Non Conventional 3D Human Face Verification System

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ABSTRACT

Different from traditional methods which use two-dimensional images and gray levels to recognize human faces, this article shows a known shape extraction methodology applied to the extraction of 3D human faces conjugated with a conventional and non conventional algorithms for face verification. The SORFACE project involves two main knowledge areas, 3D shape extraction and pattern recognition. The first is based on Fourier Profilometry and the second on Case Base Reasoning - CBR and Artificial Neural Networks - ANN, which perform a symbolic and connectionist recognition system. Although these methodologies themselves are not new, the goal of this work is conjugate all in a face verification application problem and shows the results. Are commented too the benefits achieved by this 3D extraction technique over the illumination and geometric positioning problems. This is only viable today thanks to the increase of processing capacity of the new computers. This article describes all the techniques used to build a non conventional optical system for 3D human face verification, the SORFACE project proposal.

Keywords
Computer Vision, 3D Face, Face Recognition, Neural Networks, Case Base Reasoning, Fourier Profilometry, Phase Unwrapping

1. INTRODUCTION

Humans are capable to identify faces in almost any scenario, with minimal work. But machines need a set of techniques and devices to be capable to a recognition effect. Therefore, to build a human recognition system it is necessary achieve some characteristics, such as fast acquisition time, simplicity and low cost, making the use of this system efficient and robust.

Humans recognize face images with skewed, low or hidden details due to the fact that the human brain has a region dedicated to this kind of task. To apply this model in a machine, the use of biologic inspiration, trough Artificial Intelligence - AI, follows the modern techniques of recognition computation.

Behind any face recognition system there are many other theories, because the identification is only the final system task. It is necessary to acquire and process the face image in order to subtract the needed information for the identification step. Then, computer vision and digital image processing are two theories walking together with AI in the face recognition problems.

The SORFACE project has a few differences with the conventional face recognition systems. Firstly of all, the optic metrology technique was applied. This acquisition method is called Fringe Projection.

2. THE COMPUTER VISION SYSTEM

To reach requisites, such as minimum interaction between individual and machine, it is necessary to keep in mind all devices and methodologies for 3D human face information extraction and think of these theories and equipments as one whole system.

3D Face Extraction Methodology

The shape extraction method consists of a Spatial-Carrier Phase Measurement that uses the Fourier Transform to recover the phase information. The structured light over the real face, shown in Figure 2.1, produces a line pattern carrying height information.

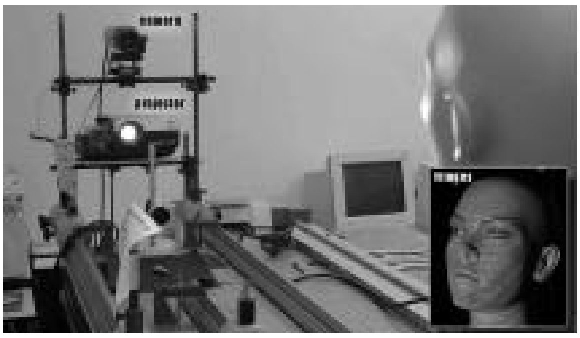

Figure2.1 Fringes Projection and Data Acquisition System.

2.1.1 Fourier Profilometry

The Profilometry method used is Fourier Transform Profilometry [Tak83a]. The optical geometry is very similar to Moire Topography, however, the advantage of this proposed method is that with one projected grating only it is possible to produce the object's fringes. The fringes intensity on the object surface *g(x,y)* is given by:

$$g(x,y) = a(x,y) + b(x,y)\cos[q(x,y) + 2pf_o x] \quad 2.1$$

Applying Fourier Transform, the phase is found by:

$$q(x,y) = tg^{-1}\frac{\mathrm{Im}[c(x,y)]}{\mathrm{Re}[c(x,y)]} \quad 2.2$$

Figure 2.2 shows intensity and modulation signals, where it is possible to see the frequencies spectrum. Only frequencies with higher modulation are used to reconstruct a face shape. Unfortunately this map gives an unwanted wrapped phase (see Figure 2.3), where the values vary between ð and -ð.

