Algorithm Research and Advances in Pattern Recognition

Chapter 1: Introduction to Pattern Recognition (Sections 1.1-1.6)

- What is Pattern Recognition
- Machine Perception
- An Example
- Pattern Recognition Systems
- The Design Cycle
- Learning Paradigms
- Conclusion

What is Pattern Recognition

- A **pattern** is a form, template, or model (or, more abstractly, a set of rules) which can be used to make or to generate things or parts of a thing, especially if the things that are generated are common enough for the underlying pattern to be inferred or discerned, in which case the things are said to *exhibit* the pattern. The detection of underlying patterns is called pattern recognition

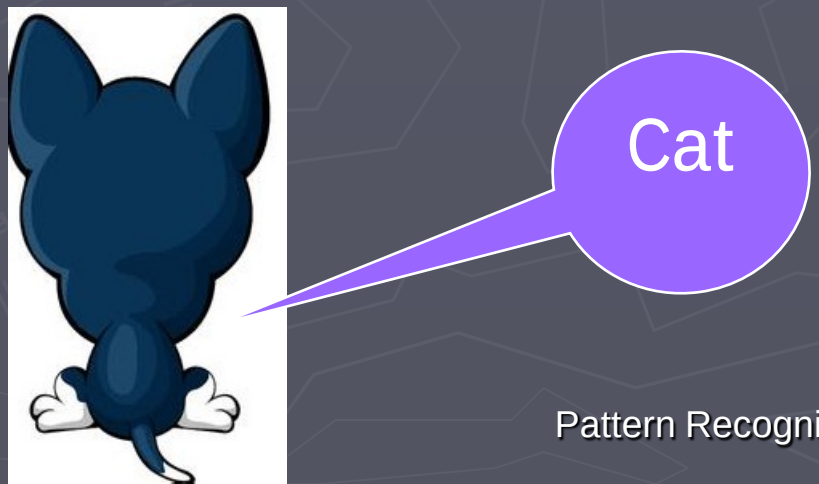
- Pattern Examples

  Students study

  Teachers teach lessons

  Pattern: n. + verbal phrase

- In layman terms: take in raw data to describe a **pattern** **(sample)**and then assign a **category** or **class** to the pattern



A widely used technology

- (PR Target) Build a machine that can recognize patterns, for example:
  - Speech recognition
  - Fingerprint identification
  - OCR (Optical Character Recognition)
  - etc

Pattern recognition technology has been used in almost all of the fields

A Pitfall of the World Wide Web

"On the Internet, nobody knows you're a dog."

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BIOMETRICS

- Large-scale SDKs
- Fingerprint SDKs
- Face SDKs
- Eye iris SDKs
- Voice SDKs
- End user products

A.I. & ROBOTICS

- Research
- Computer vision SDKs
- End user products

RESOURCES

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ORDERING

- Licensing model
- Prices
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SERVICES

VeriSpeak SDK

Speaker recognition for PC or Web applications

VeriSpeak voice identification technology is designed for biometric systems developers and integrators. The text-dependent speaker recognition algorithm assures system security by checking both voice and phrase authenticity. Voiceprint templates can be matched in 1-to-1 (verification) and 1-to-many (identification) modes.

VeriSpeak is available as a software development kit that enables the development of PC- and Web-based applications on Microsoft Windows, Linux and Mac OS X platforms.

Download **VeriSpeak SDK brochure** (PDF)

Advantages of VeriSpeak

- **Text-dependent algorithm prevents unathorized access with a covertly recorded user voice.**
- **Two-factor authentication by checking voice biometrics and pass phrase authenticity.**
- **Regular microphones are suitable for recording user voices.**
- **Available as a multiplatform SDK that supports multiple programming languages.**
- **Reasonable prices, flexible licensing and free customer support.**

Technology and SDK

PRODUCTS

MegaMatcher SDK
AFIS or multi-biometric fingerprint, iris, face and voice identification for large-scale systems.
Read more

VeriLook SDK
Face identification for PC or Web solutions.
Read more

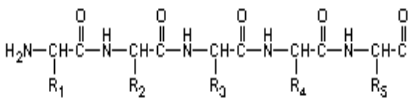
VeriFinger SDK
Fingerprint identification for PC and Web solutions.
Read more

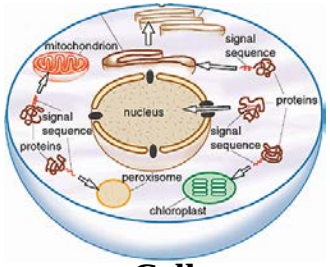
VeriEye SDK
Iris identification for PC and Web solutions.
Read more

VeriSpeak SDK
Speaker recognition for PC or Web applications.
Read more

Sequence, Structure and Function

AGCWY……

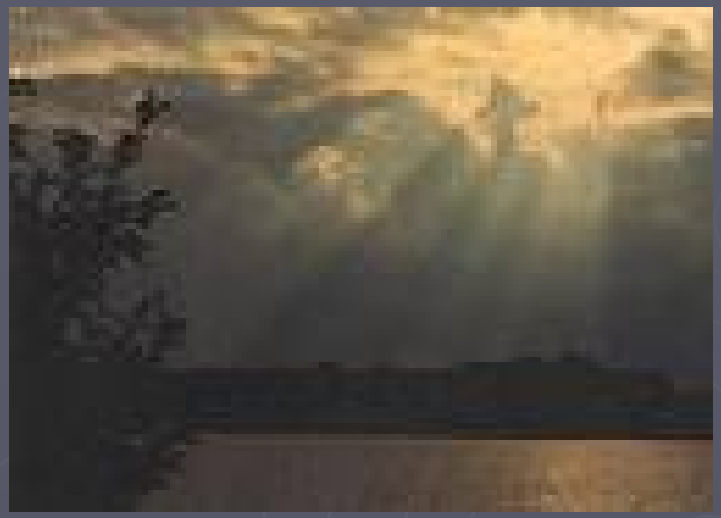


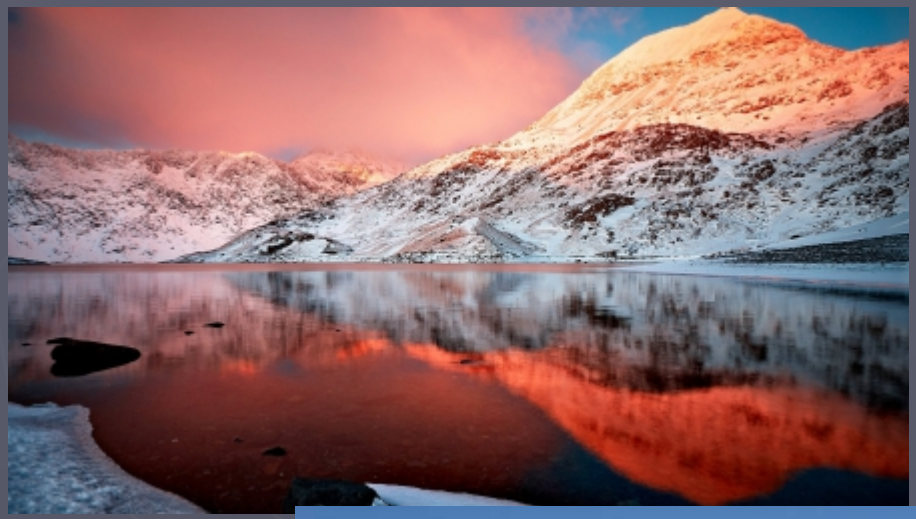


Cell


Tree Label Training
paved road
building
ground
crop
grass
pine
decidious
water
Add
Remove
AERIAL::BAND1 - AERIA
AERIAL::BAND2 - AERIA
AERIAL::BAND3 - AERIA
AERIAL_BAND1_GABO
AERIAL_BAND1_GABO
IKONOS2_SUB::BAND3
IKONOS2_SUB::BAND4
Add
Remove
Fort Subset, Image 8, Tile 8
Probability
Classification
Segmentation
Load Tile
Update
Undo
Show Info
Show Tree
Show Rules

