Introduction to pattern recognition

- **Outline:**

  1. What is pattern recognition?

  2. How to perform pattern recognition?

  3. Some examples

  4. Components of a pattern recognition system

  5. How to evaluate a pattern recognition system?

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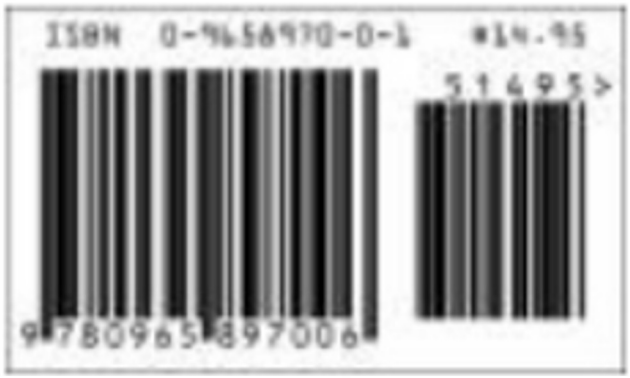
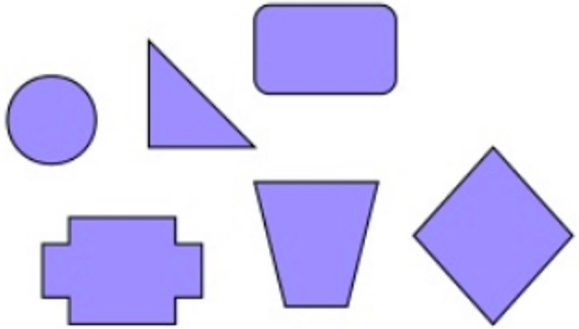
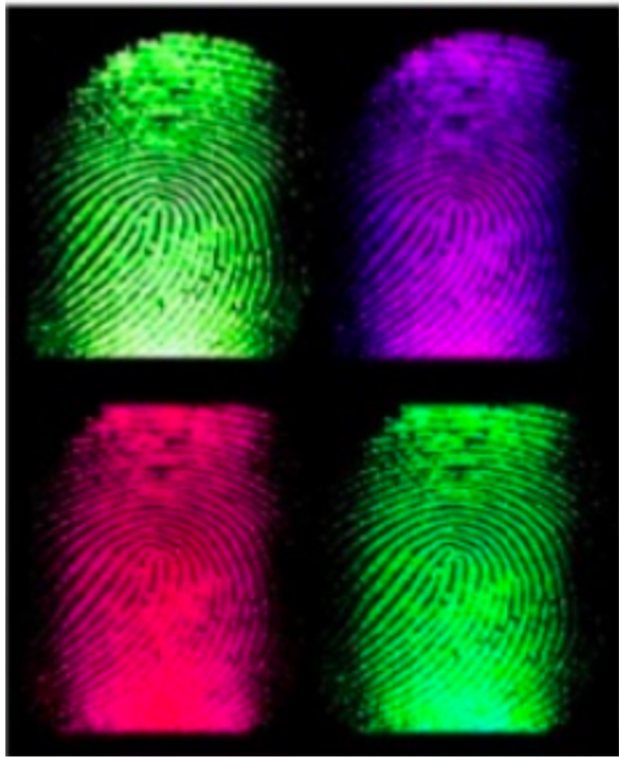
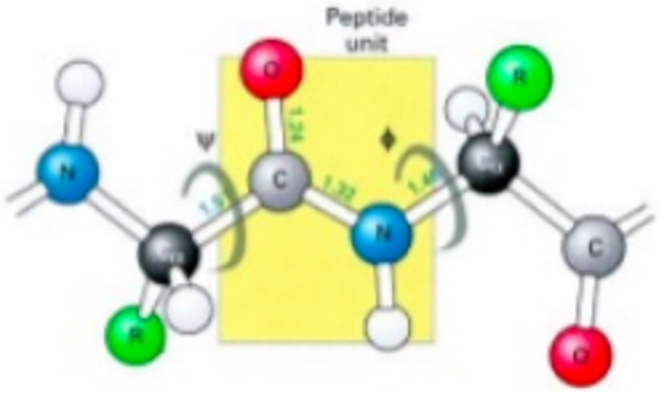
Examples of patterns









What is pattern recognition?

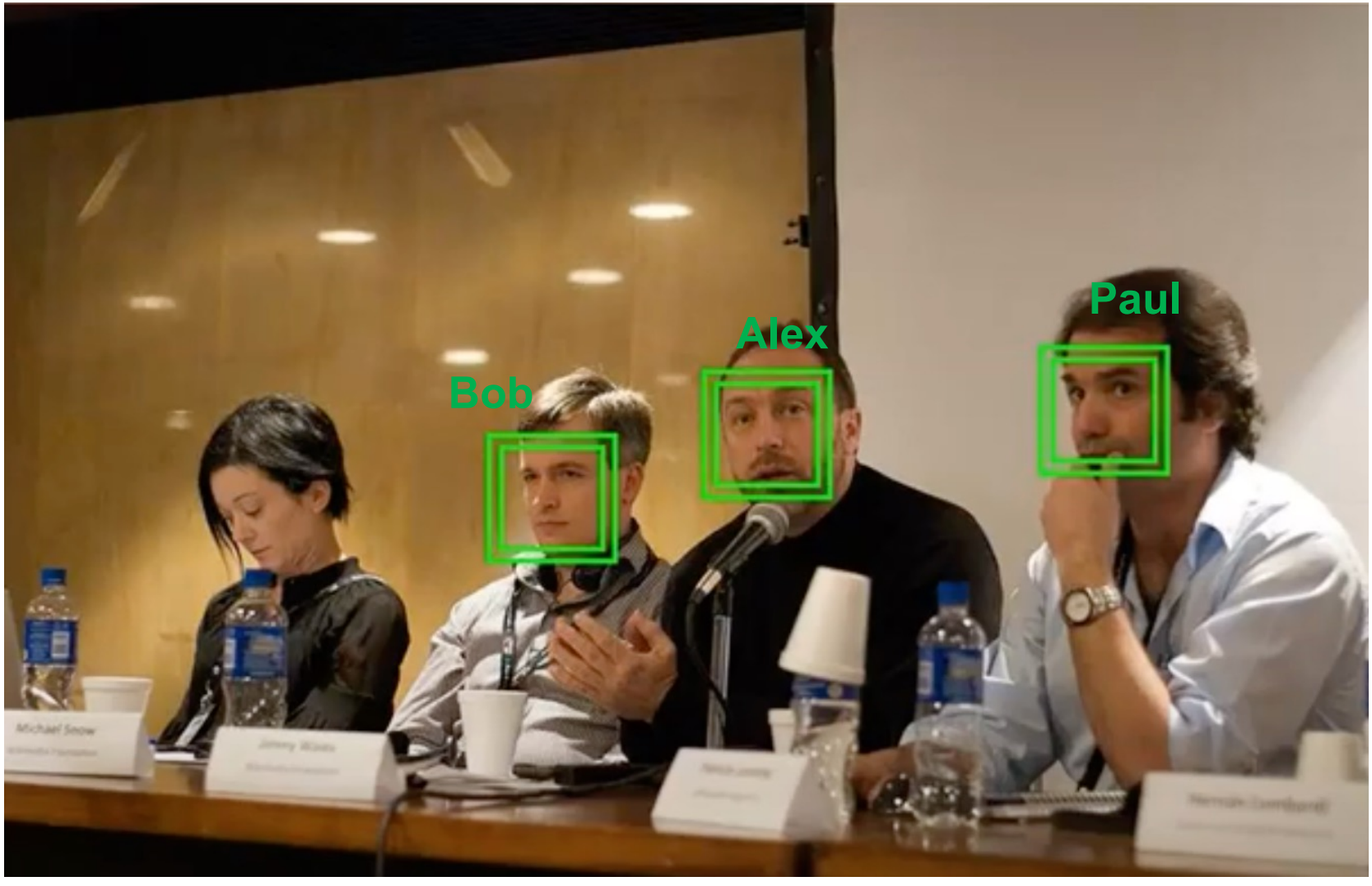
- Important component of AI systems
- One of the most common applications of machine learning
- Aiming to give human perception capabilities to machines
- Process of recognizing regularities in data by using machine learning algorithms, based on statistical information, historical data, or the machine's memory.
- During recognition given objects are assigned to prescribed classes

Applications of pattern recognition

People detection

Applications of pattern recognition

Face recognition



Applications of pattern recognition

License plate recognition

Applications of pattern recognition

- OCR (Optical Character Recognition): handwritten, printed text,…
- Biometrics: face, finger prints, speech,…
- Medical diagnosis: X-ray, MRI analysis,…
- Education
- Biology: fruit, leaf,…
- Smart transportation: traffic light, traffic sign,…

Applications of pattern recognition

- Security surveillance
- Entertainment, sport
- Agriculture
- Commercial
- Military technology: target recognition, satellite image analysis,…