2.1.2 Phase Unwrapping

To correct the discontinuity in the result of Figure 2.3, a 1D phase unwrapping technique is the first and natural approach to solve this task. Unfortunately this simple algorithm gives poor results when applied over complex shapes like human faces.

Because of these few problems with the 1D technique, the Flood Fill unwrapping algorithm is used [Ass98a]. This approach uses 2D information and divides the phase matrix in weighted regions. The modulation's signal is a measurement of the local fringe quality, being used to separate phase information in regions.

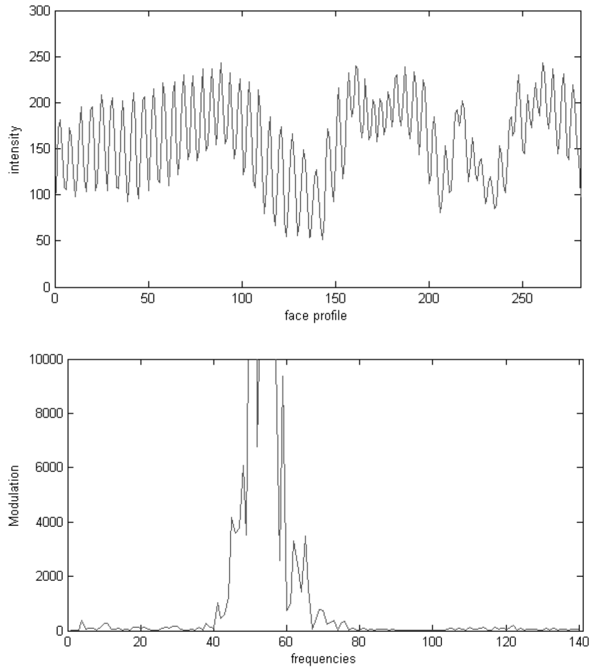

Figure 2.2. Intensity and modulation signals from one face profile.

Those regions are grouped from the higher modulation value to the lowest. The unwrapping process starts at the best regions, higher values, and goes, step by step, to the worst regions, lower values, making the entire unwrapping computation more robust.

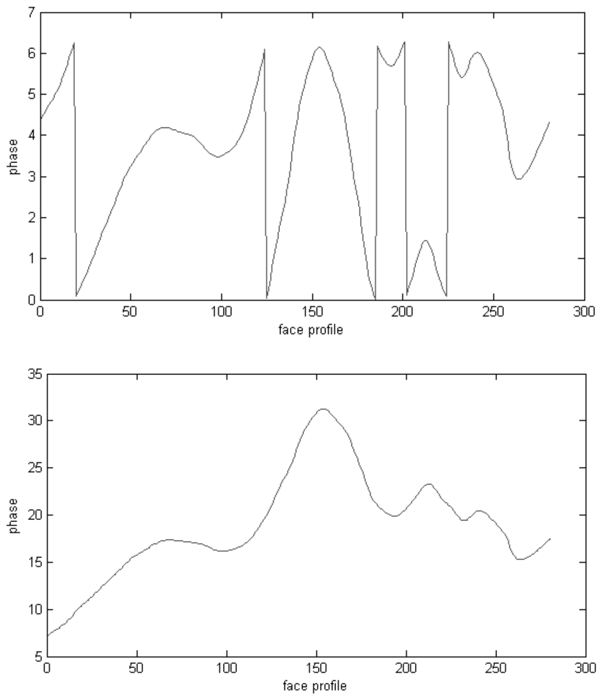

Figure 2.3. Wrapped and unwrapped phase signals from one face profile.