Cloud Patterns



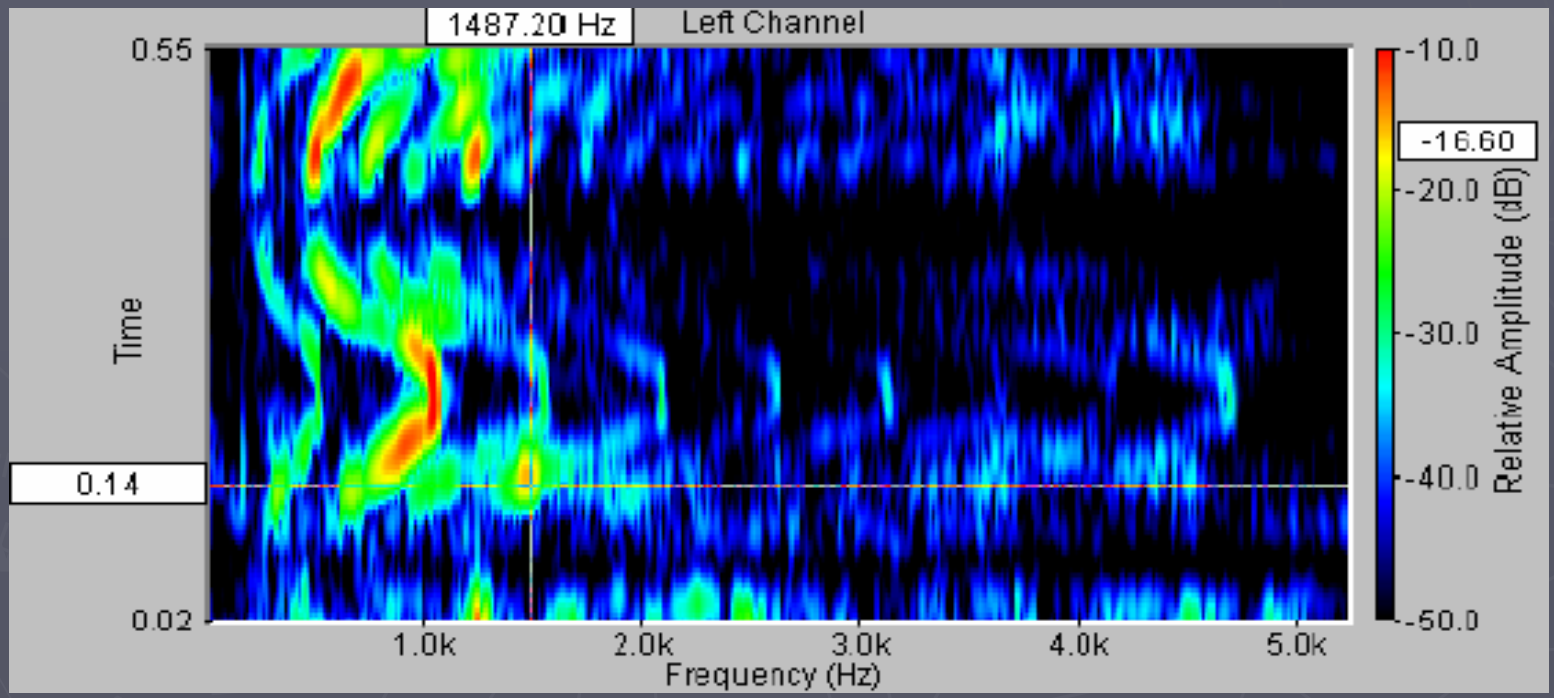



ChaoFace


昵图网 www.nipic.com

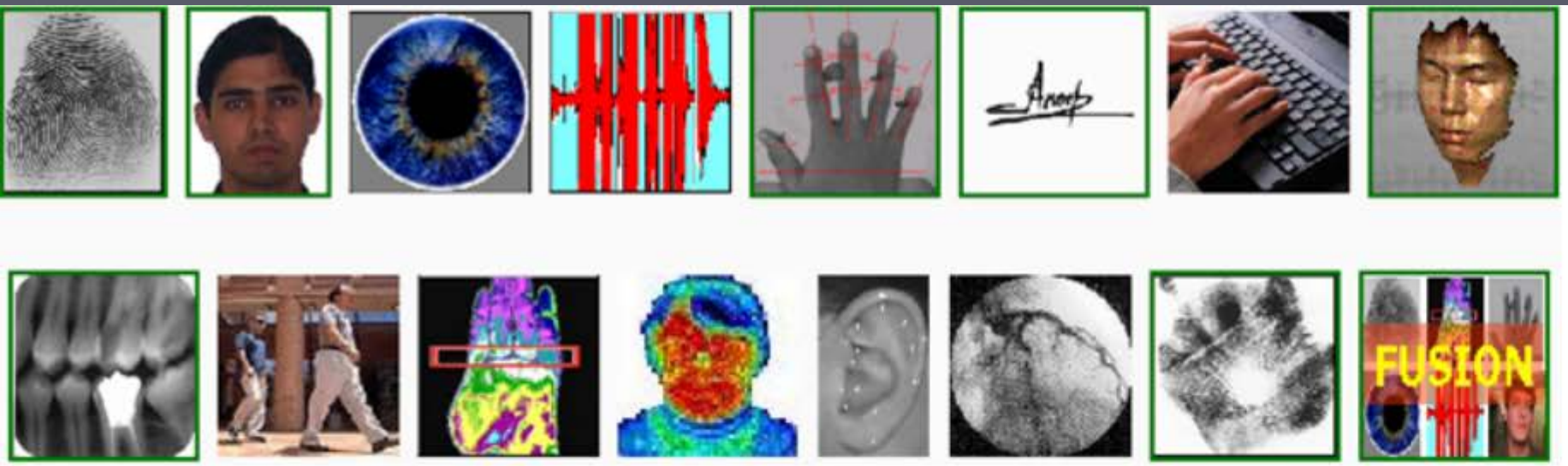
Example: Speech Recognition

- **Input Raw Data**: speech waveform



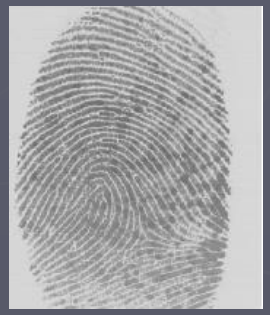
- **Output categories**: spoken words

- **Example: Fingerprint Verification**
  - **Input Raw Data**: fingerprint image



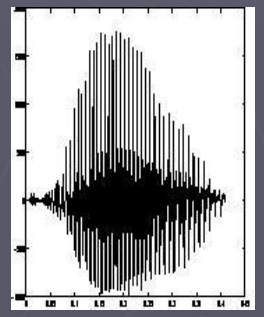
Biometrics recognition technology

Face



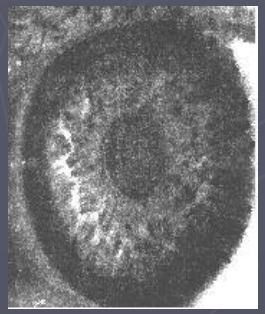
Fingerprint

Hand Shape



Sound

Palmprint



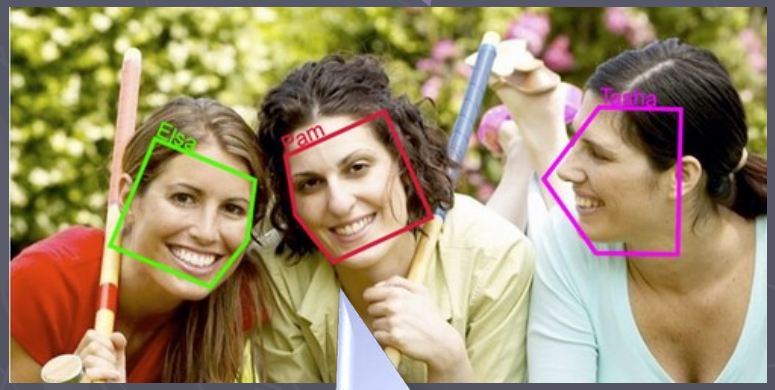
Iris

Finger print application

The finger print recognition in Iphone5, which can used to lock/unlock the phone.

fingerprint time attendance system

Face Recognition?



1. Is there any body in the pic? (detection)

2.Is it a human face? (verification)

3.Who is that? (recognition)

Face Recognition in Camera.

- Face detection.
- Focus on the human face.

- Detect the human smile.
- Capture the happy moment.

Face Recognition in spy

- Detect human faces.
- Find out the criminal

Face Recognition in our life

Finland developed the world first face recognition payment system.

Difficulty in Face Recognition

Face expression of the same people are different in different time and different place.

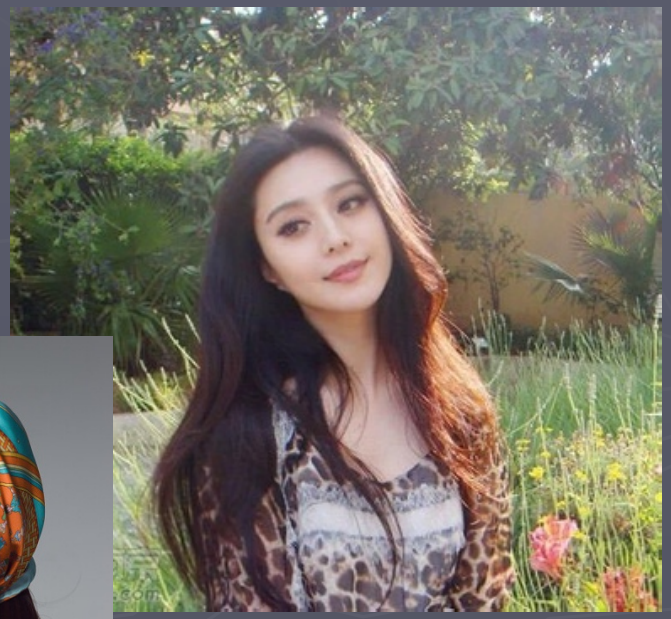
How to recognition?

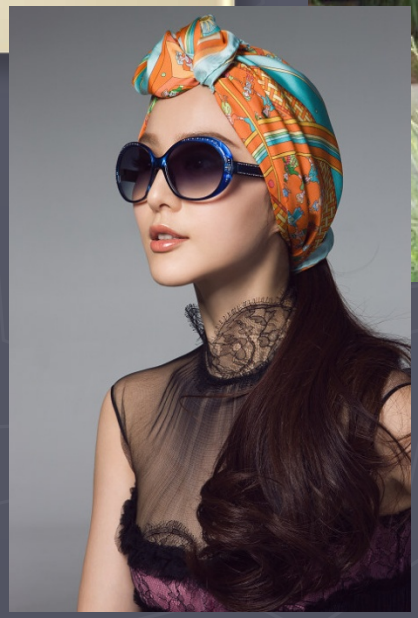
Difficulty in Face Recognition

People may were glasses/hat/scarf.

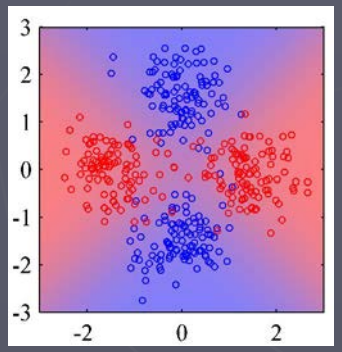
Which make he/she look very different.

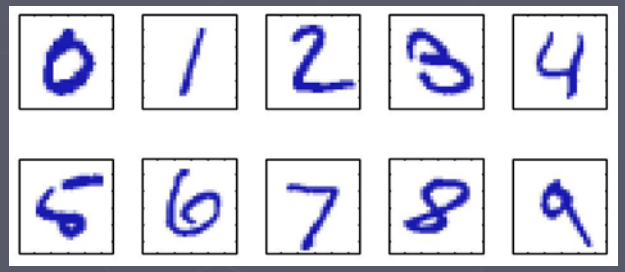
How to recognition?

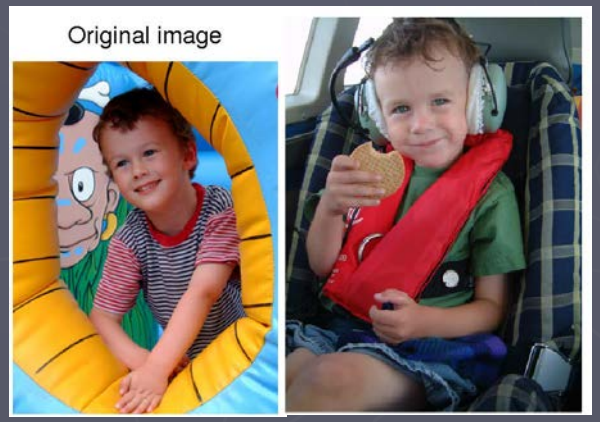




Other examples of patterns







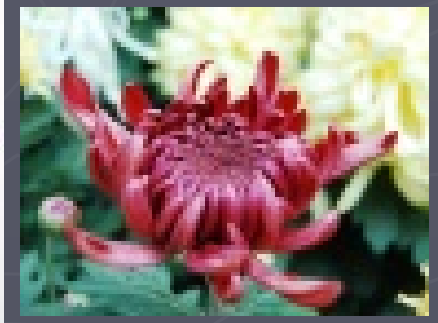


Figure 10: License plate recognition: US license plates.

Table 1: Example pattern recognition applications.

Problem Domain	Application	Input Pattern	Pattern Classes
Document image analysis	Optical character recognition	Document image	Characters, words
Document classification	Internet search	Text document	Semantic categories
Document classification	Junk mail filtering	Email	Junk/non-junk
Multimedia database retrieval	Internet search	Video clip	Video genres
Speech recognition	Telephone directory assistance	Speech waveform	Spoken words
Natural language processing	Information extraction	Sentences	Parts of speech
Biometric recognition	Personal identification	Face, iris, fingerprint	Authorized users for access control
Medical	Computer aided diagnosis	Microscopic image	Cancerous/healthy cell
Military	Automatic target recognition	Optical or infrared image	Target type
Industrial automation	Printed circuit board inspection	Intensity or range image	Defective/non-defective product
Industrial automation	Fruit sorting	Images taken on a conveyor belt	Grade of quality
Remote sensing	Forecasting crop yield	Multispectral image	Land use categories
Bioinformatics	Sequence analysis	DNA sequence	Known types of genes
Data mining	Searching for meaningful patterns	Points in multidimensional space	Compact and well-separated clusters

MOTIVATION FOR THE STUDY OF PATTERN RECOGNITION

It is threefold.

- It is an essential part of the broader field of Artificial Intelligence, which is concerned with techniques, that enable computers to do things, that seem intelligent when done by people.

- It is an important aspect of applying computers to solve problems in science and engineering, since many of them involve analysis and classification of measurements, taken from physical processes.

- Pattern Recognition techniques provide a unified frame work to study a variety of techniques, in mathematics and computer science, that are individually useful in many different applications.