… and more…

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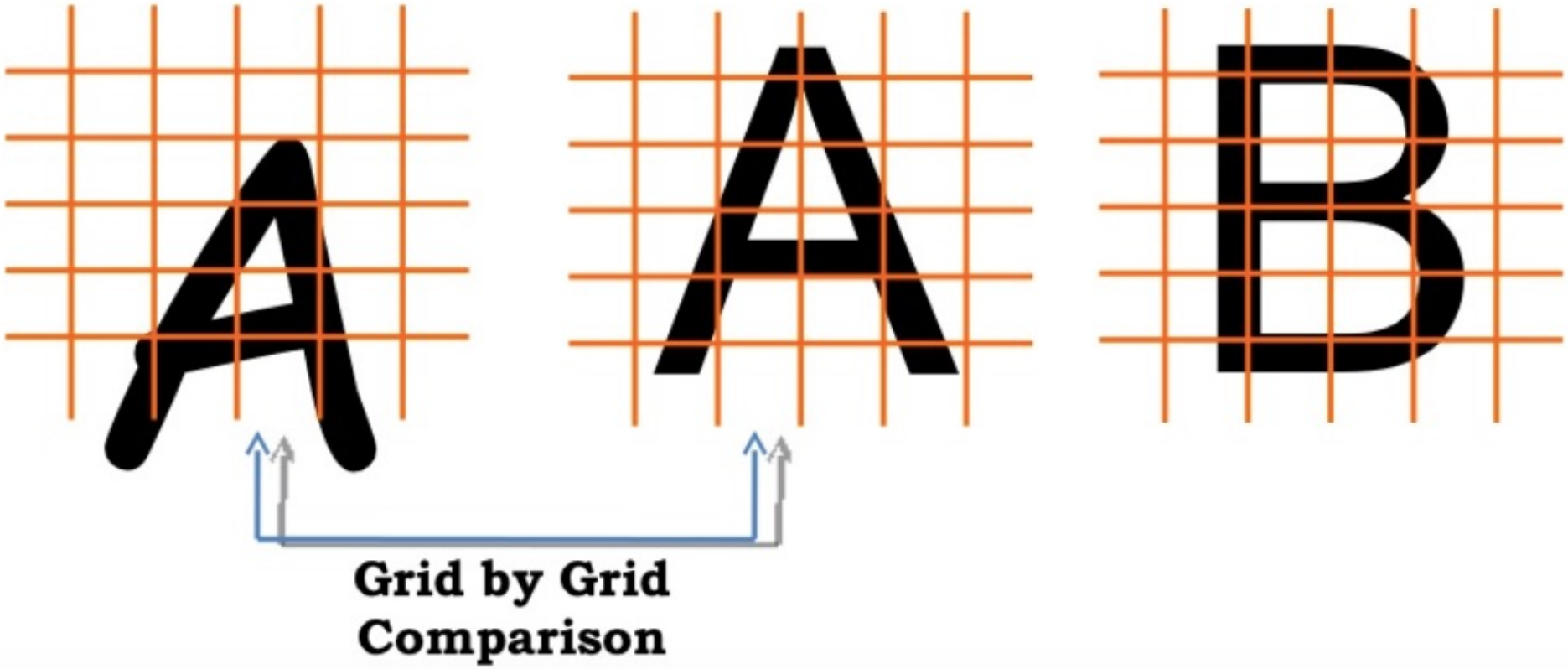
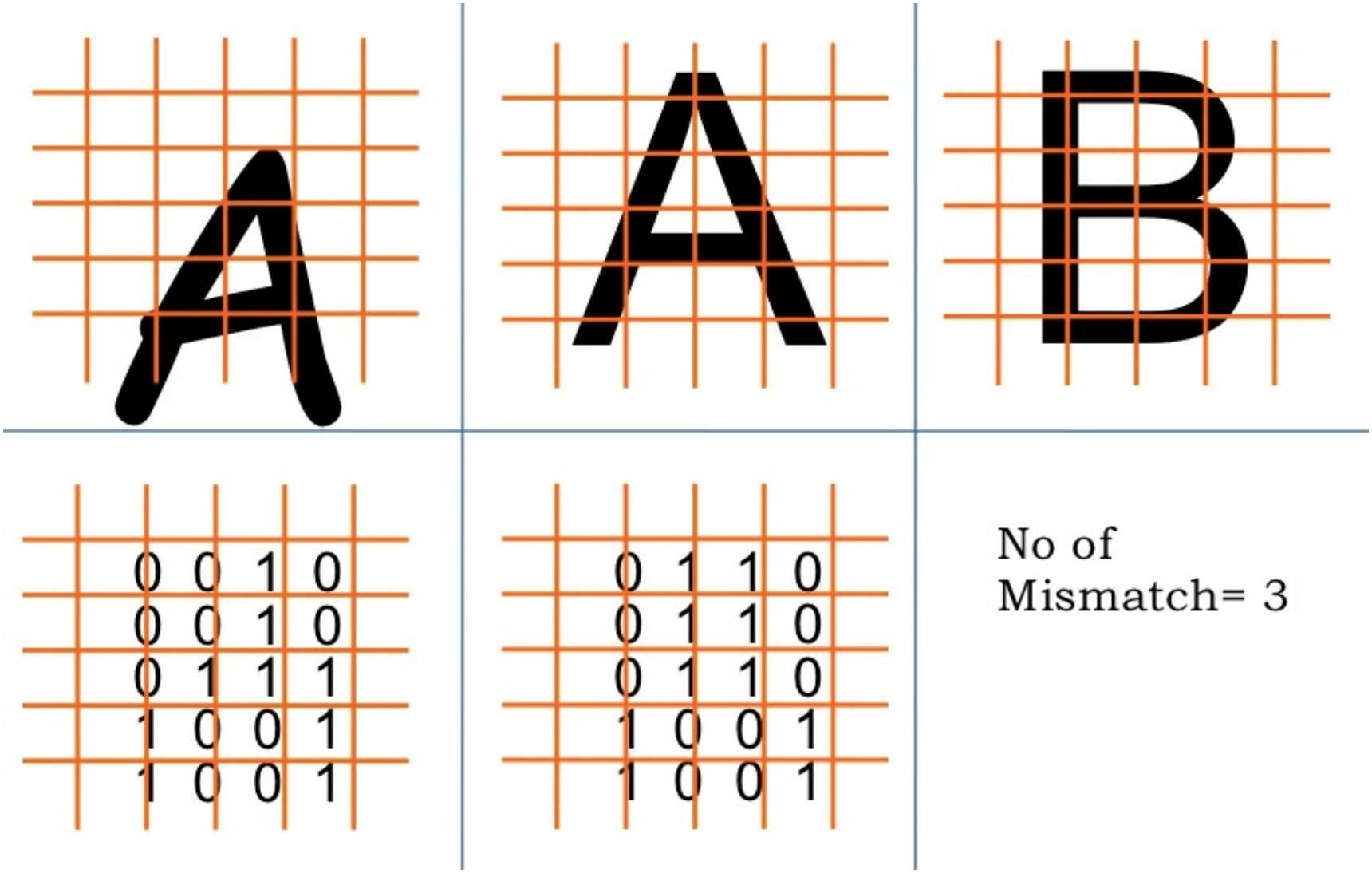
  4. Components of a pattern recognition system
  5. How to evaluate a pattern recognition system?

Grid-by-grid comparison



From: Talal Alsubaie

Grid-by-grid comparison



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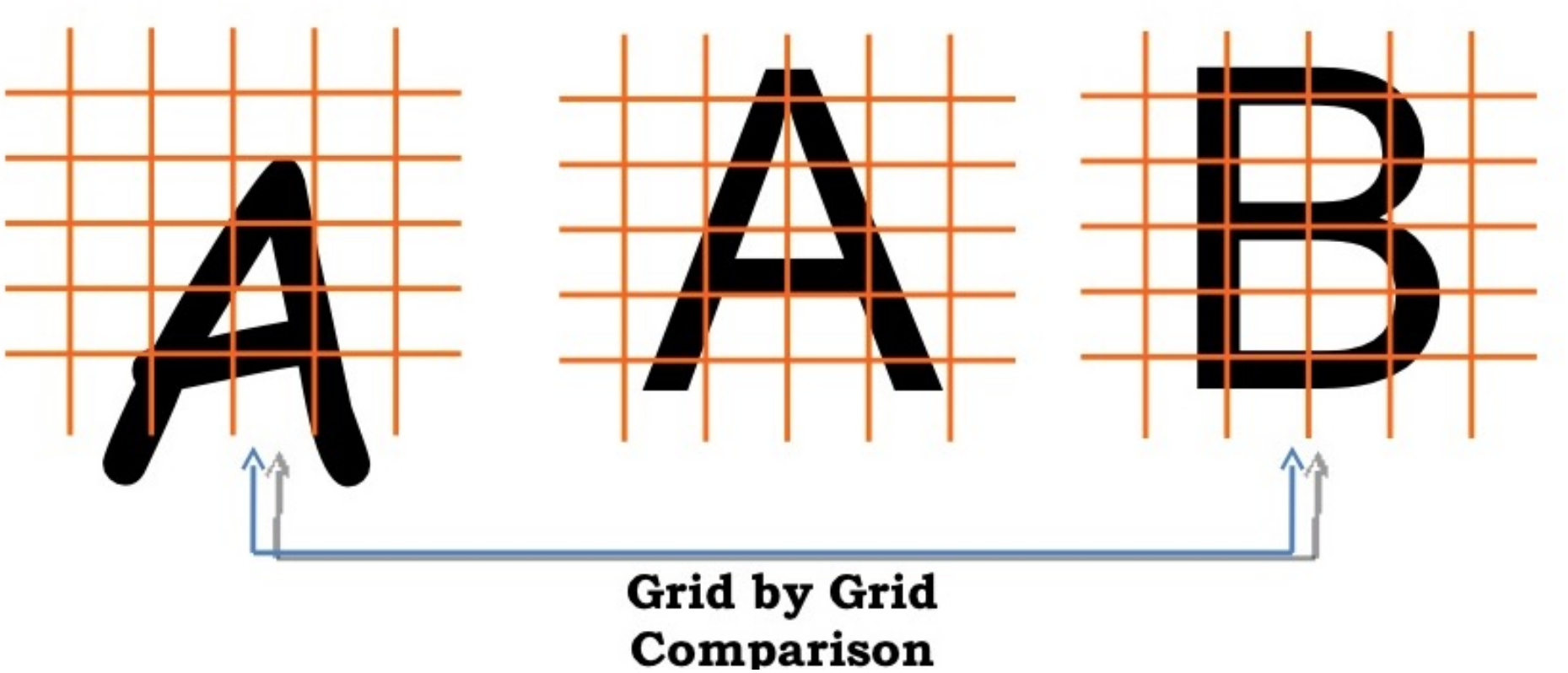
Grid-by-grid comparison



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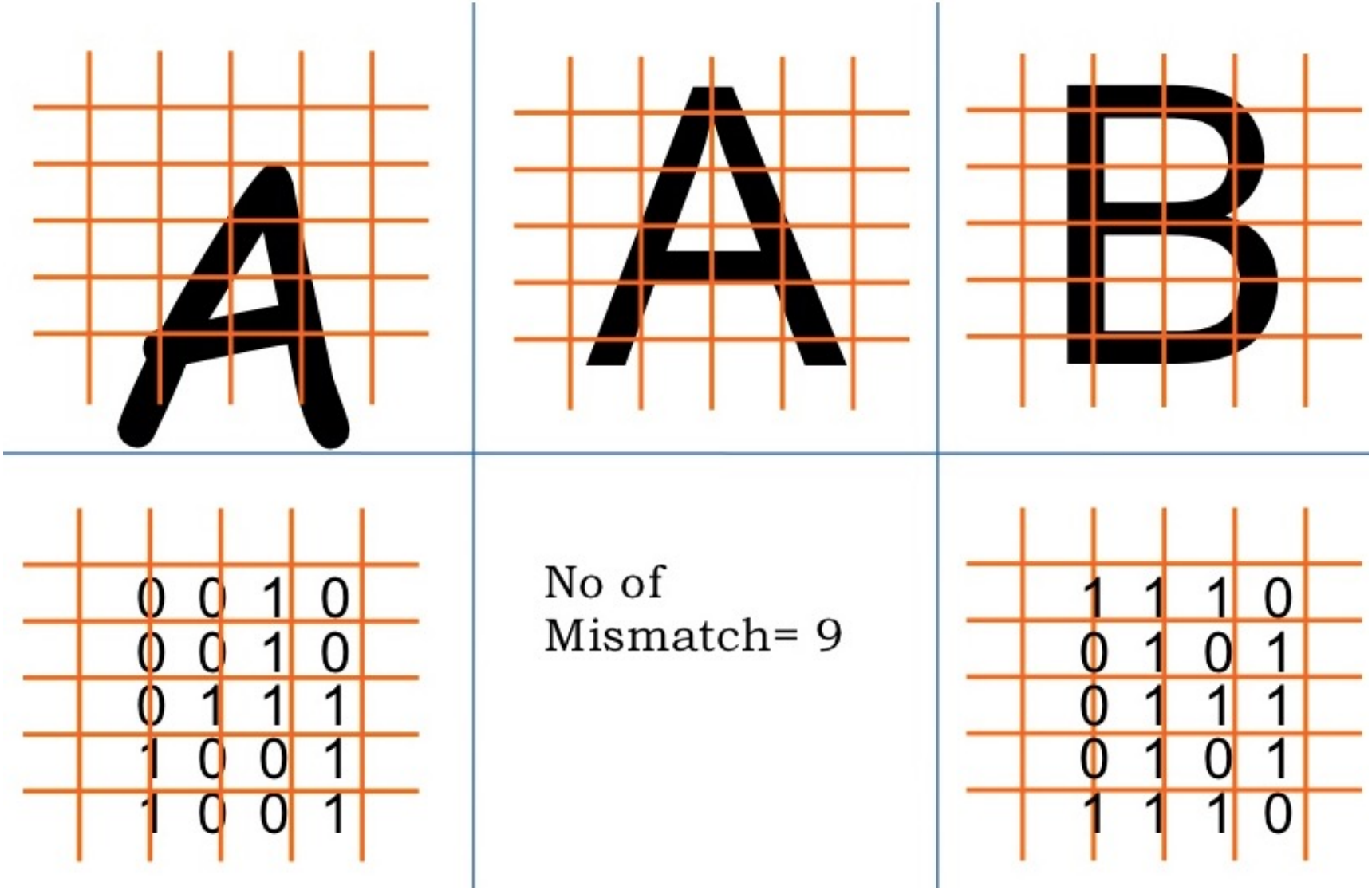
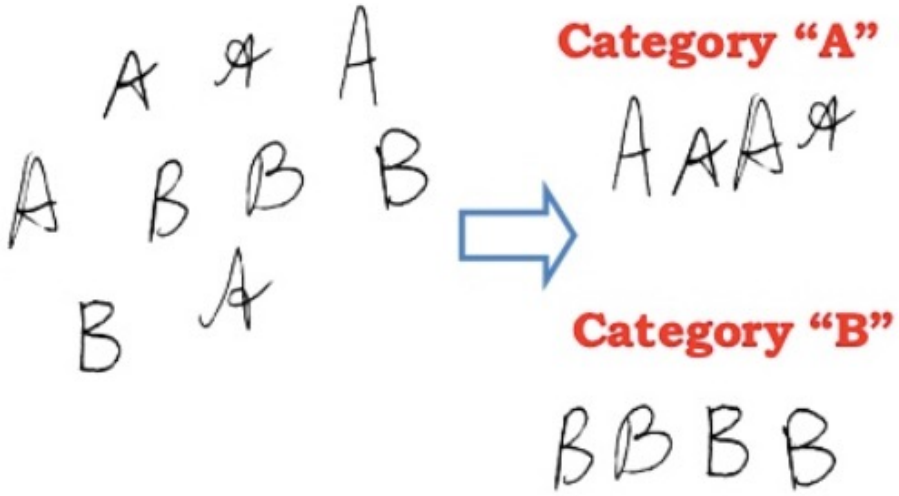


