Face Biometrics without Intrusion in Airports

Dr. Enrique Cabello Pardos
July 20 2011
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ONCE UPON A TIME, AT THE LABORATORY...

Research Center Contract

• Make it possible.
  • (as fast as possible)
• Use the best equipment.
  • (as cheap as possible)
• Publish the results.
  • (as soon as possible)
ONCE UPON A COMPANY THERE SAT A RESEARCHER...

Research Center Contract

Make it possible.
(as fast as possible)
Use the best equipment.
(as cheap as possible)
Publish the results.
(as soon as possible)

The Company
Research Center
Researcher
... UNTIL THE COMPANY GETS INTERESTED.
... UNTIL THE COMPANY GETS INTERESTED.
... AND THE ADVENTURE BEGINS!

The Company
WHAT DOES THE COMPANY WANTS?

Company Contract

Few parameters. (two are too many)
Do not bother the user. (can't miss the flight)
Alarm system. (alarms, the fair ones)

The Company

The Company

Researcher
WHAT DOES THE COMPANY WANTS?

Company Contract

• For 50,000,000 of users.
• For 2,000 cameras
• Using current infrastructure.
WHAT DOES THE COMPANY NEEDS?
If I miss my plane, someone will die!
WHAT DOES THE RESEARCHER FACE?

How many of you have 500 cameras in your lab?

How many of you have 50 cameras in your lab?

How many of you have 5 cameras in your lab?
WHAT DOES THE RESEARCHER FACE?
Annual turnover of the biometric industry worldwide (Millions USD $)
Evolution of the number of patent applications per year of the traditional biometrics techniques versus the emerging biometrics techniques.
Evolution of the number of patent applications per year of the emerging biometrics techniques.
Evolution of the number of patent applications per country.
Comparison between generation and publication of patents per country.
The biometric industry is a fragmented market. There are big and small companies!

<table>
<thead>
<tr>
<th></th>
<th></th>
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<td>36,0</td>
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HOW DO WE ATTACK THE PROBLEM?

Identification

Is it useful?
HOW DO WE ATTACK THE PROBLEM?

Verification !
HOW DO WE ATTACK THE PROBLEM?

Verification

Supervised?
Unsupervised?

Is it useful?
HOW DO WE ATTACK THE PROBLEM?

Verification

Supervised?
Unsupervised?

Is it useful?

Help to frequent flyers?
APPLICATION OF FACE BIOMETRICS SYSTEMS FOR PEOPLE RECOGNITION IN AIRPORTS
PROJECT OBJECTIVES

☒ Evaluate a biometric system based on face features in a real environment (Barajas airport).

☒ Test a biometric system in an environment with uncontrolled lighting, but with high security requirements.

☒ Study of the viability of the cameras system of the Barajas airport.
A complete system has been developed. The system includes the image acquisition and digitalization, the face extraction and localization and the subject verification processes.

The prototype of the face verification system has been tested with images obtained from a set of surveillance cameras at the Barajas airport.


Experiments:

The system was trained with images obtained under controlled conditions and tested with images obtained from the surveillance cameras of the Barajas airport.

The system was trained and tested with images obtained in the Barajas airport.

In general, the results show that a face verification system based on images could be helpful to an operator who watches wide zones of an airport.
RESEARCH GROUP BACKGROUND

- European Project
  - “Video-sensor Object Request Broker Open Architecture for Distributed Services”

- Two projects in cooperation with airport and Spanish Police
  - “Face Recognition in the airport without cooperation”
  - “Automatic user behavior recognition in the airport”

- Spanish funded project
  - “Automatic face recognition in Automatic Border Crossing Systems”
FRAV2D database:

- 109 subjects.
- 32 images per subject.
- Resolution of 320 x 240 pixels.
- Purpose: Serve as test set for verification algorithms.
- Different positions and lighting conditions.
RESEARCH GROUP BACKGROUND

- FRAV3D: Multimodal database (2D y 3D).
In the last 10 years, several face recognition techniques through global methods based on statistics theories have been developed.