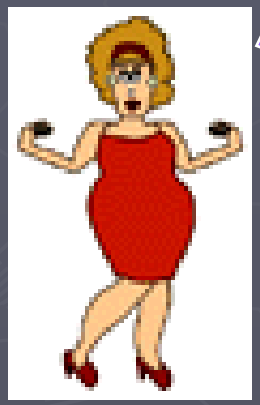
I think it's fair to say that personal computers have become the most empowering tool we've ever created. They're tools of communication, they're tools of creativity, and they can be shaped by their user.---**Bill Gates**

Bill also said that our final goal would be to make the computer able to listen, see and speak!!

Basic goal

- Assign a proper label to a new pattern (sample)

known



Woman

Man

unknown

Woman or man ??

How to a system work: simple demo

- Face recognition

An example

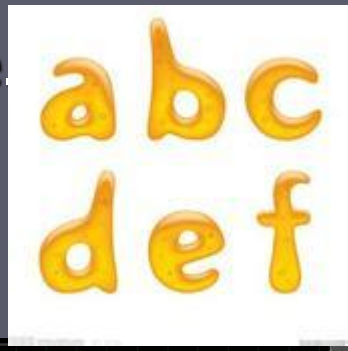
Another example

TYPE OF PATTERNS

1.SPATIAL PATTERNS- These patterns are located in space.

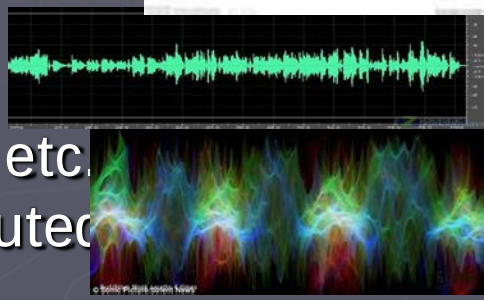
Eg:- characters in character recognition

* images of ground covers in remote sensing
* images of medical diagnosis.



2.TEMPORAL PATTERN-These are distributed in time.

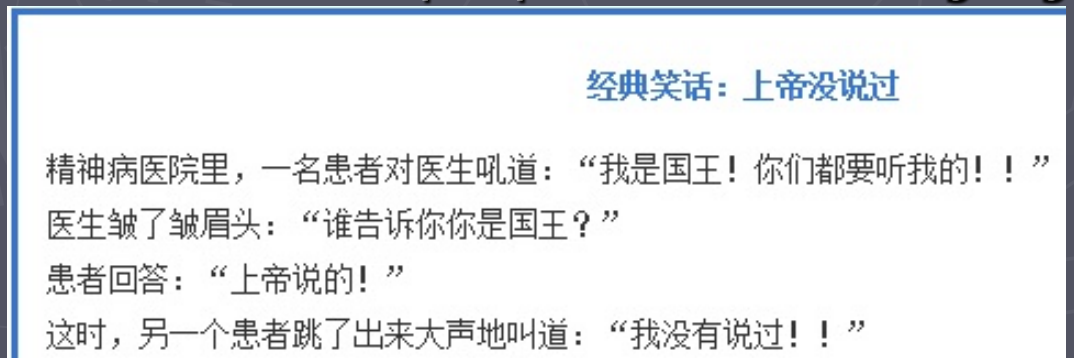
Eg:- Radar signal, speech recognition, sonar signal etc.



3.ABSTRACT PATTERNS-Here the patterns are distributed space nor time.

Eg:- classification of people based on psychological tests.

* Medical diagnosis based on medical history and other medical tests.
* Classification of people based on language they speak.



经典笑话：上帝没说过

精神病医院里，一名患者对医生吼道：“我是国王！你们都要听我的！！”

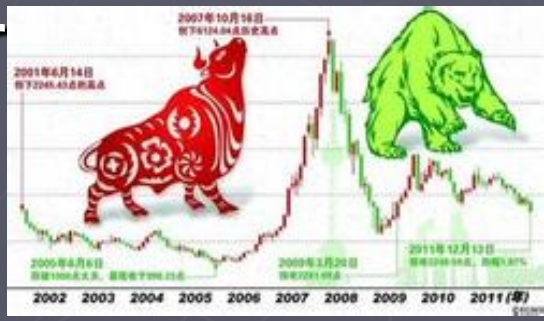
医生皱了皱眉头：“谁告诉你你是国王？”

患者回答：“上帝说的！”

这时，另一个患者跳了出来大声地叫道：“我没有说过！！”

APPROACH TO PATTERN RECOGNITION

1. Statistical or decision theoretic or discriminant method.



2. Syntactic or Grammatical or structural approach.

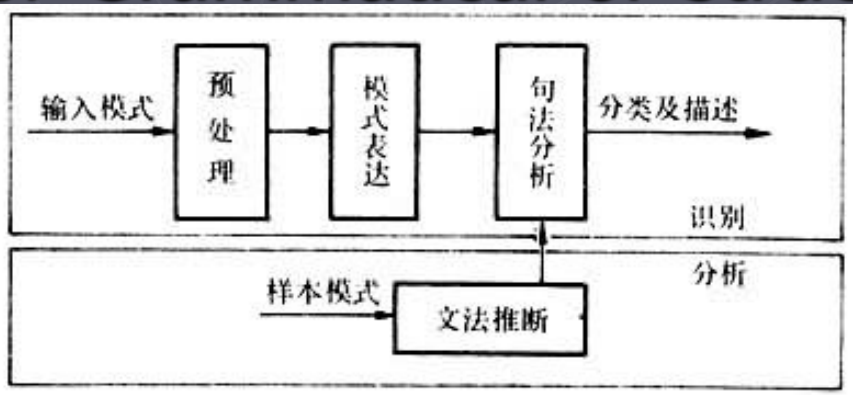


图1　句法模式识别系统框图

STATISTICAL APPROACH:

Using statistics to determine the relationship

between inputs and outputs

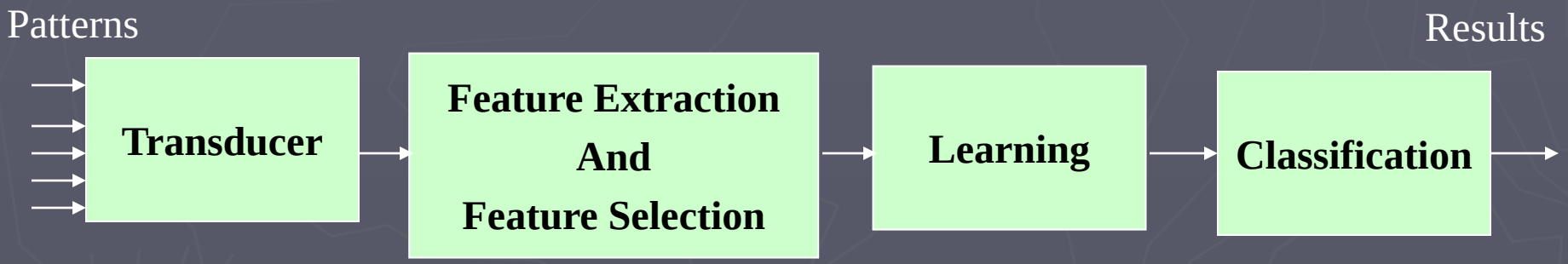


Fig1.1: Block diagram representation of statistical approach

Transducer : It is used for making measurements for various attributes of the pattern.

Feature Extractor: From the measurements, it extracts, number of features which are required for describing the pattern and classifying.

Feature selector : Depending on the problem the feature selector selects minimum number of features that are sufficient to classify the pattern.

STATISTICAL APPROACH

There are two feature selector methods.

1.Transformation Method :

Here we reduce the features by considering the linear or nonlinear combinations of original features. This is also called as aggregation method.

Eg:- let us assume originally we have four features f1,f2,f3,f4.

One method of selecting two features is

f5 = f1 + f2

f6 = f3 + f4.

2.Subsetting or filtering Method:

Here we select a subset of the original features.

Eg:- Original features are f1,f2,f3,f4.

We can select a subset like

f5 = f1 and f6 = f3.

Learning : It is a process of determining useful parameters which are required for classifying the patterns efficiently.

Classifying: Here the patterns are assigned to different classes using a suitable classification method as shown in the fig 1.1

Classification Method

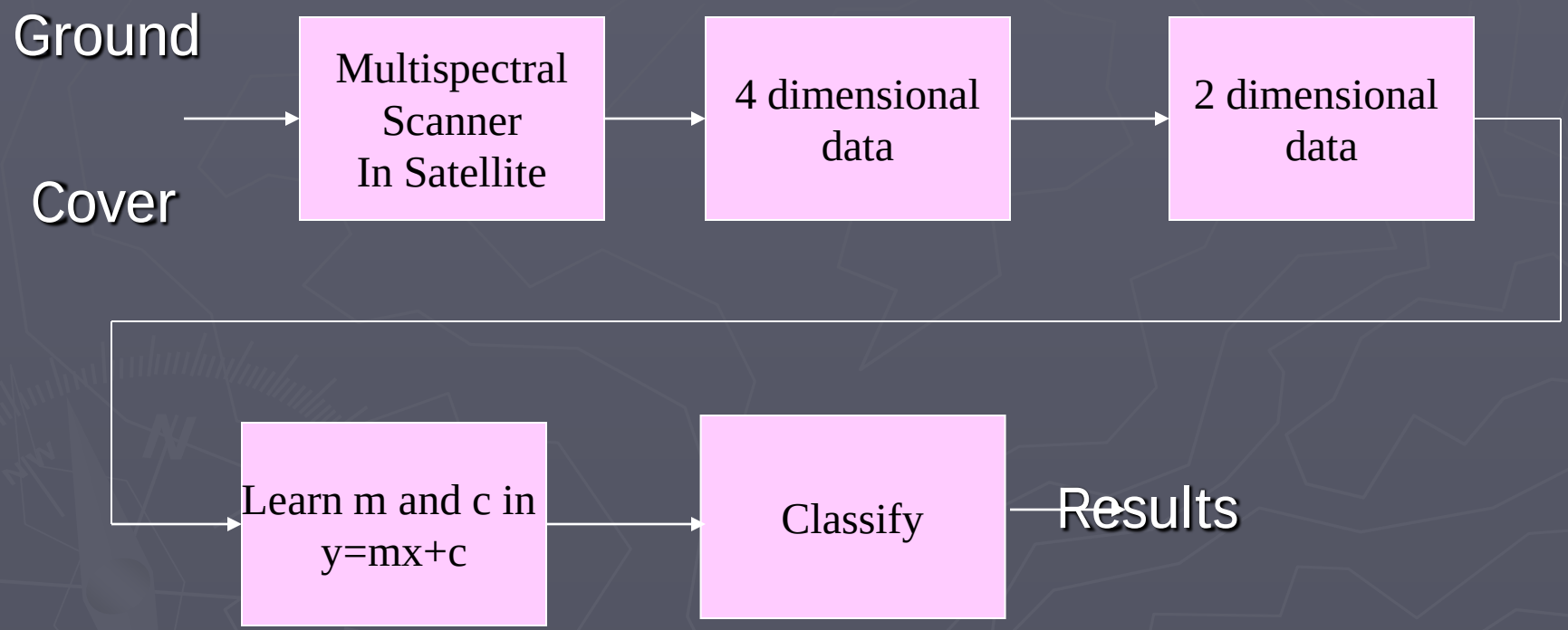


Fig : A Classification Method

SYNTACTIC APPROACH

Here we use the analogy between the structures of a pattern and the structure of sentence, written using a grammar.

E.g.: Rama was a very good king.

Here we decompose the pattern into sub-patterns called primitives when primitives are combined together using a certain syntax rule, we get the original pattern. So this method consists of parsing the pattern using a syntax rule.

Advantages : It classifies the pattern.

It describes the pattern.