From: Talal Alsubaie

The statistical way

- Problems with grid-by-grid comparison: too costly
- **Solution: artificial intelligence/machine learning**
- **Two phases:** learning and classification
  - *Learning:* learn the rule from data (supervised and unsupervised)
  - *Classification:* decide a pattern to a known category/class



Challenges

- Intra-class variability
- Inter-class variability

Intra-class variability

Ex: different typefaces of letter “T

Inter-class variability

Ex: lisianthus (hoa cát tường) and carnation (hoa cẩm chướng)

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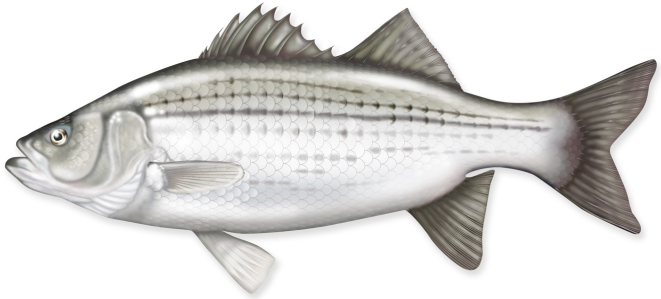
Example 1: fish classification

Fish



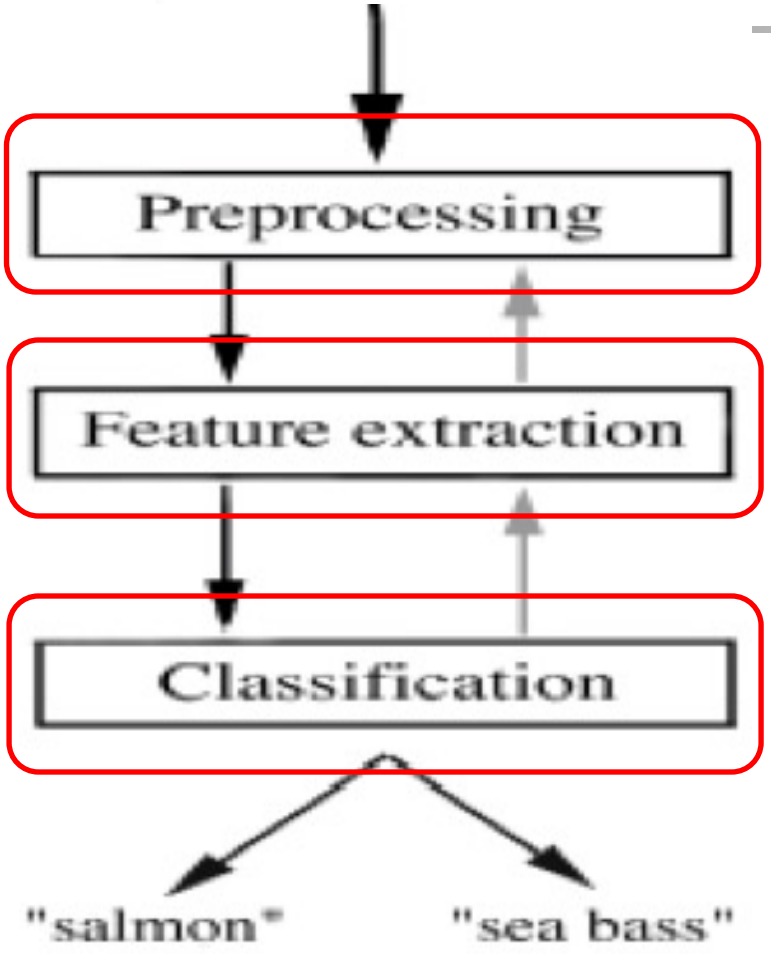
Sea bass

Salmon

Problem analysis

- Set up a camera
- Take some sample images
- Note physical differences (features):
  - Length
  - Lightness
  - Width
  - Number and shape of fins
  - Position of the mouth, etc…
- Classify fish

Implementation



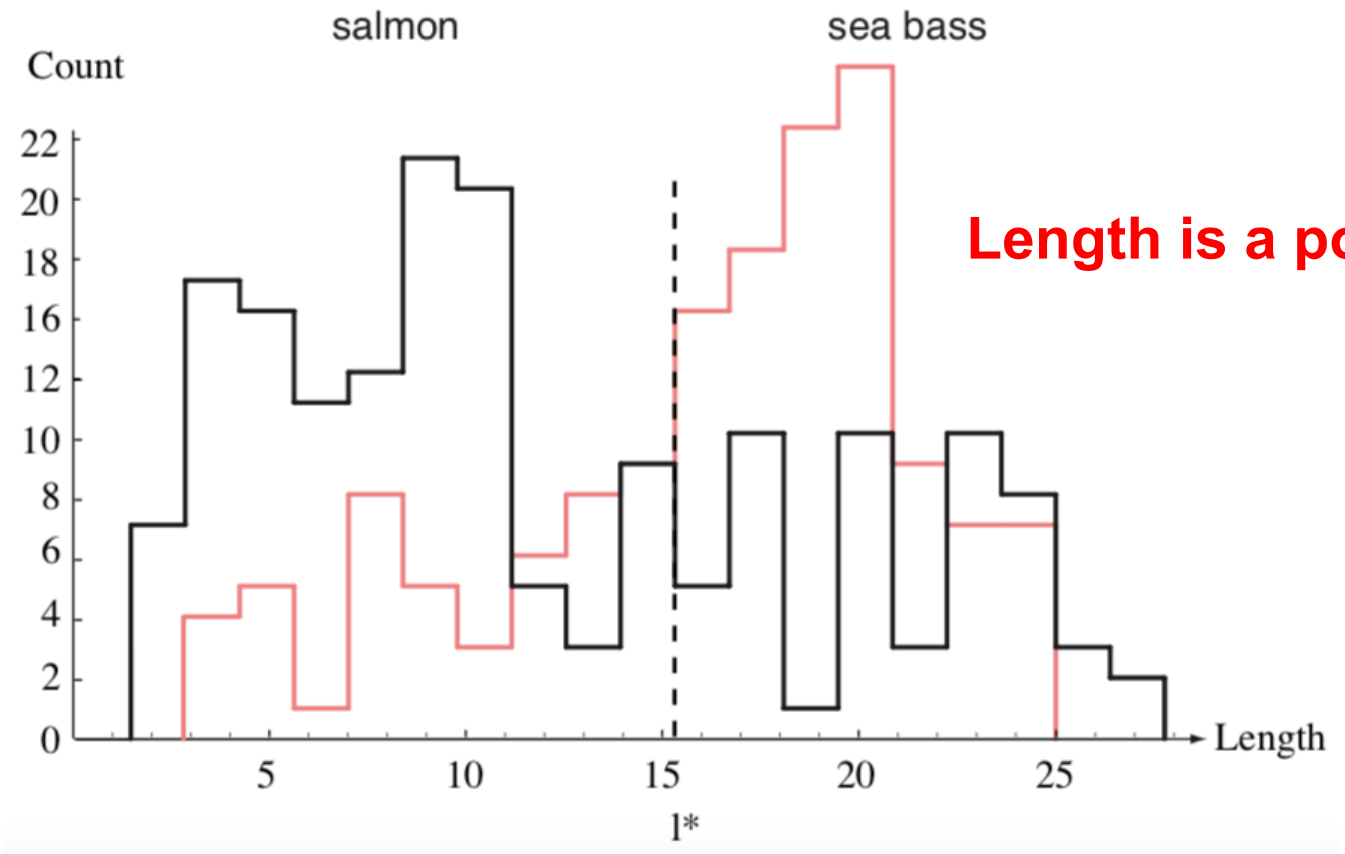
To isolate fishes from one another and from the background

To reduce the data by measuring certain features

To discriminate salmon and sea bass (by statistical/ by machine learning)

Feature selection

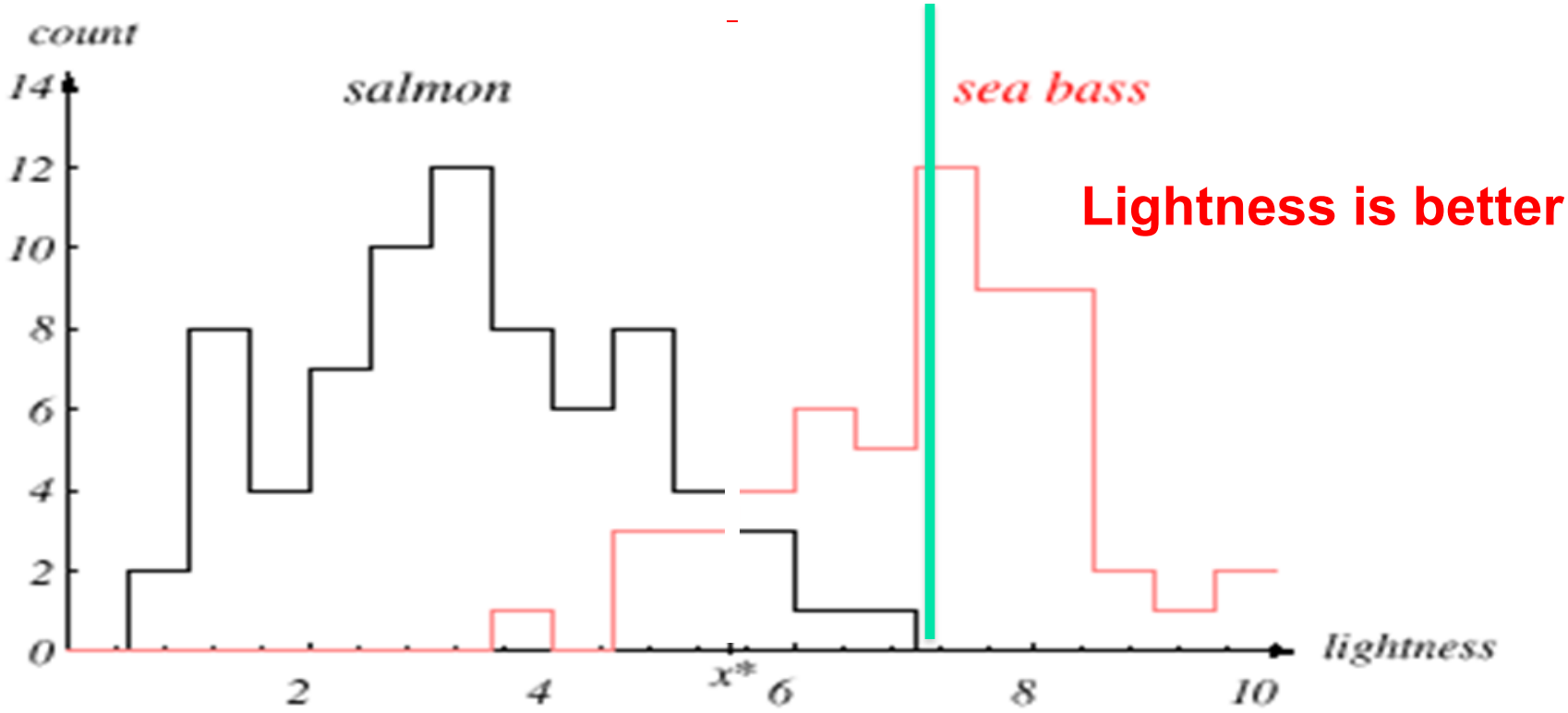
- Sea bass is generally longer than salmon → Length becomes a feature.



