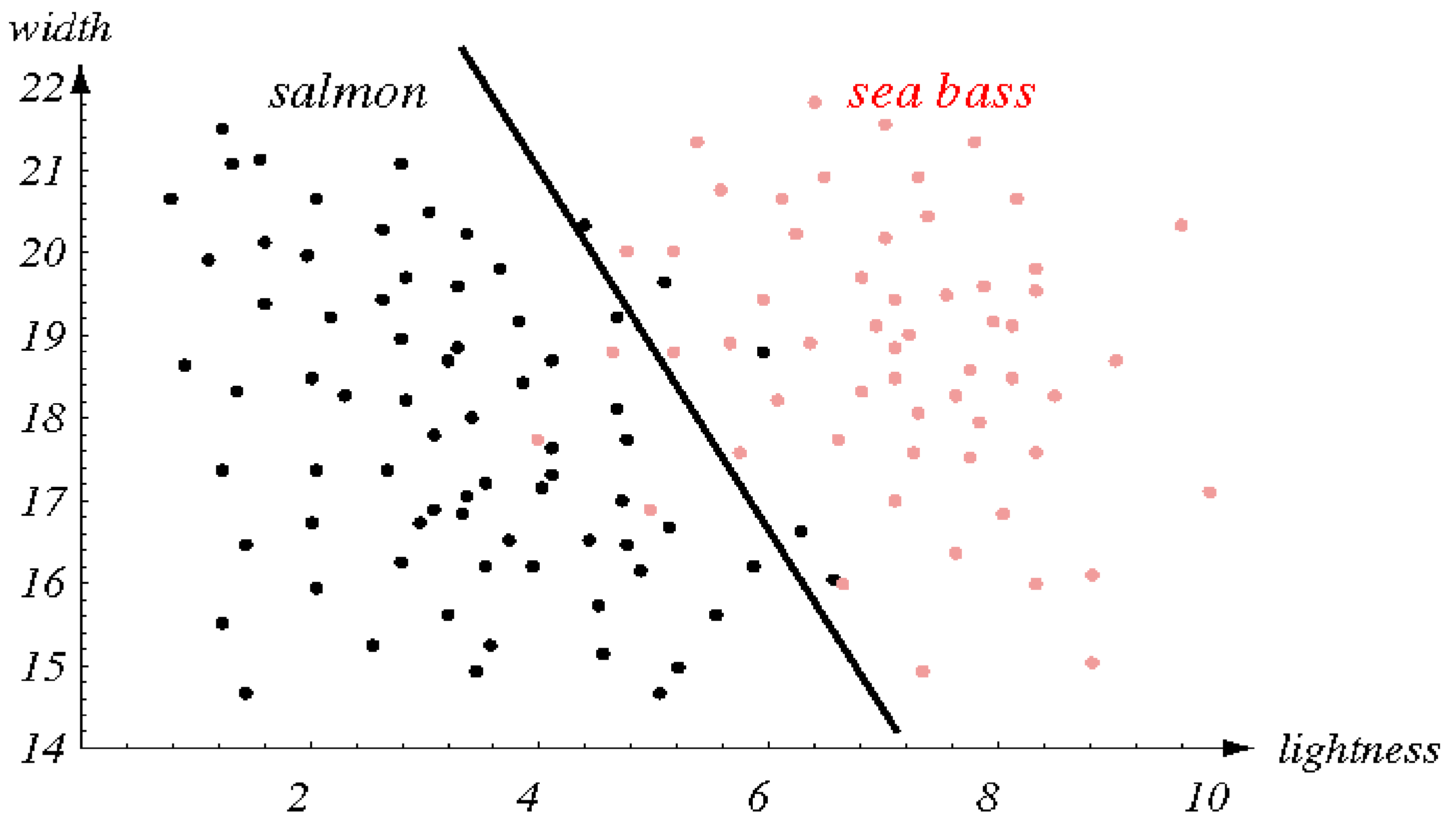
We should also consider *costs of different errors* we make in our decisions.

- For example, if the fish packing company knows that:
  - Customers who buy salmon will object vigorously if they see sea bass in their cans.
  - Customers who buy sea bass will not be unhappy if they occasionally see some expensive salmon in their cans.
- How does this knowledge affect our decision?