MACHINE PERCEPTION

It is natural that we should seek to design and build machines that can recognize patterns. From automated speech recognition, fingerprint identification, optical character recognition, DNA sequence identification, and much more, it is clear that reliable, accurate pattern recognition by machine would be immensely useful. Moreover, in solving the myriad problems required to build such systems, we gain deeper understanding and appreciation for pattern recognition systems in the natural world- most particularly in humans. For some problems, such as speech and visual recognition, our design efforts may in fact be influenced by knowledge of how these are solved in nature, both in the algorithms we employ and in the design of special-purpose hardware.

- **Example: Character Recognition**
  - **Input Raw Data**: image

  - **Output categories**: characters

Difficulty in Face Recognition

Different people have very similar face, as twins.

How to recognition them?

Difficulties

- Similar patterns of different classes

How to correctly distinguish the blue sky from blue water?!

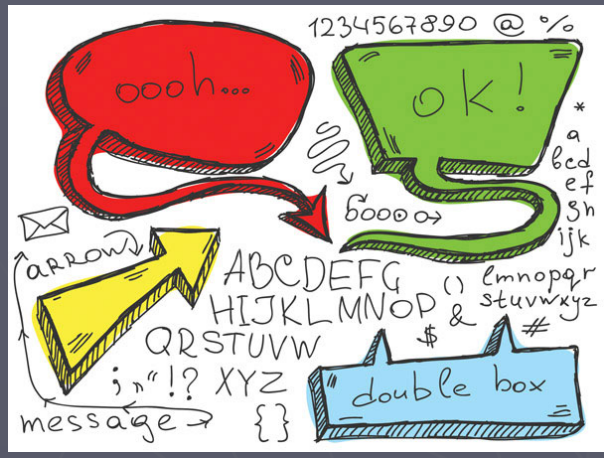
- Noise

Zhou Bichang ?

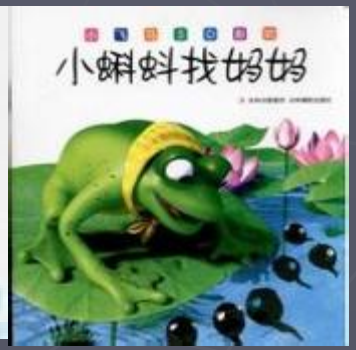
- Outlier

The men more beautiful than women!: Italian

Difficulties



- Similar characteristics etc.
- Deformable patterns



轻松一刻：某男拿着医生开的处方在医院里转了半天，回来问：“13超到底在
女医生笑曰：“那不是13超，是B超。”

Story: this is not a person !

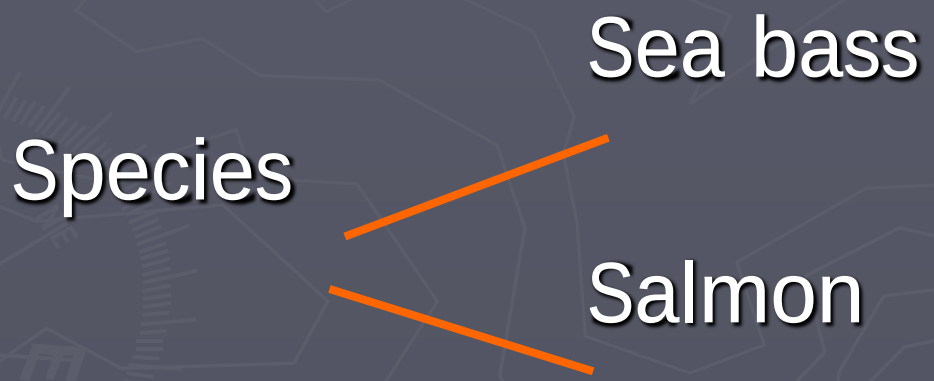
万能处方

来源：http://www.xxhh.net/ 关键词： 92429人浏览

爆笑笑话推荐:病人去做体检，大夫用他常人难辩的字迹开了张处方，病人把处方揣进袋里，忘了去拿药。有两年的时间，他每天早晨把处方当作铁路通行证出示给检票 员；还用它进了两次电影院，一次棒球场和一次交响音乐会；用它冒充老板的字 条得到一次提升。一天，这个人把处方弄丢了，他的女儿捡到后，在钢琴上照其 演奏，结果获得了进公立音乐学院的机会。

An Example With More Details

- Sorting incoming Fish on a conveyor belt according to species using optical sensing

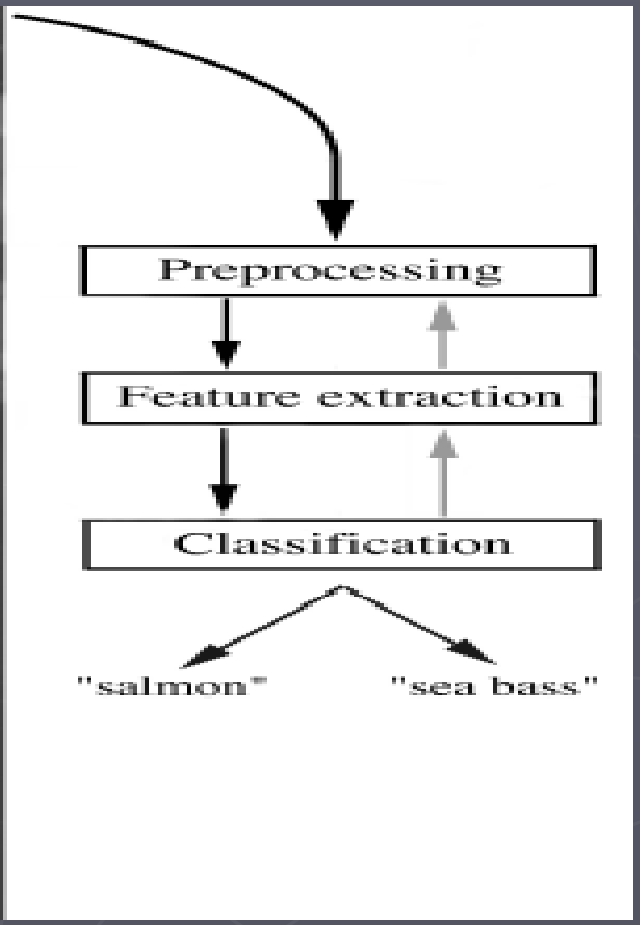


- Sensing
  - Set up a camera and take some sample images to extract features
    - Length
    - Lightness
    - Width
    - Number and shape of fins
    - Position of the mouth, etc…
    - This is the set of all suggested features to explore for use in our classifier!

Other application

- Preprocessing
  - Use a segmentation operation to isolate fishes from one another and from the background
- Information from a single fish is sent to a feature extractor whose purpose is to reduce the data by measuring certain features
- The features are passed to a classifier

