Current subjects in computer science

Seminar #2

PATTERN RECOGNITION

1

Seminar Description

- *Introduction to pattern recognition systems*
- *Bayesian decision theory*
- *Feature Extraction and Selection Methods*
- *Example: Face Recognition*
- **Example: Robot Navigation**

2

APPEARANCE-BASED ROBOT NAVIGATION

3

ROBOT NAVIGATION

- *The navigation of a mobile robot form one point to another in the environment, requires a representation of the environment (a map).*
- *This map should contain enough information to make possible that:*
  - *The robot recognize its position.*
  - *To calculate the control action so that the robot navigates until the target destination.*

4

ROBOT NAVIGATION

- *The conventional approaches make use of geometric models.*
  - *Natural or artificial landmarks are extracted from the scene.*
  - *Comparison between the current features with those previously stored in a database.*
  - *High complexity.*
    - *Difficulty in features extraction.*
    - *Comparison of patterns in realistic and changing environments.*
    - *Non-structured environments.*

5

APPEARANCE-BASED ROBOT NAVIGATION

- *Appearance-based approach.*
  - *Images are stored without any feature extraction and recognition is carried out based on direct comparison between images.*
- *Useful for complicated scenes in real world.*
- *2 phases:*
  - *Learning. The robot stores some visual information from several points of view along the environment.*
  - *Autonomous navigation. The robot compares the current image with the stored ones to carry out navigation.*

6

APPEARANCE-BASED ROBOT NAVIGATION

- *Disadvantages of appearance-based robot navigation:*
  - *Necessity of high amounts of memory to store the information in the learning phase.*
  - *High computational cost to compare the current images with the stored ones.*
- *Key points of the approach:*
  - *Type and quantity of information to store.*
  - *How to make the comparison between the current view and the stored information.*
- *Approaches:*
  - *VSRR. Use of low resolution images.*
  - *PCA. Compression of the information to store.*

7

USE OF LOW RESOLUTION IMAGES

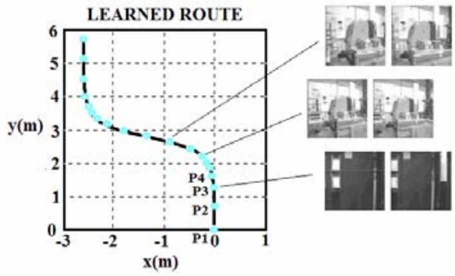
- *The size of the images is reduced by reducing its resolution.*
- *The size of the database is reduced with an automated learning phase.*

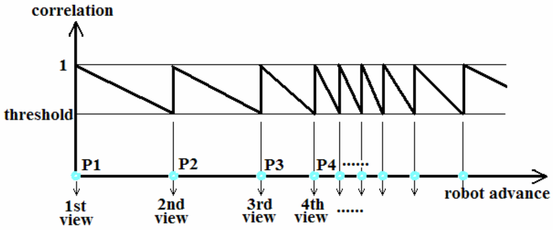

- *The objective is following pre-recorded routes using just visual information.*

8

USE OF LOW RESOLUTION IMAGES

- *LEARNING PHASE*
  - *The robot is teleoperated through the route to learn, taking images.*
  - *To optimize the size of the database, a threshold is chosen.*



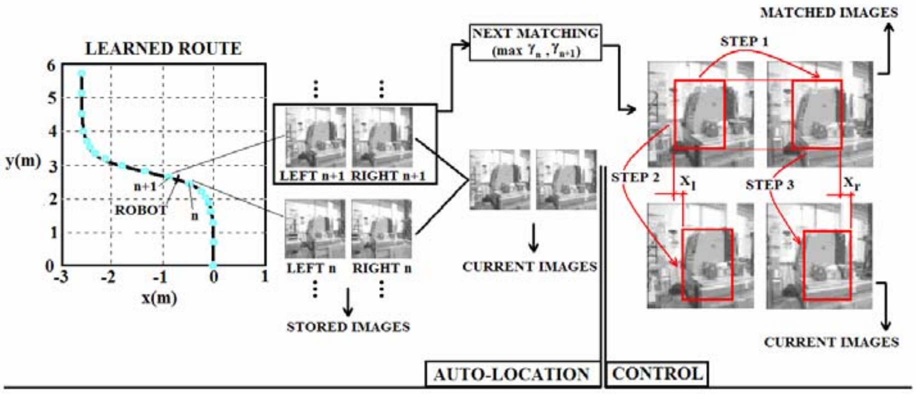


9

USE OF LOW RESOLUTION IMAGES

- *AUTONOMOUS NAVIGATION*
  - *1. AUTO-LOCATION. The current images are compared with the stored ones to know where the robot is.*
  - *2. CONTROL. The robot steering is corrected using a sub-window on the images.*

$$\omega^i = k_l \cdot x_l^i + k_r \cdot x_r^i$$
$$v^i = k_3 \cdot \gamma_{av}^i .$$