Length is a poor feature

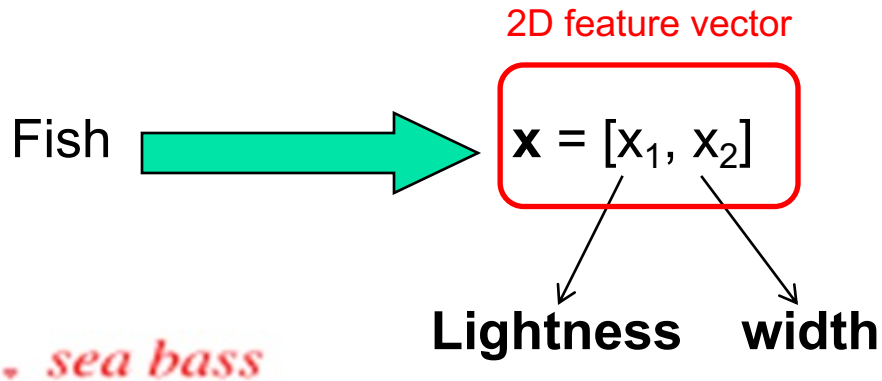
Feature selection

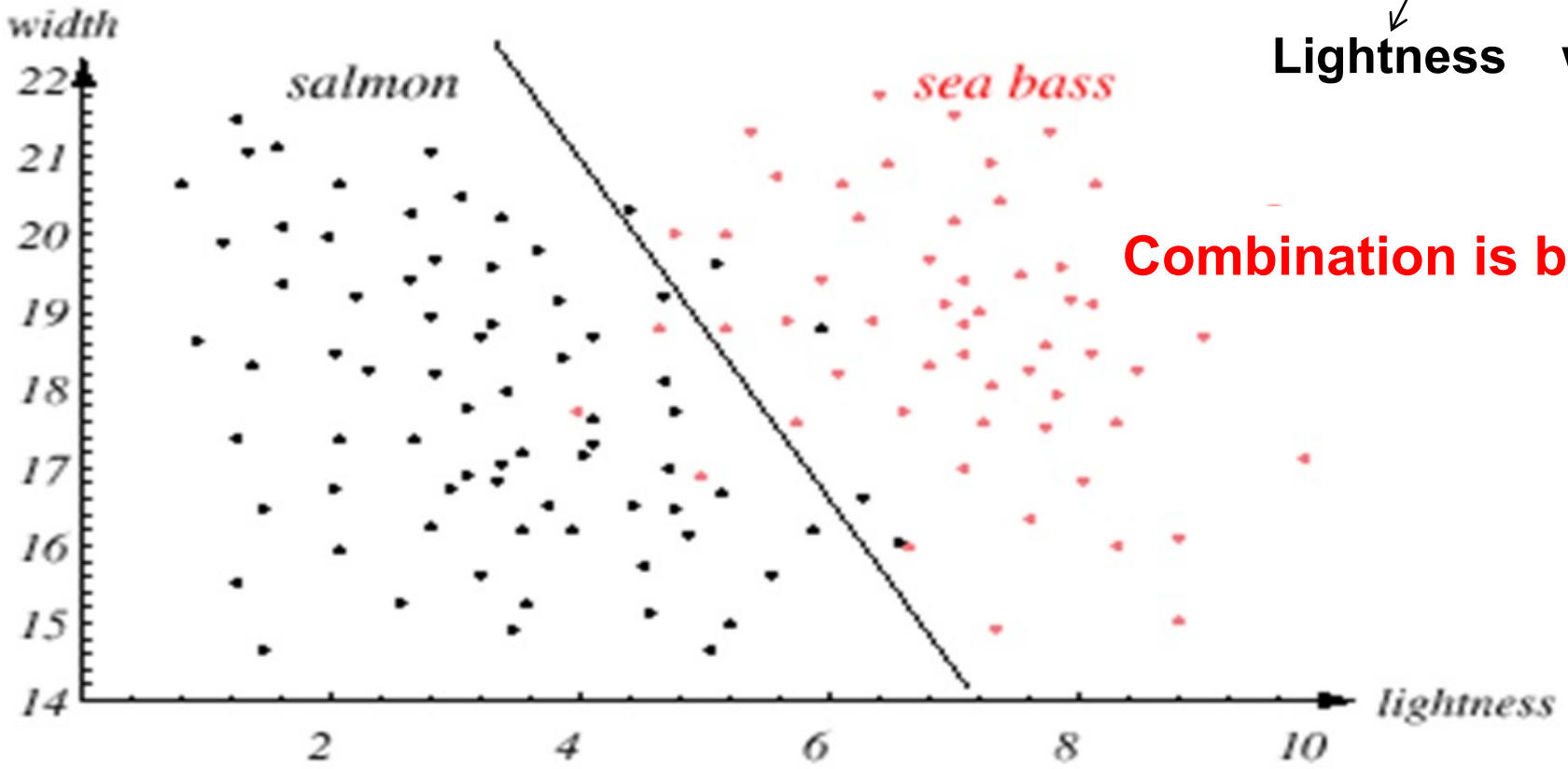
- **Lightness feature:** better than length feature but not adequate
- Move the decision boundary toward smaller values of lightness to reduce the number of sea bass that are classified as salmon



Feature selection

- **Multiple features**
- **Lightness + width**

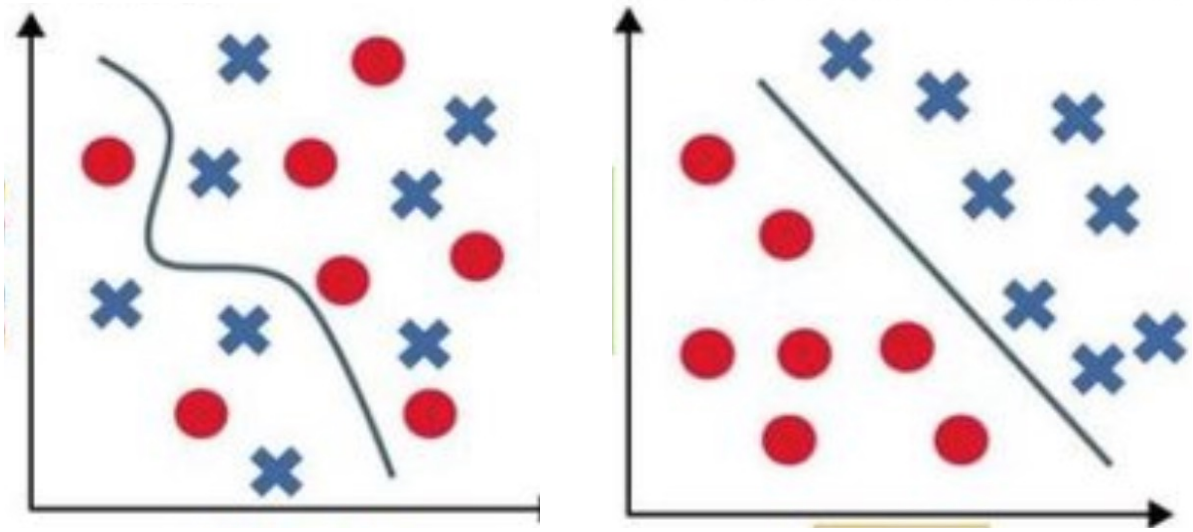




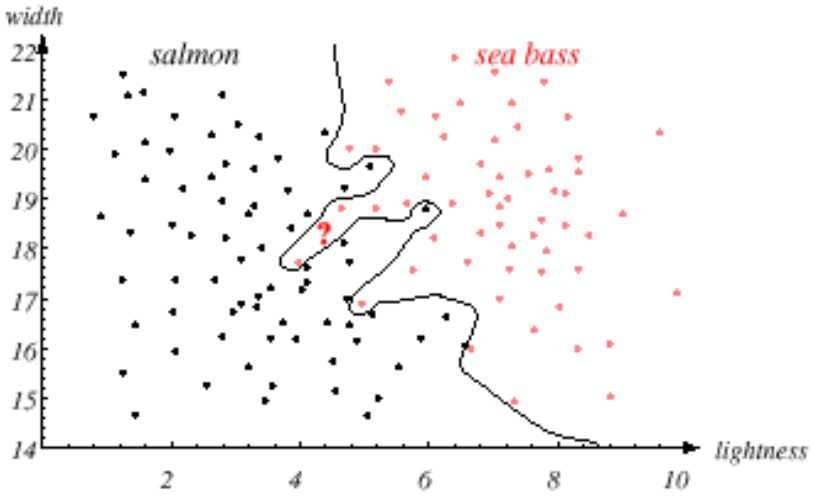
Combination is better

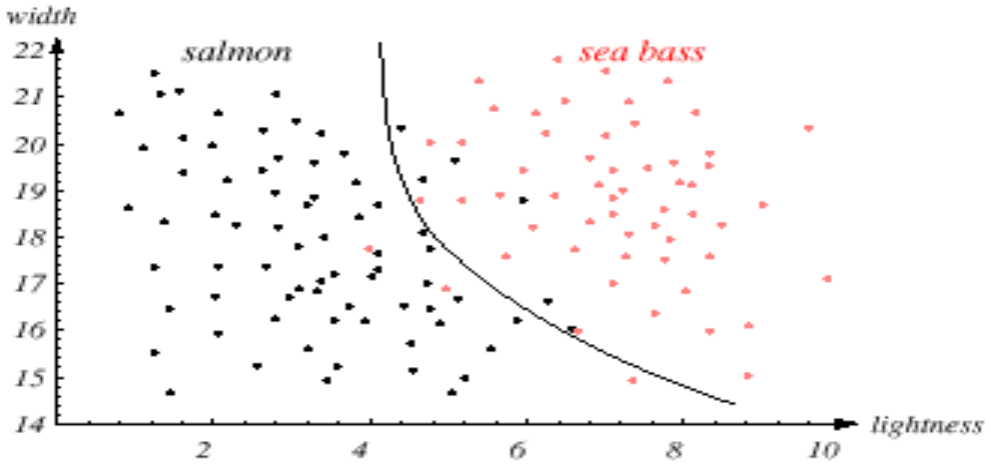
How many features?

- More is not always better
- There could be redundancy
- Over complication can occur



Classification model selection

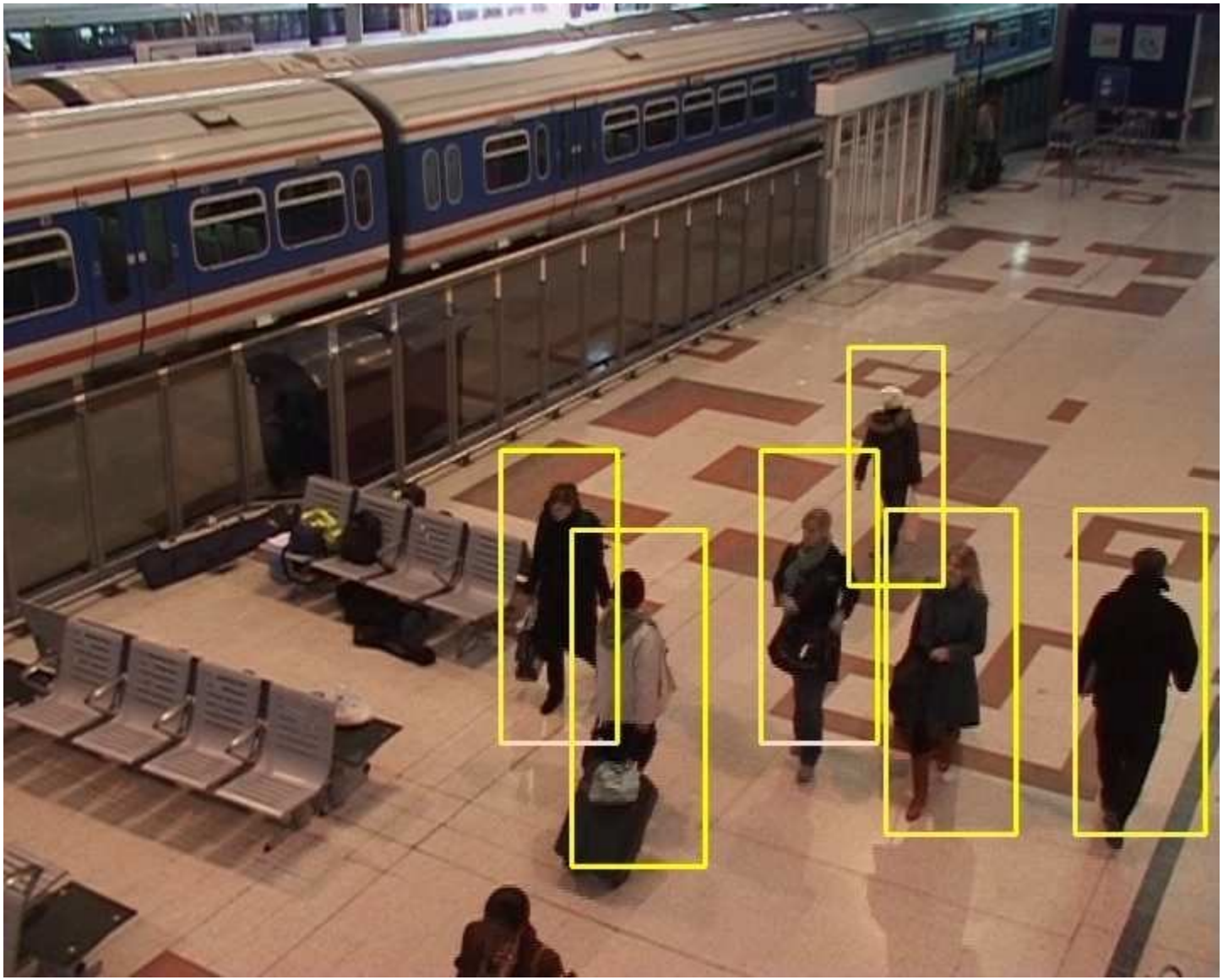




- There is a tradeoff between complexity of the decision rules and their performances to unknown patterns.
- **Generalization:** The ability of the classifier to produce **correct** results on **novel** patterns.