Gray images are used:
the pixel value is in the range of 0-255

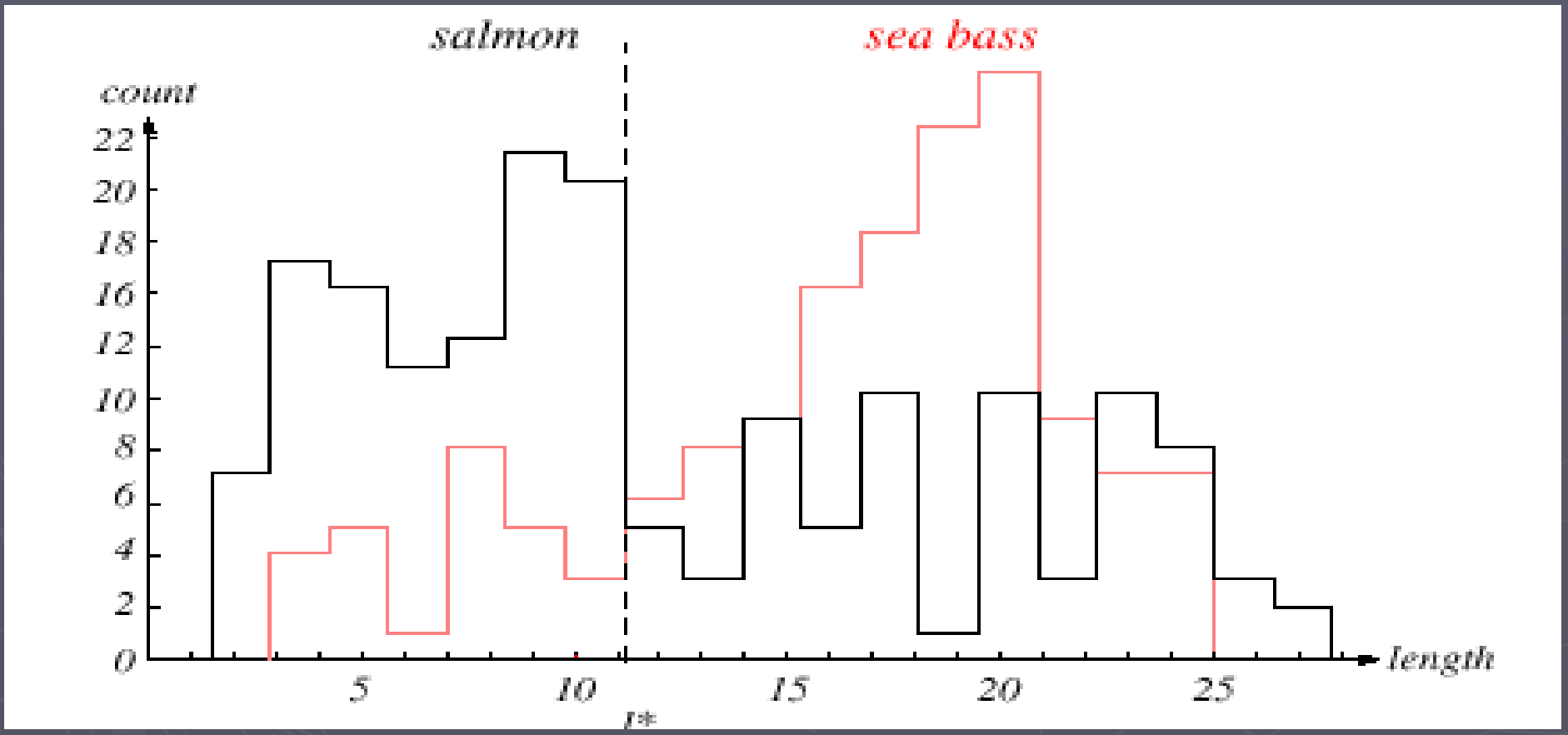


A large pixel value means that the pixel is bright in vision

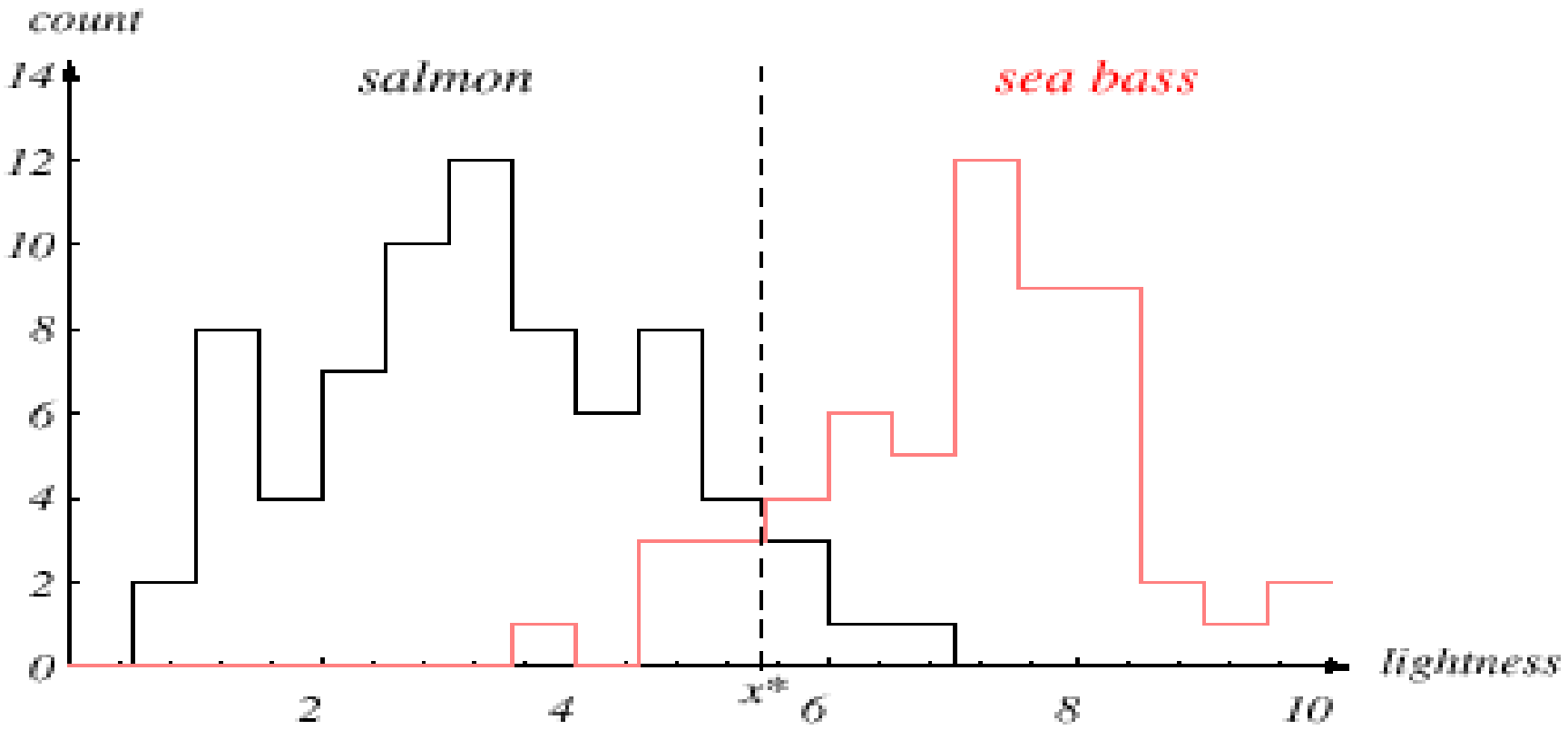
- Classification

How to select the feature?

Black Swan


salmon
sea bass
count
22
20
18
16
12
10
8
6
4
2
0
5
10
15
20
25
length
l*

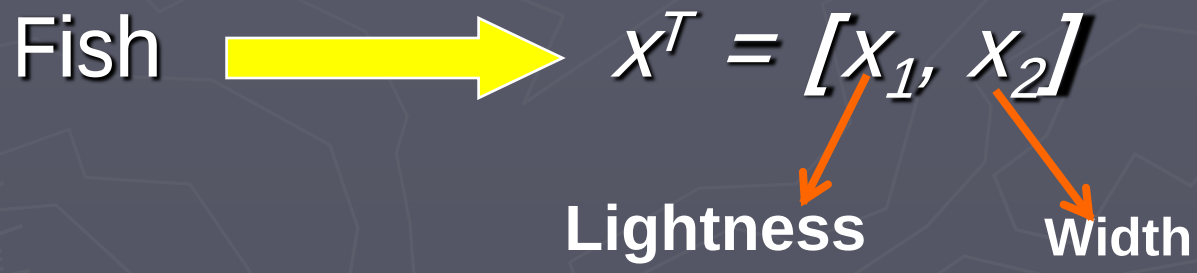
- The length is a poor feature alone!
- Select the lightness as a possible feature.

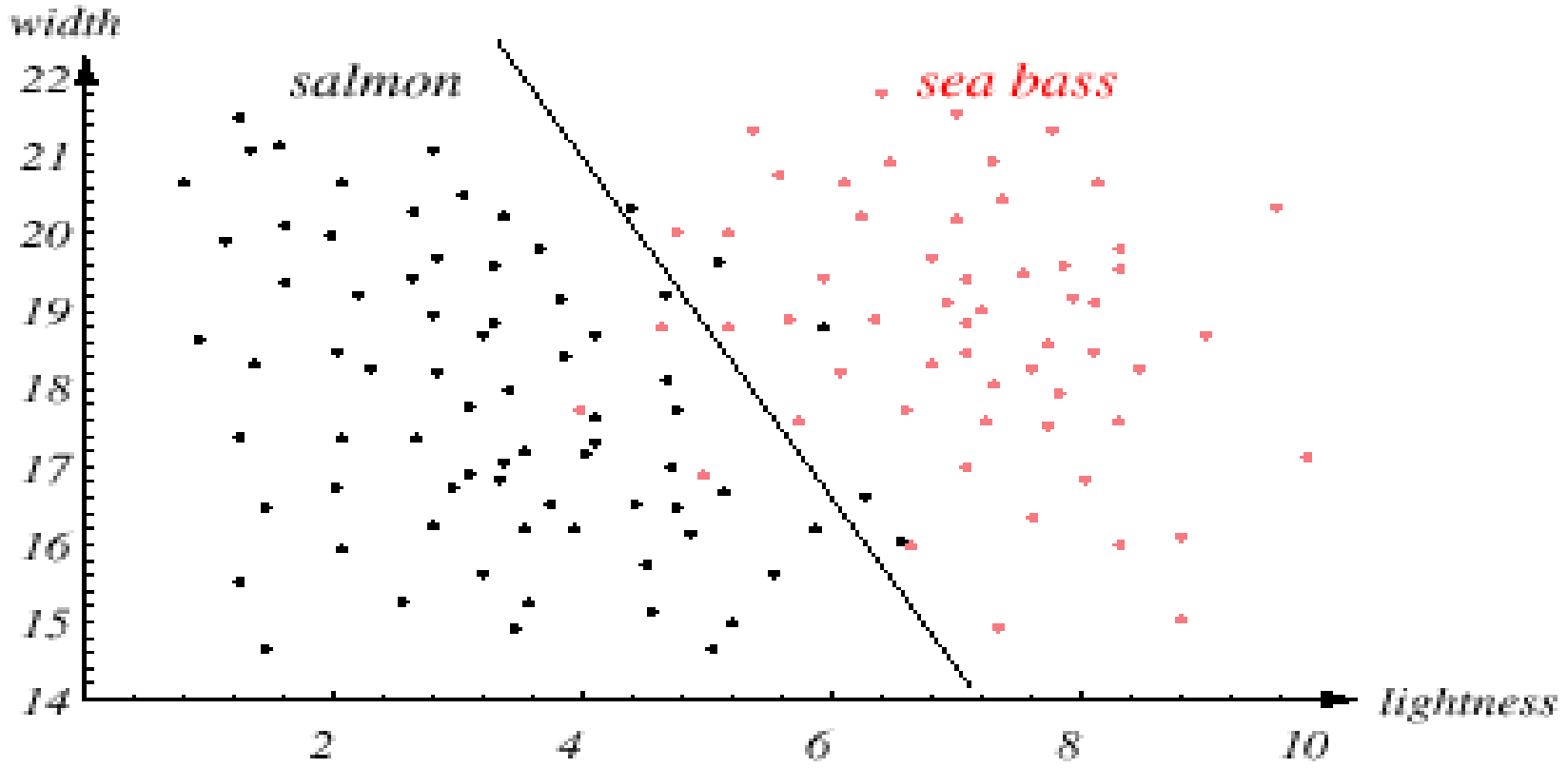

count
salmon
sea bass
14
12
10
8
6
4
2
0
2
4
x*
6
8
10
lightness

- Threshold decision boundary and cost relationship
  - Move our decision boundary toward smaller values of lightness in order to minimize the cost (reduce the number of sea bass that are classified salmon!)

Task of decision theory

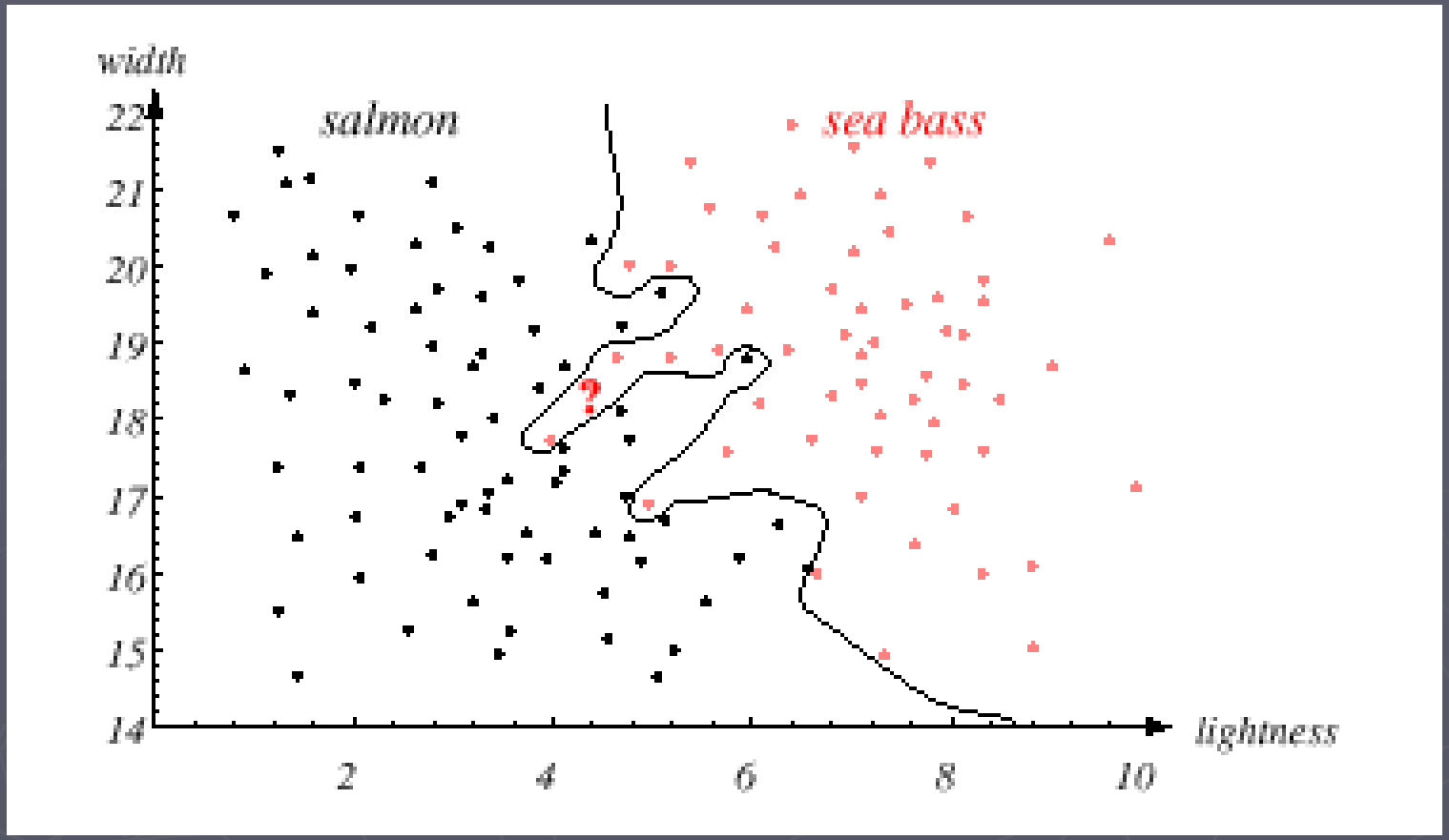
- Adopt the lightness and add the width of the fish




width
22
21
20
19
18
17
16
15
14
salmon
sea bass
2
4
6
8
10
lightness

- We might add other features that are not correlated with the ones we already have. A precaution should be taken not to reduce the performance by adding such “noisy features”