The main challenge is to confront the high variability of the images:
+ Inter-subjects variations (different appearances of the same subject).
+ Intra-subjects variations (pose, facial expression, lighting, age, etc.).
+ Some of these variations can be removed before the recognition, but others so not.

The performance: depends of the database used for testing.
INTRODUCTION TO FACE RECOGNITION TECHNIQUES

- Techniques in function of the face representation:
  - **Position dependent 2D**: a number of 2D images is stored (appearances) like a representative set of the face.
  - **Position independent 3D**: the face is represented by a 3D model.

- Techniques according to features type:
  - **Global**: are very dependent of the intra-subject variations. (Eg: PCA).
  - **Local**: is hard to identify the points that contains the desired information.
  - **Hybrid**: combine both types of features (LFA y EBGM, but they are closest to the local).
INTRODUCTION TO FACE RECOGNITION TECHNIQUES

- Current techniques according to the technology:
  - PCA (Principal Components Analysis).
  - EBGM (Elastic Bunch Graph Matching).
  - LFA (Local Feature Analysis).

- The most relevant face recognition methods:
  - Geometric features.
  - Principal Components Analysis (PCA) (Eigenfaces).
  - Linear Discriminant Analysis (LDA) (Fisherfaces).
  - Neural networks.
  - EBGM + Wavelet transform.
  - 3D face modeling.
  - Other techniques.
The first visits confirmed that, the airport cameras that should be used:

- Recorded in an analog format.
- Some had a good quality and others had a poor quality.
- The lighting was not controlled.
- Did not focus to the front of the subjects.
- Were located at different heights.
CAMERA SELECTION

- Is the first task and determines the final results.

- The selection process counted with the help of:
  - The airport civil guard.
  - With more than 1’000 cameras at the airport, the expert’s knowledge allowed us to focus on a few group of cameras.

- Many cameras were discarded due to:
  - Low quality images.
  - Background with a lot of motion or noise.
    (this makes difficult the face localization)
  - Steep angles.
  - Low lighting.
  - The installation of a face verification system normally means the installation of dedicated cameras and computer equipment.

- Once the cameras were installed, three experiments were planned.
In this experiment the application of the verification system to one subject sequentially observed by two different cameras was pretended.

Therefore, the subject must pass first in front of one camera and then in front of the other.

The cameras considered for this experiment were located in a corridor and designated as:

- Belt 1 (Camera 79)
- Belt 2 (Camera 2127).
EXPERIMENT 1: CORRIDOR

- Belt 1 (Camera 79).
EXPERIMENT 1: CORRIDOR

- Belt 2 (Camera 2127).
EXPERIMENT 2: ARC DETECTOR

- In this experiment the verification of the subject identity was pretended.
- It was decided to select one camera in an arc detector zone.
- The laboratory images (FRAV2D) for the same subject were compared with the images obtained with the surveillance cameras in this zone.
- The selected camera for this experiment was the 2154 (the camera in the zone in which the image had the best characteristics).
- In the arc detector zone, the lighting was more uniform. Hence, the face verification was supposed to be better.
- This video was labeled as arcs.
EXPERIMENT 2: ARC DETECTOR

- Camera 2154.
EXPERIMENT 3: MULTI CAMERA

- Like Experiment 1, but with two cameras focused on the same subject simultaneously.

- This experiment was discarded because it is not a normal process of the surveillance service. Moreover, the cameras were not designed to be used in this way. The cameras tested in this experiment were the 60 and the 2022.

- The simultaneous face verification with two cameras is not used.
EXPERIMENT 3: MULTI CAMERA
CAMERAS LOCALIZATION MAP

NOTA: Los escenarios marcados con un astérisco (*) no fueron finalmente considerados en el presente trabajo.
FACE RECOGNITION PROCESS:

- Phases:
  1. Detection of the face in the scene.
  2. Representation of the face.
  3. Classification of the face.
FACE RECOGNITION PROCESS:

1. DETECTION

- In some cases, the images are obtained in controlled conditions: (images obtained by the police, FRAV2D, etc.). The face localization in these scenes should be easily done.