→ Simplify the decision boundary!

Example 2: person detection

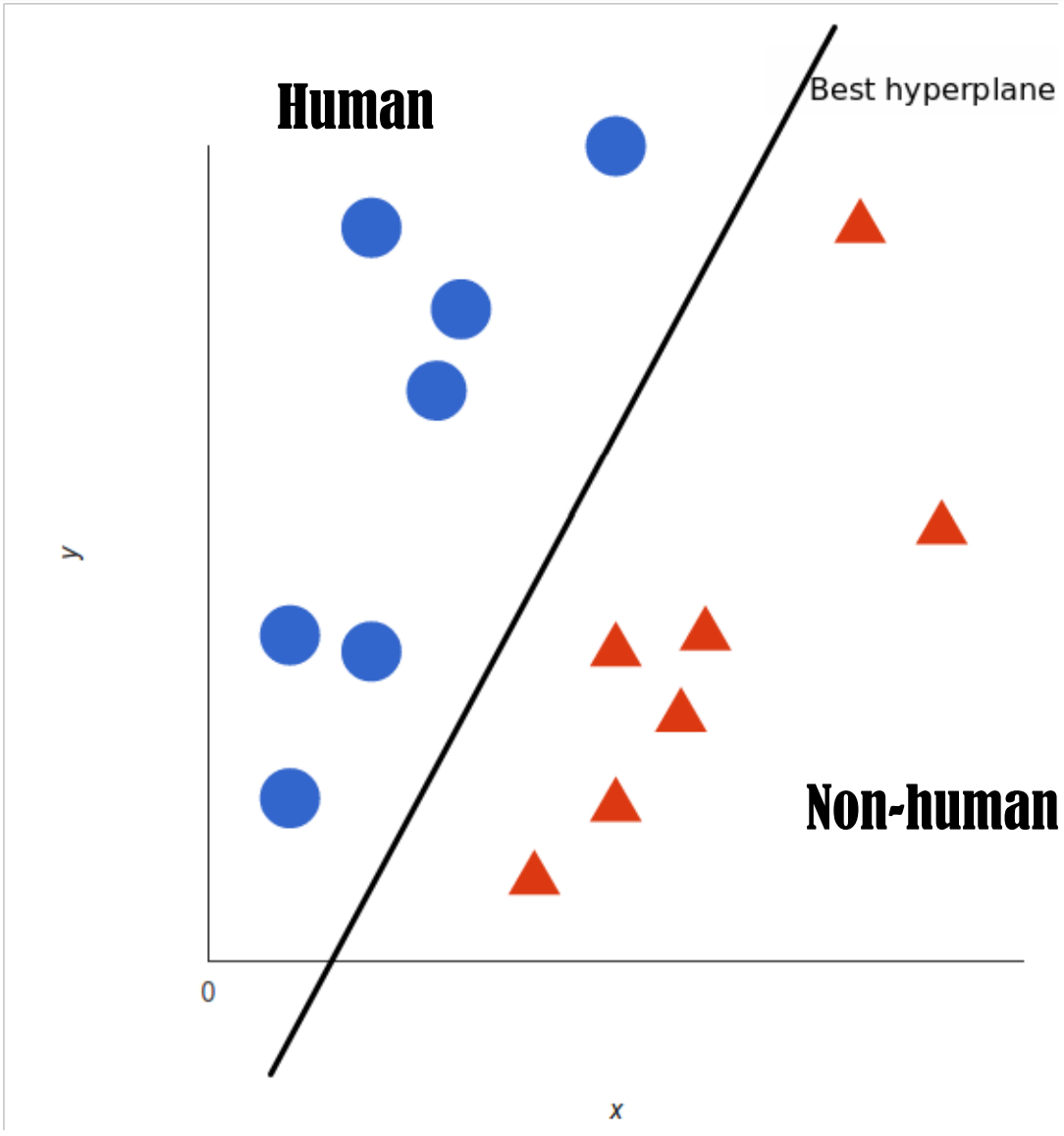


System building

- Data:
  - Images with people (**positive**)
  - Images without people (**negative**)

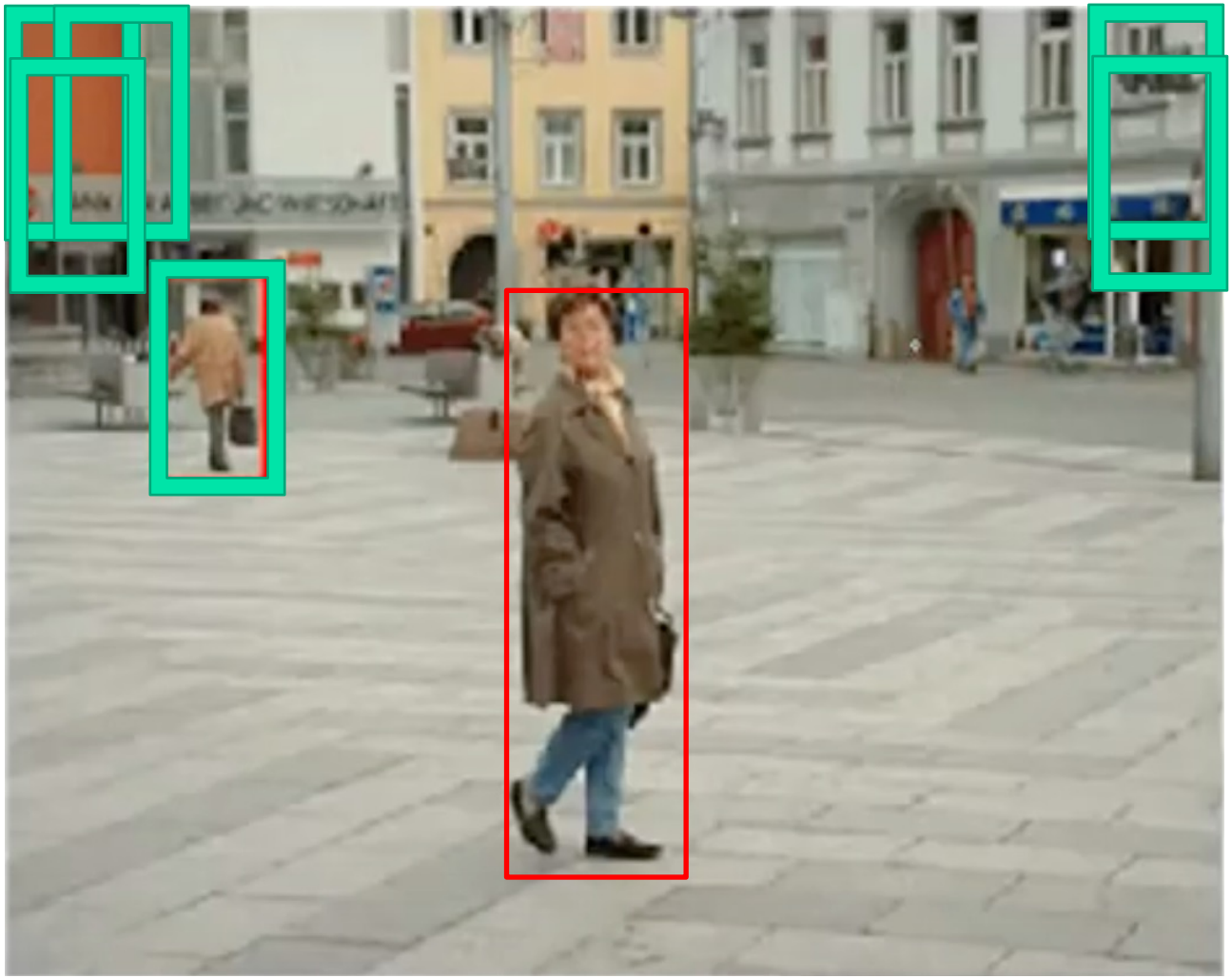
System building (cont)

- Feature extraction:
  - HOG feature
- Classification:
  - SVM classification model



System building

- Detecting:
  - Sliding window
  - Detecting a person/non-person within a sliding window (HOG+SVM)



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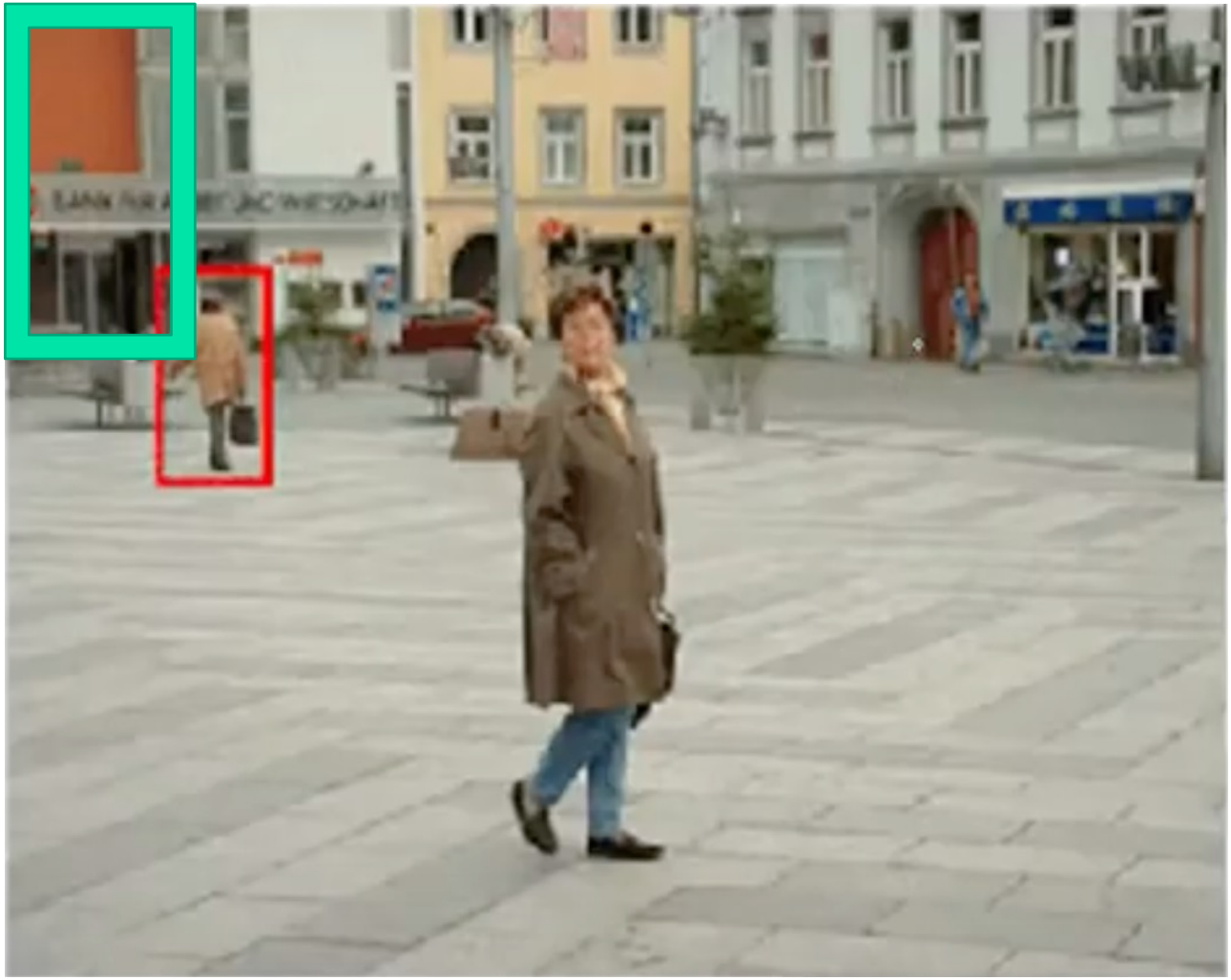