- Ideally, the best decision boundary should be the one which provides an optimal performance such as in the following figure:



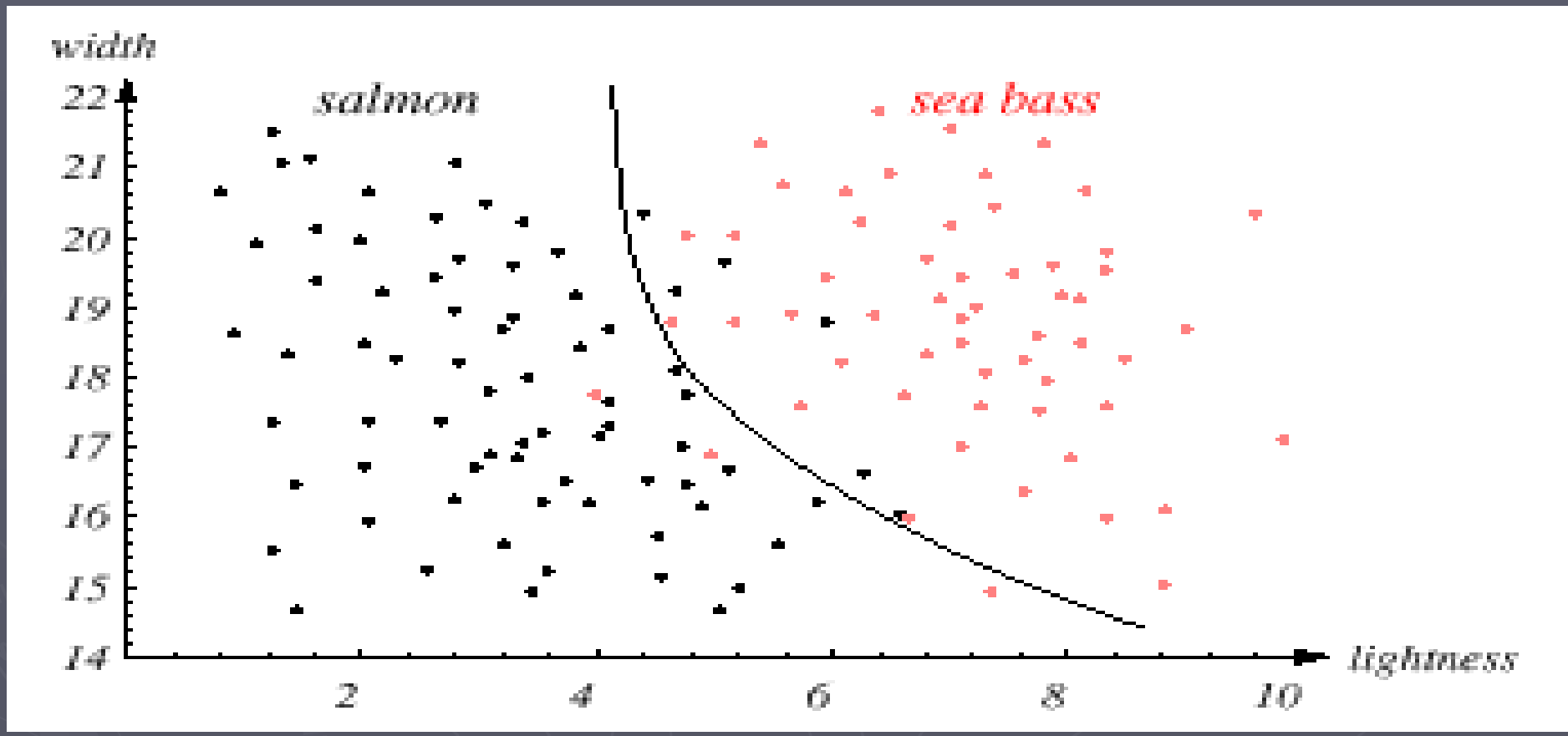
The decision boundary with high complexity means that unseen samples (patterns) cannot be recognized very well (poor generalization).

某企业引进一条香皂包装生产线，结果发现经常有空盒流过。厂长请一个博士后花了200万设计出了自动分检系统。一乡镇企业遇到同样问题，农民工花90元买一大电扇放在生产线旁，有空盒经过便被吹走。

- However, our satisfaction is premature because the central aim of designing a classifier is to correctly classify novel inputs

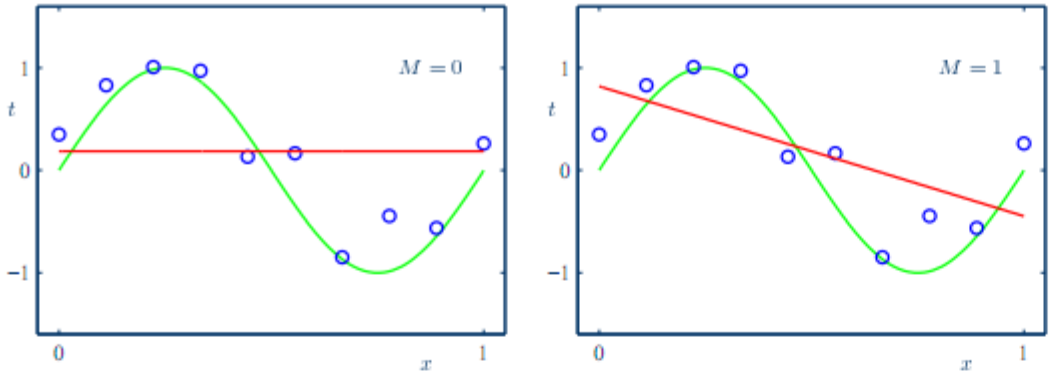
Issue of poor generalization!!


If the algorithm just “remembers” that the rose is only red or pink then it cannot correctly recognize the following blue rose as a rose

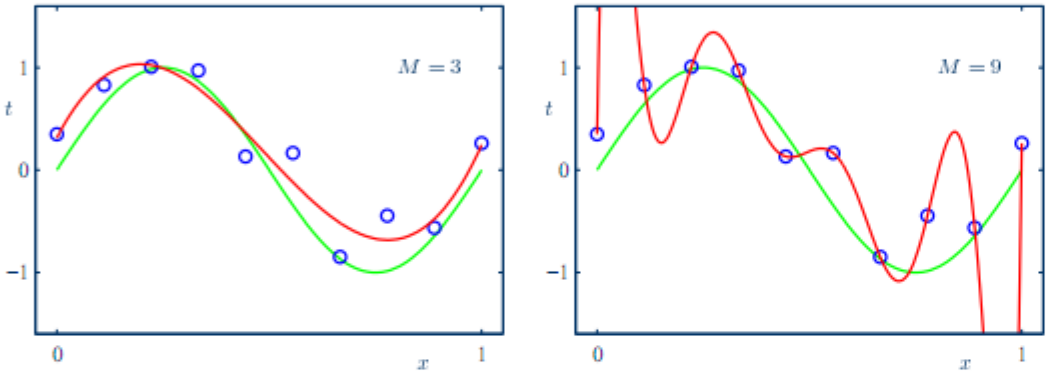


Tradeoff between the complexity of the decision boundary and classification correct rate

Algorithms with proper low complexity is favored



(a) 0'th order polynomial (b) 1'st order polynomial



(c) 3'rd order polynomial (d) 9'th order polynomial

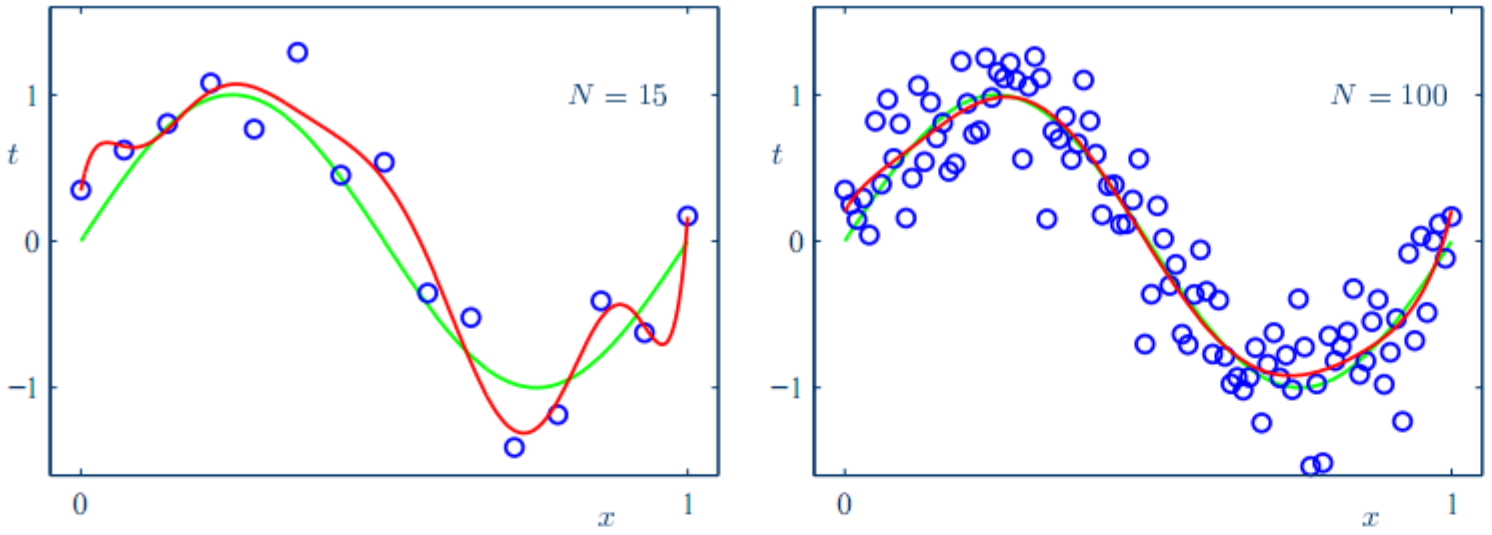
Figure 19: Polynomial curve fitting: plots of polynomials having various orders, shown as red curves, fitted to the set of 10 sample points.

- Total principles
  - Algorithms (classifiers) should be not complex.
  - Error on training samples should be low.

- Why SVM is good ?
- Subject to the above total principles
  - To minimize the structural risk (to seek simple algorithms)
  - To minimize the empirical risk (to seek minimal errors on training samples)

- Potential of SVM
  - Able to perform well for a small-scale sample set.
  - Previous statistical pattern classification algorithms can obtain optimal results under the condition that there are “infinite” or sufficient sample.

More training samples are better



(a) 15 sample points (b) 100 sample points

Figure 20: Polynomial curve fitting: plots of 9'th order polynomials fitted to 15 and 100 sample points.

- Evaluation
  - A classifier model not only should learn to classify the training samples, but it should also be able to **generalize** its classification ability to **unseen** test samples.

  - Generalization error rate

Classification error rate of a trained classifier tested on a sufficiently large set of test samples.