- In other cases, the face position in the image is not known. Therefore, the first step is to determine if there are faces or not in the scene. If there are, they must be located.

- Several factors make this a very complex problem:
  - Makeup, facial hair (mustache, beard, etc.) or elements occluding face features.
  - Variations on scale or orientation of the face in the image.
  - Lighting of the scene.
  - Image quality.

- Most of the face detection methods are based on flexible templates, eigenfaces, neural networks or face color.
A commercial program was used for face detection.

It was tested with:
- Laboratory images (FRAV2D).
- Images obtained from the security cameras of the arc zones (with better quality).

Results:
- The program works efficiently with the frontal images obtained at the laboratory.
- The program was not reliable in face turns and occlusions. It was unable to locate the face in the image (even with the laboratory images).
- In the tests with the images obtained from the security cameras of the arc zones, it was unable to make any detection.
- The system was discarded due to the poor results obtained.
1. DETECTION

**VIOLA & JONES**

- The Viola-Jones Method (Rapid Object Detection using a Boosted Cascade of Simple Features)
  - It is a robust algorithm that provides very good results even with low image qualities.
  - It is able to locate the face in a huge percentage of cases, even in adverse situations.
  - Empirically, it has been observed that this algorithm fails in the next situations:
    - 1. The subject is standing back or side.
    - 2. The subject’s face is partially occluded:
      - The subject is wearing sunglasses.
      - The subject has his head covered.
      - The subject has his face covered by the hand.
      - The subject is using a mobile phone.
      - The subject is behind another person.
    - 3. The subject makes a very large head turn (looking to the floor or to one side).
    - 4. The subject is moving away from the camera.
### FACE RECOGNITION PROCESS:

#### 1. DETECTION

**VIOLA & JONES**

Percentage of correct detections.

<table>
<thead>
<tr>
<th>BD</th>
<th>Duración estudiada</th>
<th>N° individuos contados</th>
<th>N° de individuos detectados</th>
<th>Porcentaje de localización correcta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcos</td>
<td>20 min</td>
<td>34</td>
<td>34</td>
<td>100%</td>
</tr>
<tr>
<td>Cinta1</td>
<td>26 min</td>
<td>250</td>
<td>137</td>
<td>54%</td>
</tr>
<tr>
<td>Cinta2</td>
<td>20 min</td>
<td>238</td>
<td>158</td>
<td>66%</td>
</tr>
<tr>
<td>Frav2D</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>

Tabla 3.1.- Resultados de localización.
In order to make the experiments mentioned earlier, a data base has been generated from each video.

<table>
<thead>
<tr>
<th>Nombre de la base de datos</th>
<th>Nº individuos</th>
<th>Nº de fotos / individuo</th>
<th>Ejemplos</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arcos</td>
<td>46</td>
<td>10</td>
<td>Figura 3.21</td>
</tr>
<tr>
<td>Cinta1</td>
<td>94</td>
<td>10</td>
<td>Figura 3.22</td>
</tr>
<tr>
<td>Cinta2</td>
<td>183</td>
<td>10</td>
<td>Figura 3.23</td>
</tr>
<tr>
<td>FRAV2D</td>
<td>109</td>
<td>32</td>
<td>Figura 3.24</td>
</tr>
</tbody>
</table>

Tabla 3.4.- Características de las Bases de Datos Obtenidas.
FACE RECOGNITION PROCESS:

DATA BASE GENERATION
It can be seen that the image quality is very variable (from a high quality of the images acquired at the laboratory to a very poor quality of the oldest cameras used at the airport).

Other observable factors are the variability on the lighting and position of the face in each image.