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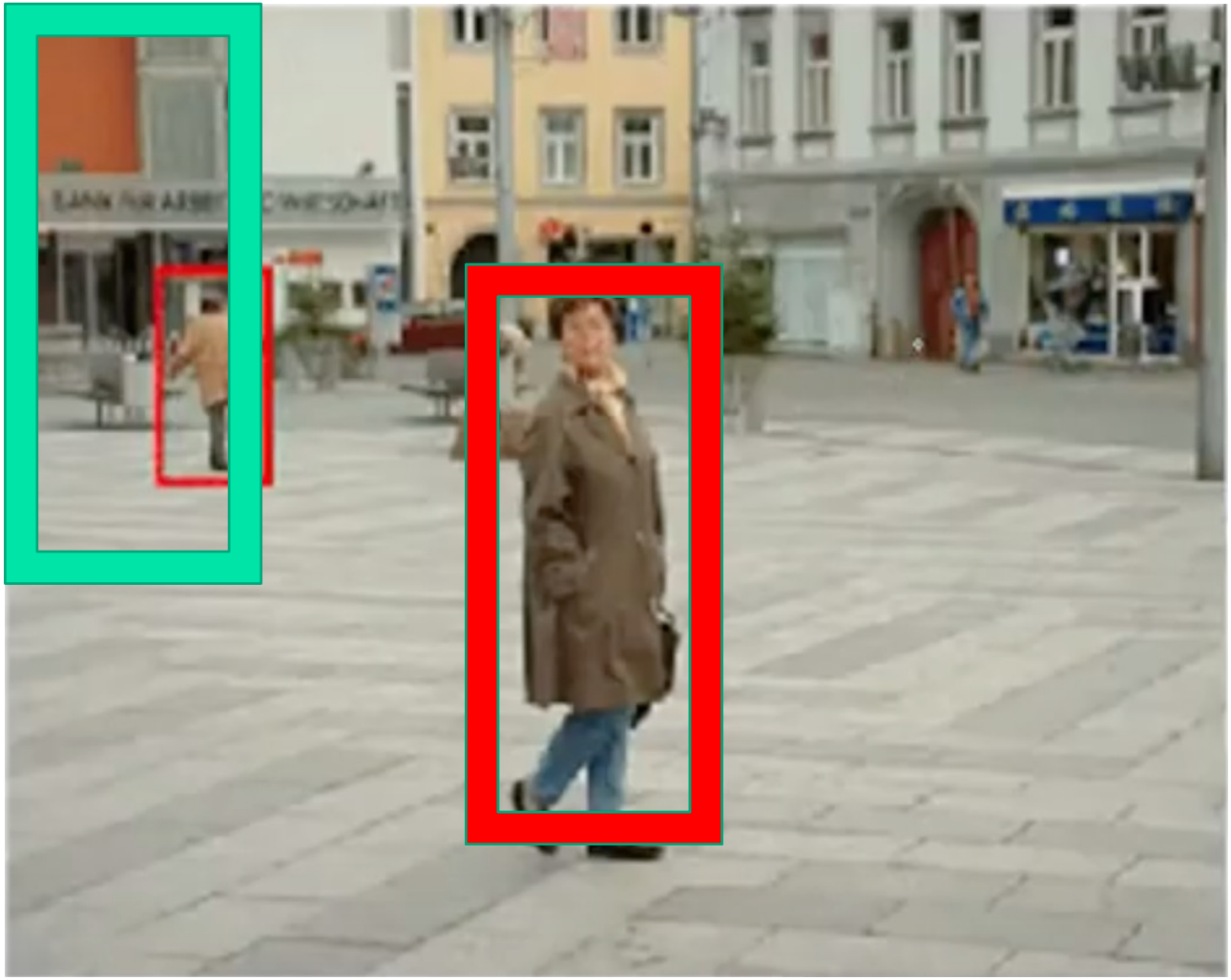
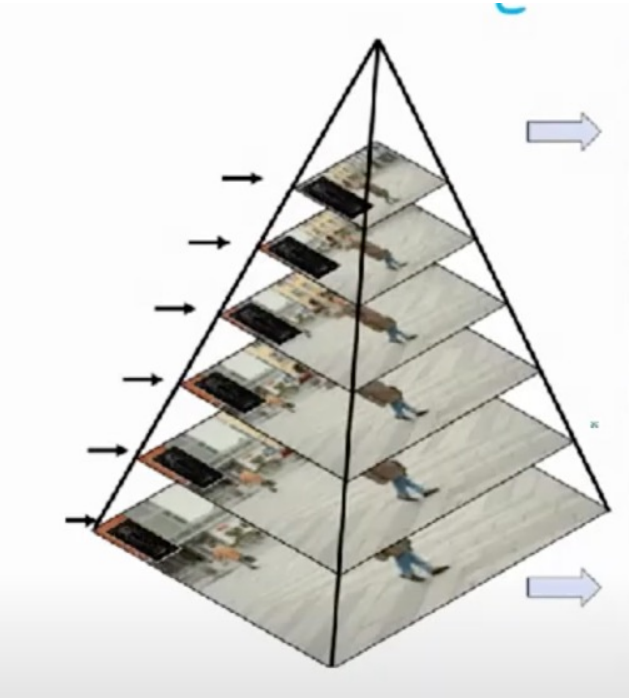
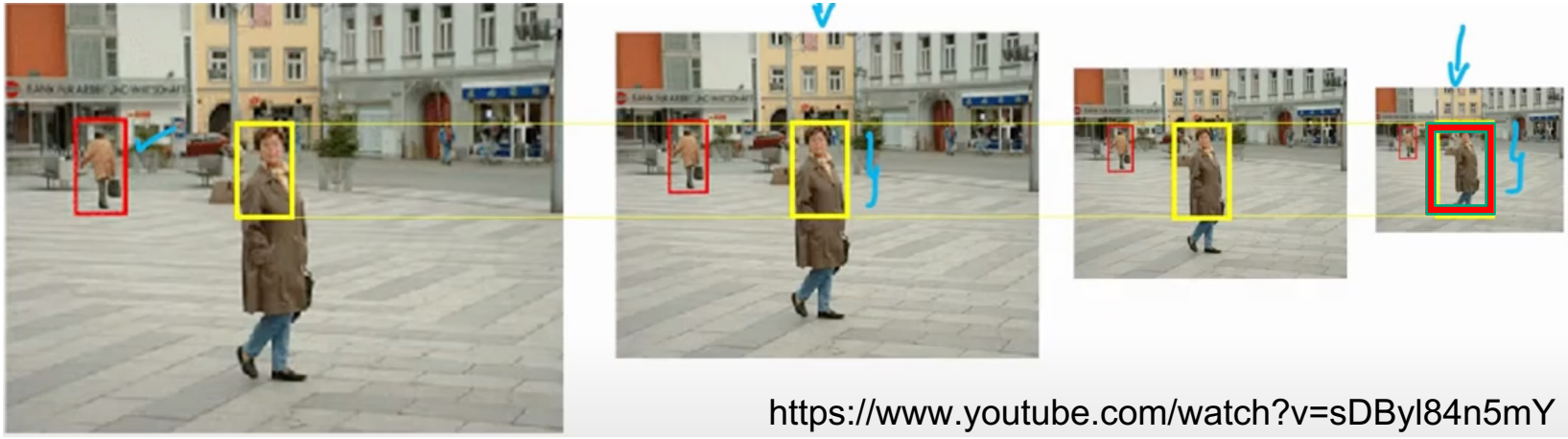


System building (cont)

- Image pyramic:
  - To change the window size





https://www.youtube.com/watch?v=sDByl84n5mY

Đọc thêm

- Fruit recognition:

https://www.youtube.com/watch?v=cBOSGQo1A10

- Grading fruit:

https://www.youtube.com/watch?v=a8UZkCQqzNQ

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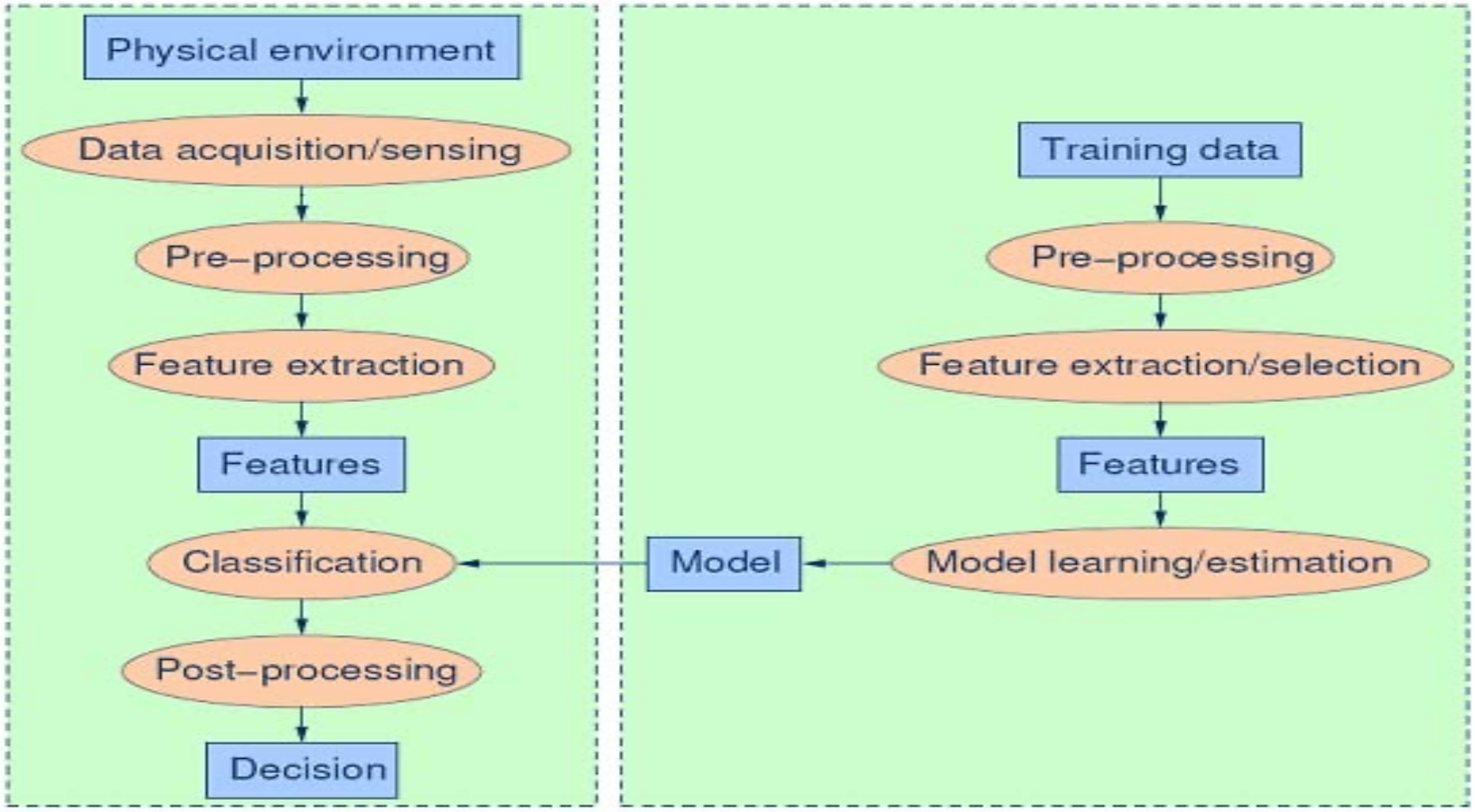
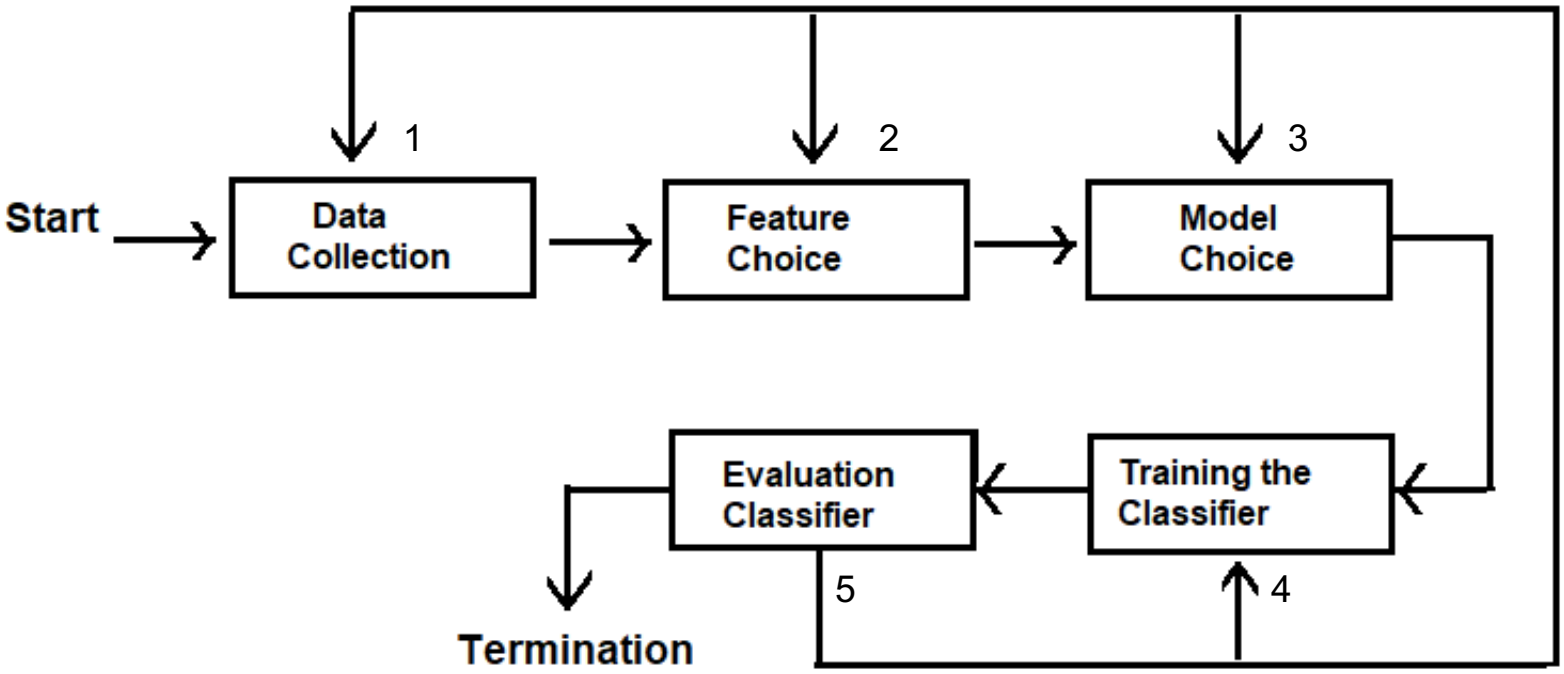
Typical pattern recognition system