Generalized ability

- Low error rate on training samples
- Low error rate on test samples

Generalize well

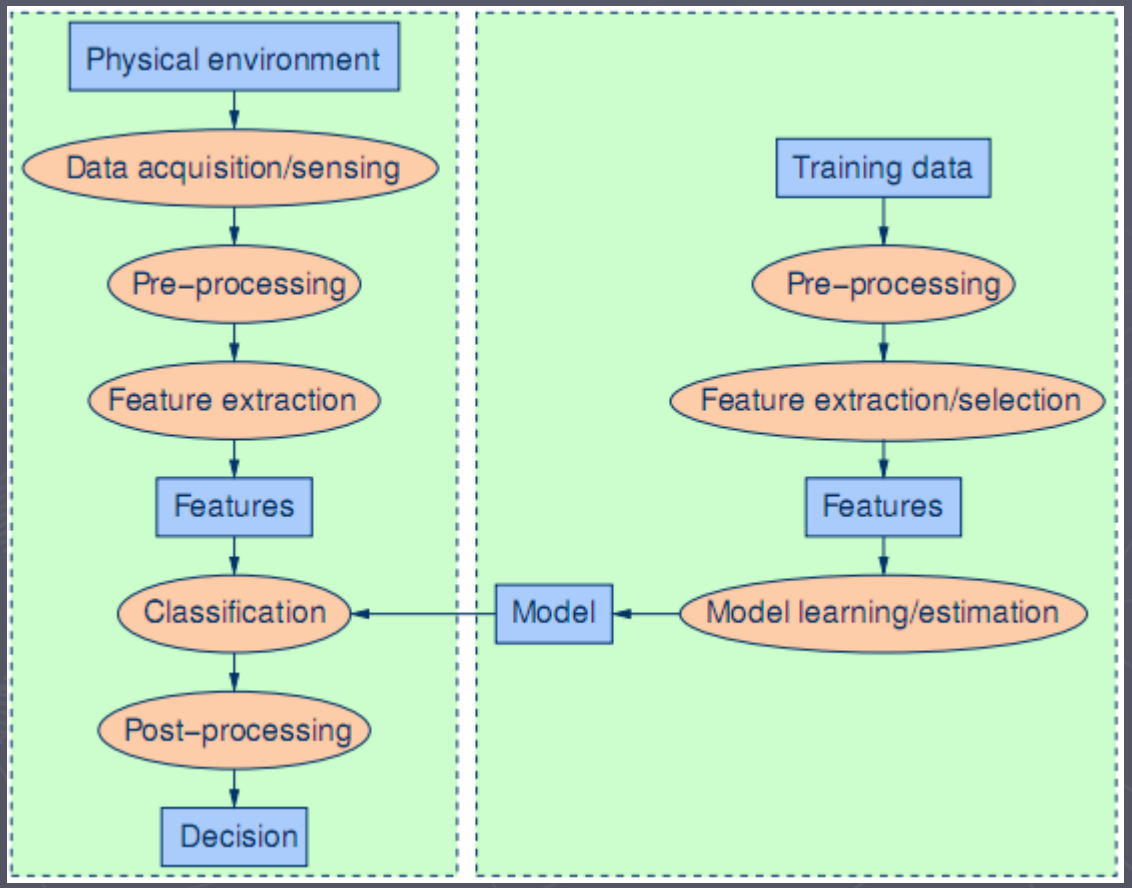
- Low error rate on training samples
- Relatively high error rate on test samples

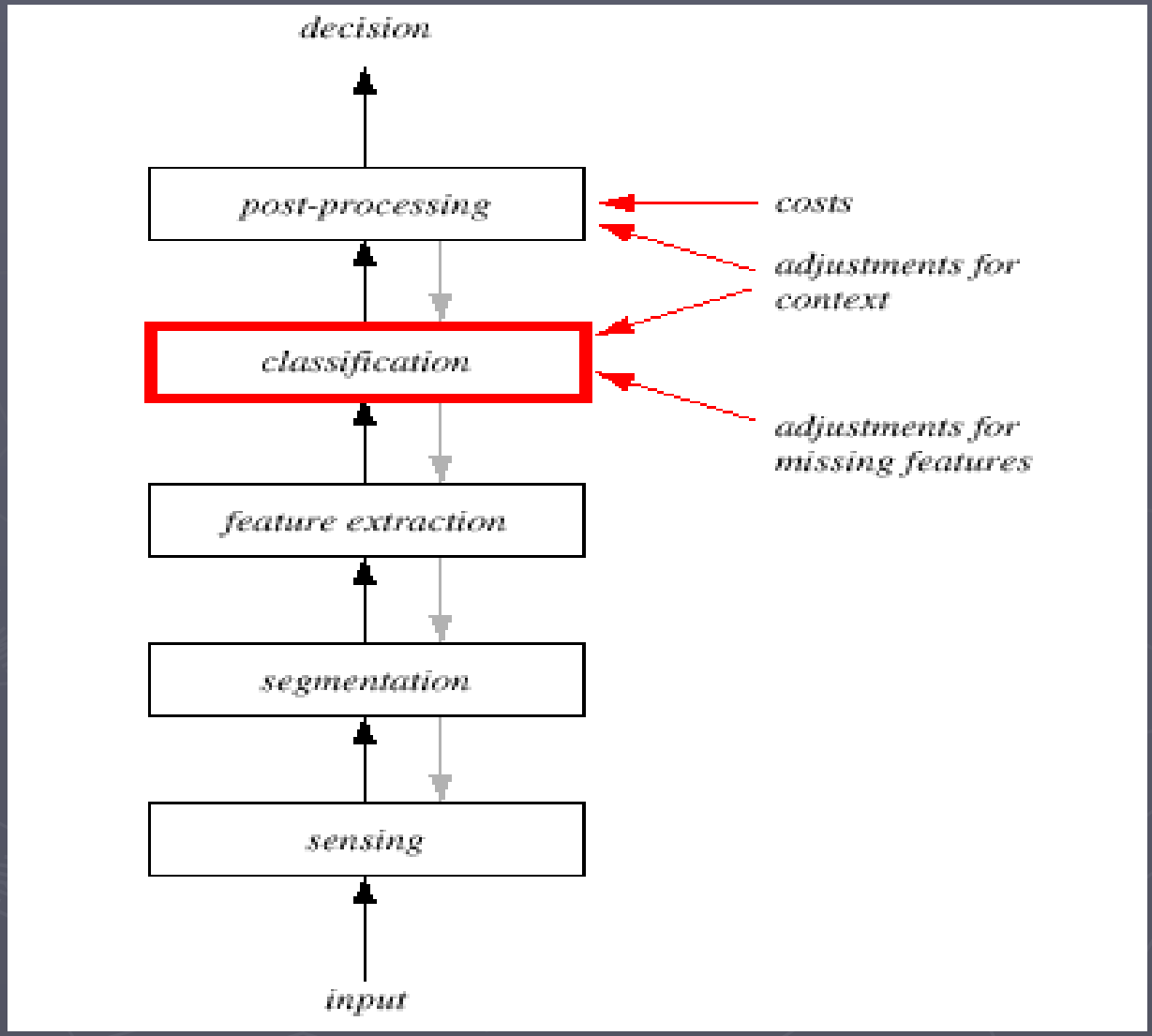
Generalize badly

Pattern Recognition Systems

- Sensing
  - Use of a transducer (camera or microphone)
  - PR system depends of the bandwidth, resolution ,sensitivity, distortion of the transducer
- Segmentation and grouping
  - Patterns should be well separated and should not overlap
  - Grouping together the various parts of a composite object

Flowchart of a pattern recognition system: Training and test

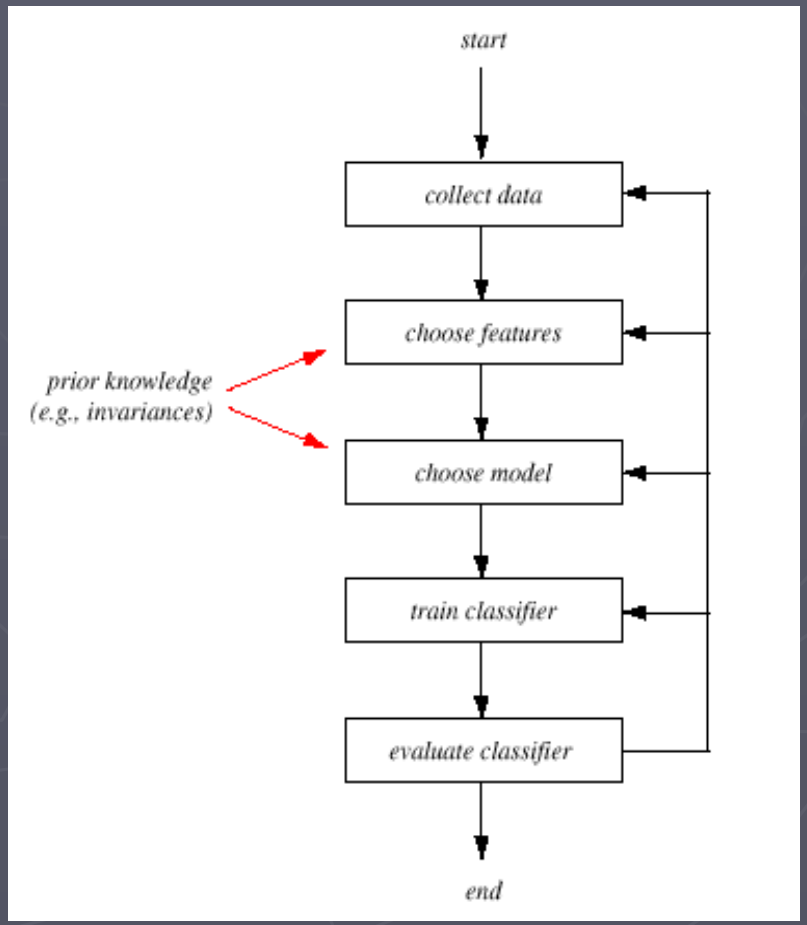



decision
post-processing
costs
adjustments for context
classification
adjustments for missing features
feature extraction
segmentation
sensing
input

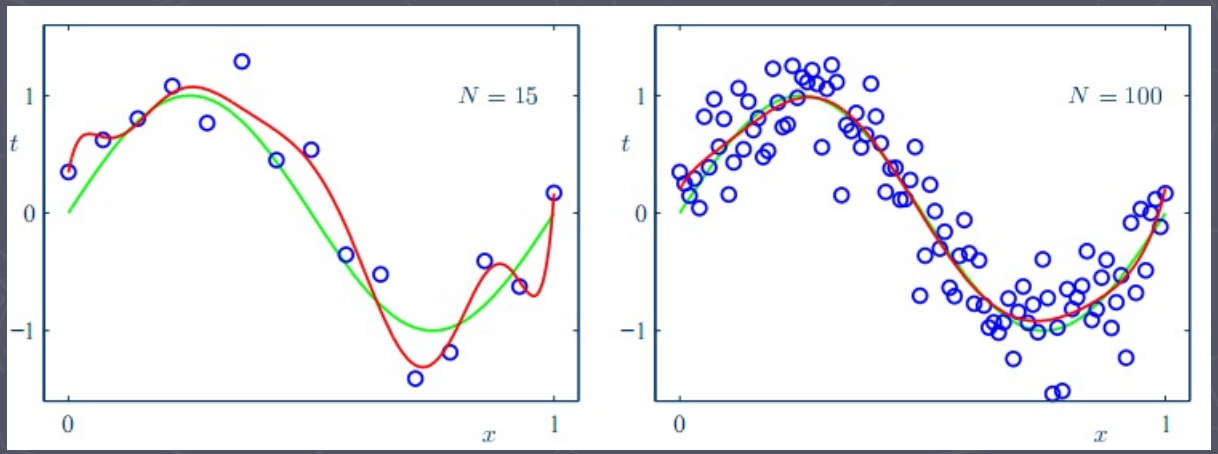
- Feature extraction
  - Discriminative features
  - Invariant features with respect to translation, rotation and scale.
- Classification
  - Use a feature vector provided by a feature extractor to assign the object to a category
  - Two factors decide the degree of difficulty of classification
    - Variability in the feature values in the same category (cpl, ns)
    - Variability in the feature values in the different categories
- Post Processing
  - Exploit context input-dependent information other than from the target pattern itself to improve performance
  - Use the output of the classifier to decide on the recommended action (cost)

The Design Cycle

- Data collection
- Feature Choice
- Model Choice
- Training
- Evaluation
- Computational Complexity


start
collect data
choose features
prior knowledge
(e.g., invariances)
choose model
train classifier
evaluate classifier
end

- Data Collection
  - How do we know when we have collected an adequately large and representative set of examples for training and testing the system?