WORKING IN THE PCA SUBSPACE

- *The main drawback of the navigation method that has been exposed arises when the scenes used to define the route are highly unstructured and varying.*
- *In this case, it is necessary to increase resolution to get an acceptable correlation in navigation, but it will suppose that the computational cost will increase, so the average speed will be considerably lower.*
- *The compression of the information using PCA allows us managing with high resolution images without slowing down the performance of the classifier.*

WORKING IN THE PCA SUBSPACE

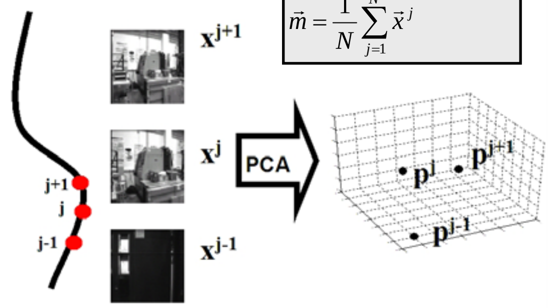
- *LEARNING STEP. It is carried out like it has been explained before. The only difference is that the information is reduced dimensionally by means of PCA, so, it is not necessary to store the entire images along the route.*

$$\mathbf{X} = \left[\tilde{x}^1 \ldots | \tilde{x}^j | \ldots | \tilde{x}^N\right]$$

$$\tilde{x}^j = \vec{x}^j - \vec{m}$$

$$\vec{m} = \frac{1}{N}\sum_{j=1}^{N} \vec{x}^j$$

$$P = V^T \cdot X$$



After this process, we have reduced each of the original images with M pixels to one vector (P) with K components. The database will consist on the N eigenvectors. The K coordinates of each point contain the most relevant information of the learned images.

WORKING IN THE PCA SUBSPACE

- *AUTONOMOUS NAVIGATION.*
  - ***Auto-location:***
    1. *The process is identical to the one described before, the only difference is in the information we are comparing.*
    2. *The current image is projected in the PCA subspace calculated in the learning phase. This would return a K-component vector corresponding to the principal components of the current view.*
    3. *Then, this vector has to be compared with all those stored in the database. The one that offers the minimum error is the matching one, which corresponds to the current position of the robot.*
       - *This operation is independent of the resolution of the images, so its computational cost is lower that working with the entire images.*

13

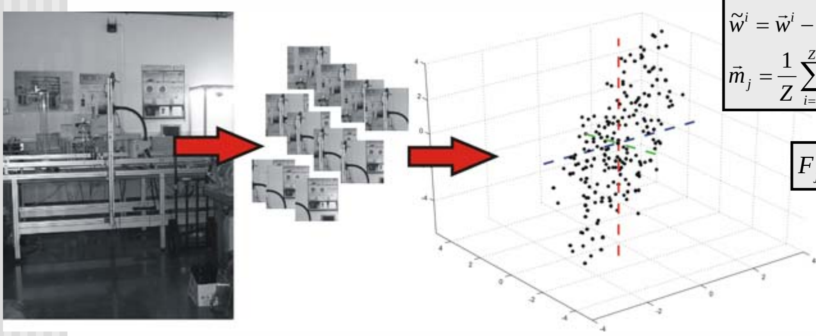
WORKING IN THE PCA SUBSPACE

- *AUTONOMOUS NAVIGATION.*
  - ***Control:***
    1. *From each image stored in the database, j, a set of Z windows is obtained from the whole image to make up the data matrix **W,** which defines the orthogonal transformation*

$$W_j = \left[\tilde{w}^1 \ldots | \tilde{w}^i | \ldots | \tilde{w}^Z\right]$$

$$\tilde{w}^i = \vec{w}^i - \vec{m}$$

$$\vec{m}_j = \frac{1}{Z}\sum_{i=1}^{Z} \vec{w}^i$$



$$F_j = U_j^{T} \cdot W_j$$

14

WORKING IN THE PCA SUBSPACE

- *AUTONOMOUS NAVIGATION.*
  - ***Control:***
    2. During the autonomous navigation, we take a central window in the current view and track it over the matching image.
       - The difference is that we do not compare the images but the transformed and reduced images by PCA.
       - To do this, once the robot knows its location, we project the central window of the current view into the PCA subspace.
       - This operation returns a K'-component vector corresponding to the most relevant information of the window. (K'< Z, Z = number of sub-windows).
       - Once we know the corresponding window, the steering velocity can be obtained without difficulty.

15