The design cycle



Performance evaluation

Computational complexity evaluation

Bài tập

- **Đề:**

Tự động đánh giá độ ngọt của quả xoài dựa vào màu sắc của vỏ

https://drive.google.com/drive/folders/1tZZ5MCpfXG0zwehCI-_uFIFpkjn4kItL

Bài tập lớn số 1

- **Đề:** Xây dựng hệ thống tự động phát hiện đối tượng trong ảnh
- **Phương pháp:** grid-by-grid comparison
- **Phạm vi:**
  - ảnh nền trơn chứa 1 đối tượng
  - kích thước cửa sổ cố định
- **Bài nộp:** báo cáo và code (pdf), riêng nhóm thuyết trình nộp thêm file ppt đã chuyển pdf
- **Danh sách nhóm thuyết trình bài tập lớn số 1: 1, 11**

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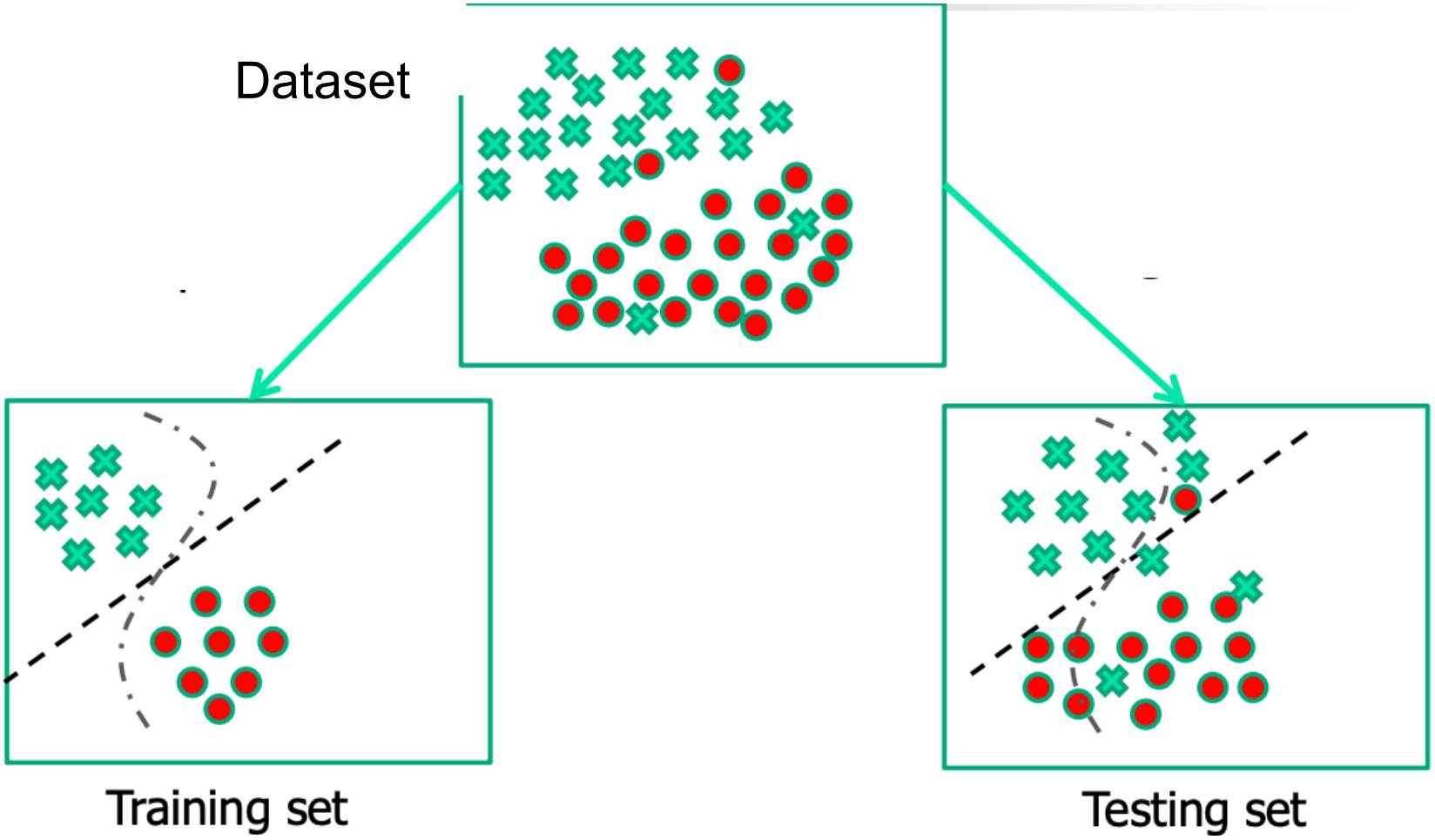
Cross validation

- **Cross validation:** not use the entire data set for training
  - Remove some of the data before training
  - Use the removed data to test the performance of the learned model on new data
- **Three methods of cross validation:**
  - holdout method
  - *k*-fold cross validation
  - leave-one-out cross validation (LOOCV)

Data splitting for cross validation



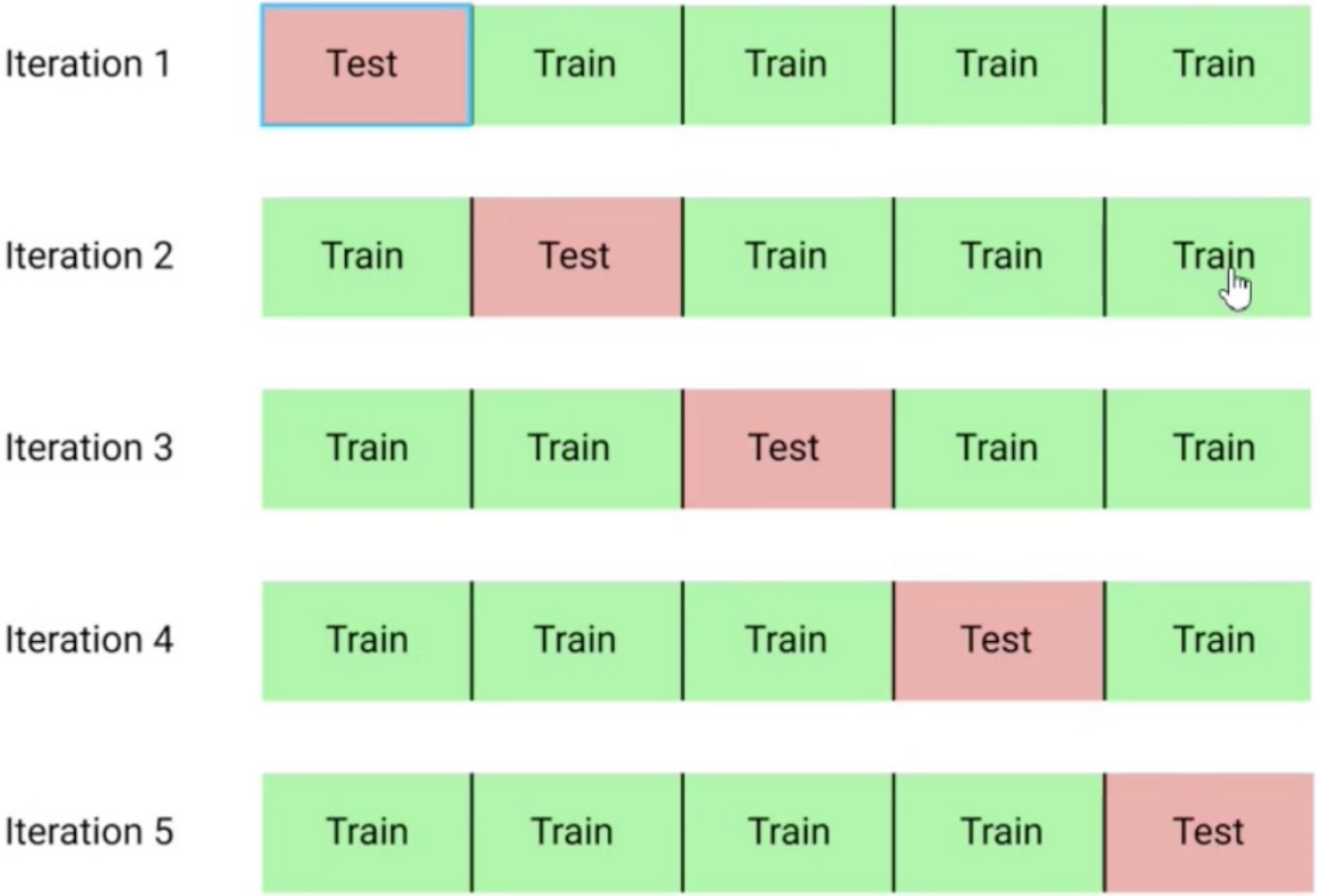
Holdout method

- **Holdout method:**
  - Data set is separated into training set and testing set
  - The model is learned using training set only
  - The learned model is asked to predict the outcome for data in testing set
  - The testing error is used to evaluate the model
  - **Pros:** simple and fast
  - **Cons:** evaluation depends on how the data division is made