- Feature Choice
  - Depends on the characteristics of the problem domain. Simple to extract, invariant to irrelevant transformation insensitive to noise.
  - A **feature vector** is a vector of features usually expressed as a column vector:

$$\vec{x} = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix}$$

- Example of bad feature: position of fish on conveyor belt.
- **A feature space** is a space of all possible feature vectors that can be represented under some feature representation scheme
- Example of a 3-dimensional feature space:

$$X = \{\vec{x} | \vec{x} \text{ is a possible feature vector that can be represented}\}$$

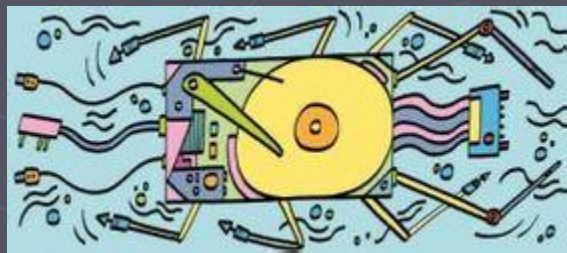
$$X = R^3$$

- Model Choice
  - Unsatisfied with the performance of our fish classifier and want to jump to another class of model
  - (Problem) How do we know to reject a class of models and try another one

Training

- The process of using data to determine the classifier. Many different procedures have been proposed for training classifiers and choosing models
- We are mainly interested in **trainable** or **learnable pattern recognition systems** in which the classifiers learn to perform classification from training

- Computational Complexity
  - trade off between computational ease and performance
  - Complexity of learning (done in lab) and the complexity of making decision (done with the fielded application)

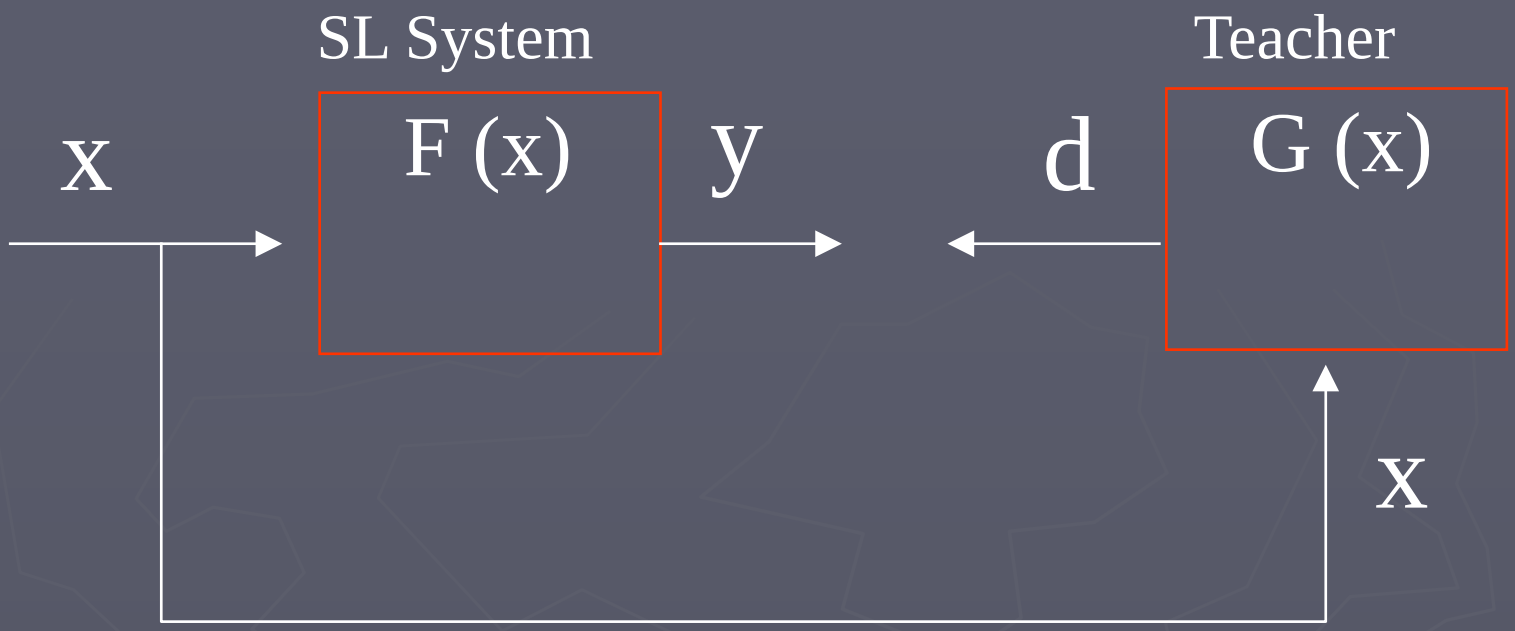


More exploration

- How to make the machine work better in pattern recognition ?
- Can the pattern recognition ability of the machine be greater than the human?
- What can we do now?

Learning Paradigms

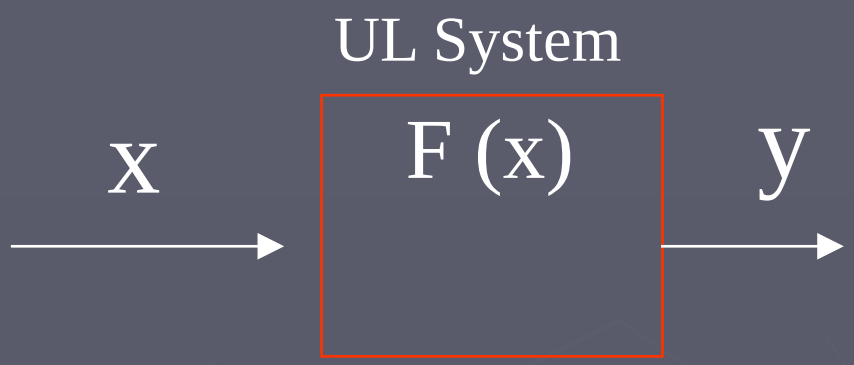
- Learning
- Supervised learning
  - A teacher provides a category label or cost for each pattern in the training set
  - Training examples as **input-output pattern pairs**, with **labeled** output provided by a **teacher**.



Examples:

Teaching children to recognize different animals.

Graded examinations with correct answers provided.



- Unsupervised learning
  - Training examples as **input patterns only** with no associated output patterns (i.e., no teacher)
  - Clustering is a form of unsupervised learning (based on some similarity
  - Examples:

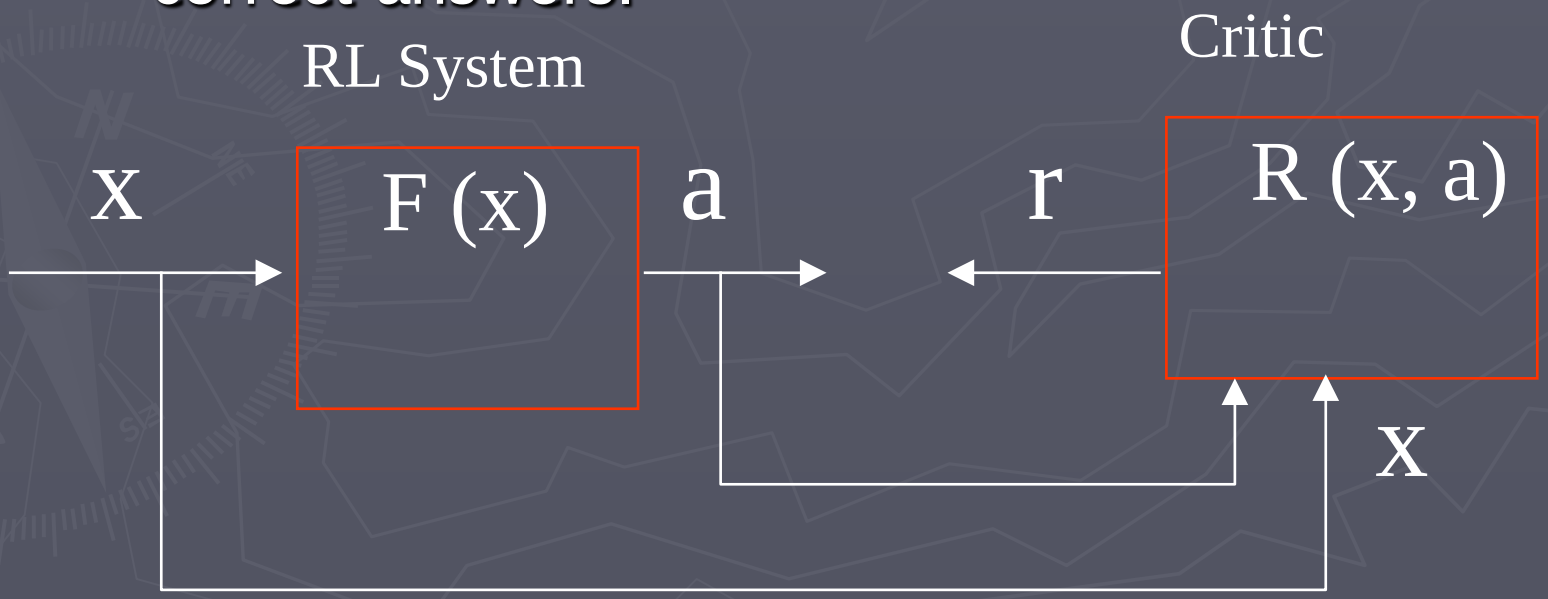
    Grouping animals into different classes according to their similarity.

Reinforcement learning

- Training examples as **input-output pattern pairs**, with **evaluative output provided by a critic("lazy" teacher)**
- **Examples**:

  Learning to play chess game.

  Graded examinations with only overall scores but no correct answers.

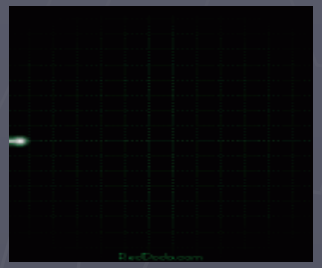


How to make the machine work better in pattern recognition ?

- Intelligent feedback learning
  - Interaction
  - Intelligent: somewhat human-like ability

Can the pattern recognition ability of the machine be greater than the human?

- In some aspects the answer is yes.
- In many aspects the answer is no.



- It's terrible for the machine is more smart than the human from the viewpoint of morality.

- What can we do now?
  - imagery thinking ? logical thinking ?

- For prompting the pattern recognition technology, we had better
  - focus on what it is good at
    - Data processing
    - Determinative decision making
    - Limited interaction learning
    - Robust

  - not waste the time on what it is incompetent.
    - Imagery thinking

What's the extreme potential of the pattern recognition technology?

- Will the time when the intelligent machine govern the earth and people come ?



- Where is the farthest place?