At the laboratory, the face position is almost frontal and, at the airport, the subject can freely turn his face in any direction.
FACE RECOGNITION PROCESS:

2. REPRESENTATION

- Dimensional reduction:
  - PCA (Principal component analysis) This transformation is defined in such a way that the first principal component has as high a variance as possible (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (uncorrelated with) the preceding components.
  - 2DPCA (Bidimensional Principal component analysis): Similar to PCA but the 2D information of the face is maintained.
FACE RECOGNITION PROCESS:

2. REPRESENTATION

- 2DLDA (Two-Dimensional Linear Discriminant Analysis) is a method to find a linear combination of features which characterize or separate two or more classes of objects or events.
- CSA (Coupled Subspace Analysis): an approach to reconstruct the original image matrices with two low dimensional coupled subspaces. These two subspaces encode the row and column information of the image matrices.
FACE RECOGNITION PROCESS:

- **Identify**: Associate a name to a face.
- **Verify**: Check if a name match with a face.
- **Selected technique**: SVM.
- **Hypothesis**: For a given face, the values of its features do not present a significant variation between different images.
- The selected features need to meet certain conditions:
  - Easy to estimate.
  - Lighting independent.
  - Face expression independent.
  - Highly discriminable.
  - Further, it is necessary to include a normalization stage in order to make the measurements independent to scale, position and orientation.

3. CLASSIFICATION
Five experiments were made:

- On the first three experiments, the system was trained with images from the laboratory and tested with images from the Barajas airport.
- On two remaining experiments, the system was trained and tested with images from the Barajas airport.

The size of the images (in pixels) was of 50x50.
The summary of the tests are presented in the table below. The EER (Equal Error Rate) is presented.

<table>
<thead>
<tr>
<th>Entrenamiento</th>
<th>Prueba</th>
<th>N° individuos</th>
<th>EER</th>
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<td></td>
<td>BD</td>
<td>N° imágenes</td>
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<tr>
<td>Gráfica 1</td>
<td>Frav2D</td>
<td>5</td>
<td>5</td>
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<td>Gráfica 2</td>
<td>Frav2D</td>
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<td>Frav2D</td>
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<td>5</td>
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<tr>
<td>Gráfica 4</td>
<td>Arcos</td>
<td>5</td>
<td>5</td>
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<tr>
<td>Gráfica 5</td>
<td>Cinta 1</td>
<td>5</td>
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Tabla 3.5.- Resultados obtenidos con los diferentes métodos
RESULTS (FRAV2D AND BELT 1)
RESULTS (FRAV2D AND BELT 2)
RESULTS (BELT 1 AND BELT 2)
RESULTS (ARCS AND BELT 1)
RESULTS (FRAV2D AND ARCS)
CONCLUSIONS

- The present study has allowed the test of a face verification system at the Barajas airport.
- All the phases of the development have been addressed:
  - Selection of the cameras.
  - Video acquisition and digitalization.
  - Localization and extraction of the faces.
  - Database generation.
  - Tests of face verification.
The results obtained are promising and comparable with the results obtained with commercial systems. (Considering that the acquisition was not made in optimal conditions)

The system used for this project has been implemented using the current cameras infrastructure in the Barajas airport without adding additional elements or interfere with its habitual use. Hence, the position and orientation of the images acquired was restricted.
CONCLUSIONS

- Although the databases used were made with a reduced group of subjects, the tests show that the considered approach for a face verification system could be helpful for decision making.

- Although it was not an objective of the project, the tests of the system showed that it is possible to make the digital image processing in real time.
CONCLUSIONS

- One of the objectives achieved has been a study of the different available cameras at the Barajas airport and its possible application in a face biometric system.

- The most modern cameras offers an acceptable quality.

- The oldest cameras has a very poor quality for its use in a face recognition system.

- Further, one of the main advantages of a face verification system based on video surveillance cameras is that the users will not feel as studied subjects.
Face Biometrics without Intrusion in Airports