An Example: Multiple Features

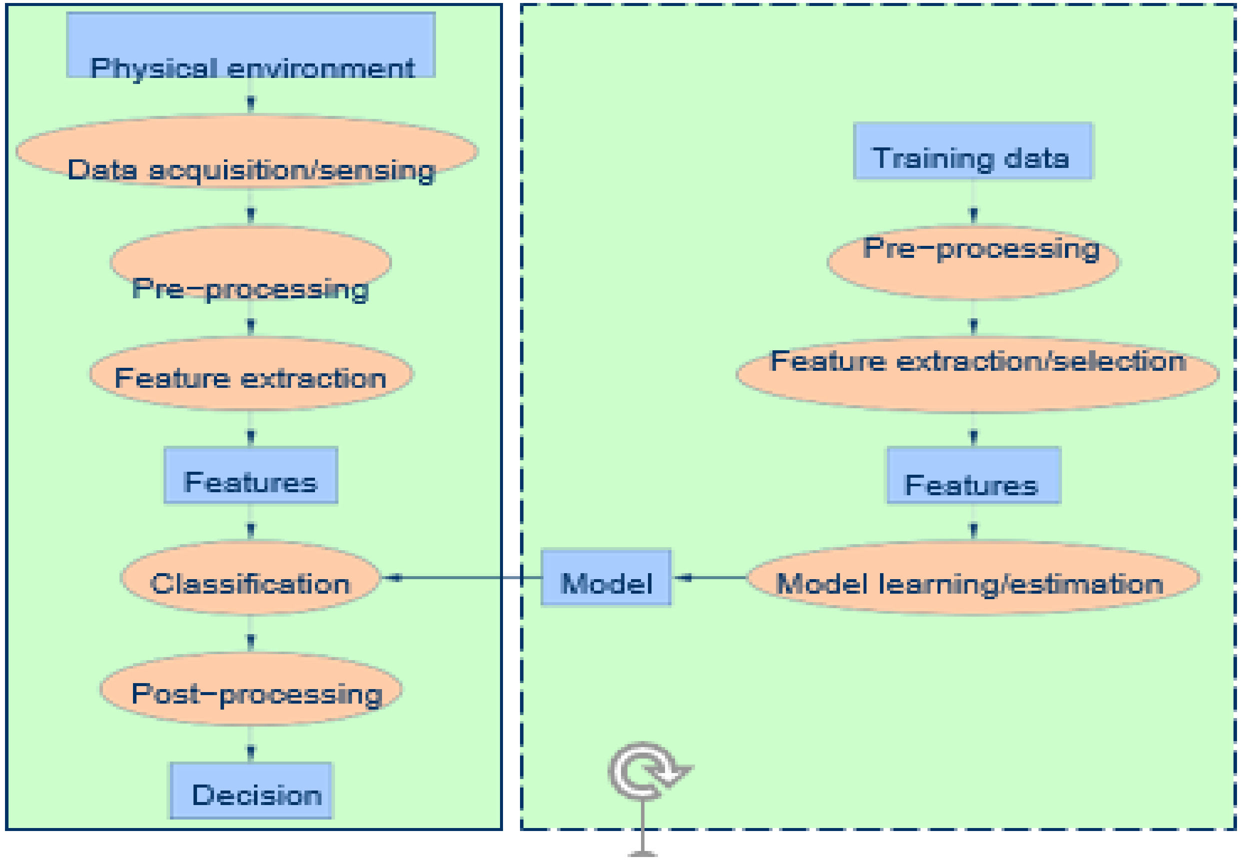
- ◭ Assume we also observed that sea bass are typically wider than salmon.
- ◭ We can use two features in our decision:
- ◭ lightness: x_1
- ◭ width: x_2
- ◭ Each fish image is now represented as a point (*feature vector*):
  - X = {X1, X2} in a two-dimensional feature space.

An Example: Multiple Features



- Figure: *Scatter plot* of lightness and width features for training samples. We can draw a *decision boundary* to divide the feature space into two regions. Does it look better than using only lightness?

Pattern Recognition Systems



- Figure: Object/process diagram of a pattern recognition system

Pattern Recognition Systems

Data acquisition and sensing:

- Measurements of physical variables.
- Important issues: bandwidth, resolution, sensitivity, distortion, SNR, latency, etc.

- Pre-processing:
  - Removal of noise in data.
  - Isolation of patterns of interest from the background.
- Feature extraction:
  - Finding a new representation in terms of features.

Pattern Recognition Systems

Model learning and estimation:

- Learning a mapping between features and pattern groups and categories.

- Classification:
  - Using features and learned models to assign a pattern to a category.
- Post-processing:
  - Evaluation of confidence in decisions.
  - Exploitation of context to improve performance.
  - Combination of experts.

Summary

Pattern recognition techniques find applications in many areas: machine learning, statistics, mathematics, computer science, biology, etc.

- There are many sub-problems in the design process.
- Many of these problems can indeed be solved.
- More complex learning, searching and optimization algorithms are developed with advances in computer technology.
- There remain many fascinating unsolved problems.