K-fold cross validation method

- ***k*-fold cross validation method:**
- Data set is divided into *k* subsets
- Repeat the holdout method *k* times circularly
- The average of testing errors of all *k* trials is used to evaluate the model
- **Pros:** less depends on how the data is divided
- **Cons:** training has to be run *k* times → much time and computation
- **Variant:** randomly divide the data into training and testing sets *k* different times

K-fold cross validation



Leave-one-out cross validation method

- **Leave-one-out cross validation method:**
  - *k*-fold cross validation with *k* = *N* (i.e., the number of data points in the set)
  - **Pros:** good evaluation
  - **Cons:** very expensive

Evaluation tools and metrics

- Confusion matrix
- Accuracy
- Recall, Precision, F1-score
- AUC (Area Under the ROC Curve), ROC (Receiver Operating Characteristic)
- MAE (Mean Absolute Error)
- MSE (Mean Squared Error)
- IoU

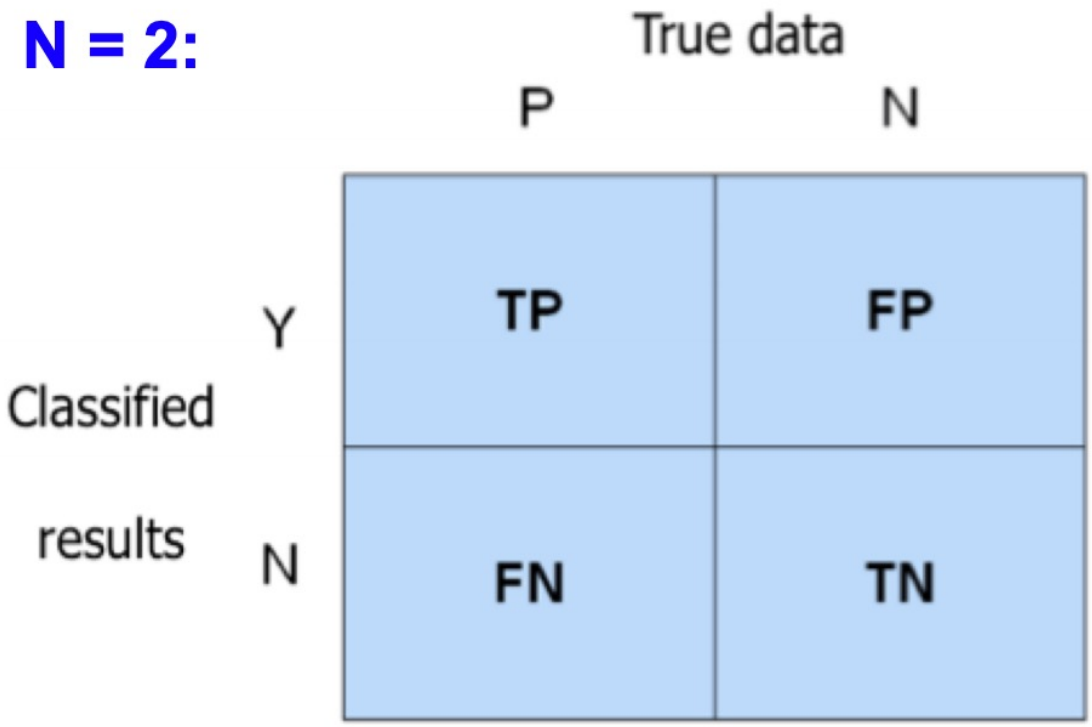
Confusion matrix

- A table summarizes how successful the model is at predicting
- **Confusion matrix:** the number of correct and incorrect predictions made by the classification model compared to the actual outcomes
  - Row: instances in a predicted class
  - Column: instances in an actual class
  - Size: N x N, where N is the number of outcomes

An example of confusion matrix

Recall, Precision, F1-score

N = 2:



TP: True Positive

FP: False Positive

FN: False Negative

TN: True Negative

$$RC = \frac{TP}{TP + FN}, PR = \frac{TP}{TP + FP}, ACC = \frac{TP + TN}{TP + TN + FP + FN}, F1score = \frac{2}{\frac{1}{RC} + \frac{1}{PR}}$$

An example of Recall, Precision, F1-score

	spam (predicted)	not spam (predicted)
spam (actual)	23	1
not spam (actual)	12	556

- TP = 23, TN = 556
- FP = 12, FN = 1
- RC = 0.96, PR = 0.66, F-1 = 0.78, ACC = 0.98

Receiver operating characteristic

- **ROC (Receiver Operating Characteristic):** curve of TPR vs. FPR at different classification thresholds

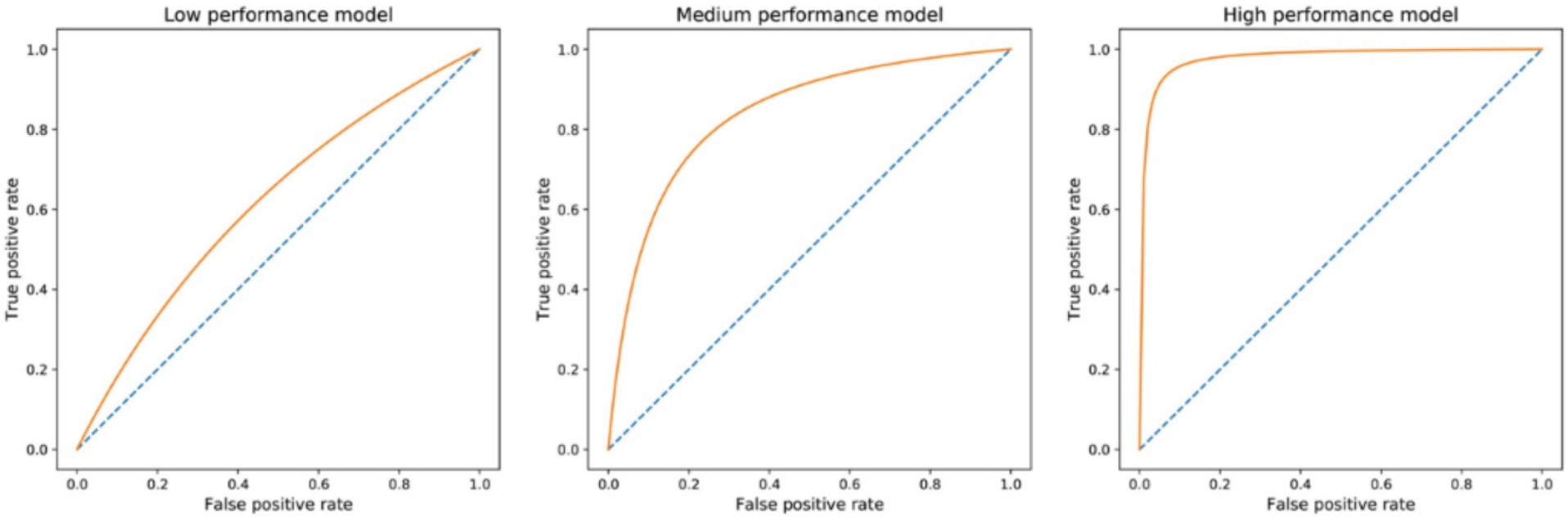


Illustration of possible ROC curves depending on the effectiveness of the model. On the left, the model has to sacrifice a lot of precision to get a high recall. On the right, the model is highly effective: it can reach a high recall while keeping a high precision.

Area under the curve

- **AUC (A**rea **U**nder the **C**urve**)**

AUC	Performance
> 0.9	Excellent
08 – 0.9	Good
0.7– 0.8	Fair
0.6 – 0.7	Poor
0.5 – 0.6	Fail

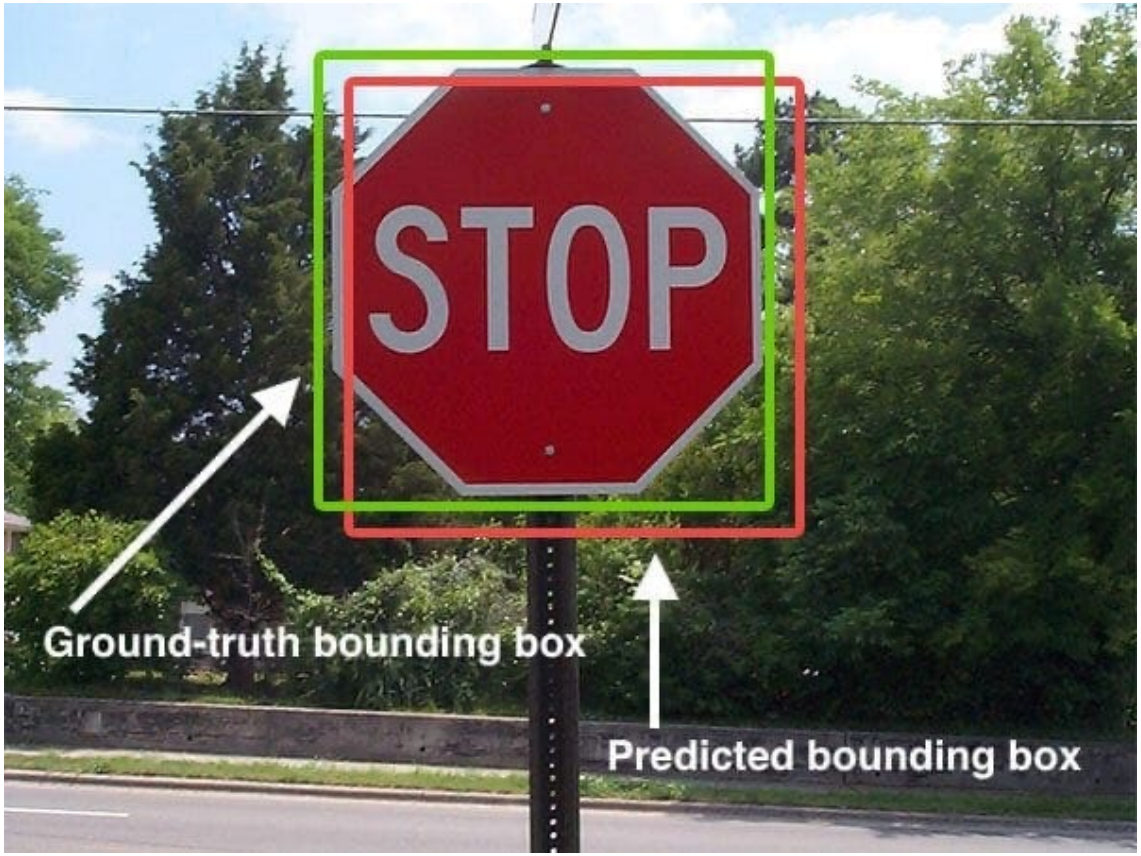
How to get ROC for multiclass classification model?

- **ROC for multi-class classification model**
  - N classes ← → N ROC curves
  - Using One-versus-All methodology
- **Example:** 3 classes X, Y and Z
  - ROC_1: X classified against Y and Z
  - ROC_2: Y classified against X and Z
  - ROC_3: Z classified against Y and X

Intersection over Union (IoU) for object detection

- Be used to evaluate the performance of object detection on a particular dataset.
- Comparing the ground truth bounding box to the predicted bounding box

Intersection over Union (IoU) for object detection



Intersection over Union (IoU) for object detection

$$IoU = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$

Bài tập lớn số 2

- **Đề:** Phân loại rượu vang Ý bằng phương pháp template matching
- **Cơ sở dữ liệu:** https://github.com/MukeshTirupathi/Wine-Classifier-Italy?tab=readme-ov-file

These data are the results of a chemical analysis of wines grown in the same region in Italy but derived from three different cultivars. The analysis determined the quantities of 13 constituents found in each of the three types of wines.

- **Phương pháp đánh giá:** hold-out crossvalidation (30:70), 10-fold cross validation, LOOCV

Bài tập lớn số 2

- **Bài nộp:** báo cáo và code (pdf), riêng nhóm thuyết trình nộp thêm file ppt đã chuyển pdf
- **Danh sách nhóm thuyết trình bài tập lớn số 2:**
  - Nhóm
  - Nhóm