3. FACE DATABASE

The system performance is directly connected to the face database construction. In the SORFACE project a new database was built because the recognition system is based in 3D human face and no data was available. Two criteria were followed:

1. Try to cover all possibilities that can occur in functioning of the system.
2. Permit its utilization in classification learning process, like Artificial Neural Networks.

The database contains the data of 52 different individuals. From each individual, 32 pictures were taken. These pictures were then classified in two groups, facial expressions and spatial positioning. Some samples are shown in Figure 3.1.

Figure 3.1 Samples from the SORFACE face database.

The pictures shown are in the 2D gray levels image representation. However, the recognition system uses the 3D representation of face as shown in Figure 3.2.

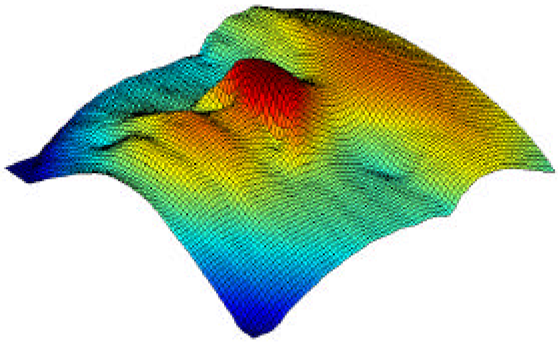

Figure 3.2 Result of 3D face reconstruction.

4. THE CONECTIONIST/SYMBOLIC RECOGNITION SYSTEM

Since human being recognize each other through the face, this recognition is the most friendly and natural biometric system. It is starting to gain importance over other applications because the human interaction with the recognition system is almost null. Face verification is a particular case of pattern recognition where the individual gives his identity and the machine makes the verification of his authenticity. It is different from the identification task where the machine needs to search in a face data base for the best face representation that matches with the individual being tested.

The Biometric Error Evaluation

Biometric systems are commonly evaluated by two principal error ratios:

1. False Acceptance Ratio – FAR: incorrect classification case, which express how many times the system accepts an impostor thinking it is a correct individual (Error Type II).
2. False Rejection Ratio – FRR: incorrect case classification, too, which express how many times the system rejects a correct person (Error Type I) [Man98a].

Obviously FAR and FRR depend of the threshold value used to set the system's security level. As higher the FAR and lower the FRR higher the system acceptance and consequently lower the security. These kinds of systems are the most used in criminal applications. A lower FAR and a higher FRR give lower acceptation characteristics, good conditions for high security applications like bank access.

Case Based Reasoning Verification

Case Base Reasoning is a process to solve actual problems, where a closer past case is associated with a new case, and the past solution is adopted. Aamod & Plaza describe very well and generically all the CBR process [Aam94a]. The process of information recuperation requires a measuring algorithm to calculate the similitude degree between cases, making the choice to reuse or not that case. The SORFACE project uses the Hamming Distance to compute the similitude evaluation.

The biometric verification process, as treated here, is essentially part of a CBR case, where the face to be verified is identified as a new case on a retrieve process that uses faces from a database. CBR has one important condition in order to be used in a recognize system, the data space must be a metric space.

4.1.1 The Similitude Calculation

Generally the similitude measures the proximity between two cases *a* and *b* and is called S(*a*,*b*), [Bar01a]. This function associates all data pairs from *U*, a real value set, non negative, such that

$d(a,b) \rightarrow \mathbb{R}^+$, $\forall\, a,b \in U$. The similitude proprieties are defined below:

$$d(a,b) = 0 \quad \text{if} \quad a = b \qquad 4.1$$

$$d(a,b) = d(b,a) \qquad 4.2$$

$$d(a,c) \le d(a,b) + d(b,c) \qquad 4.3$$

In this case, the Hamming Distance was used as similitude evaluator because it gives low computational cost and does not add gain to high differences values like the Euclidean Distance. The Equation 4.4 shows how the Hamming Distance is calculated.

$$dH(a,b) = \sum_i |a_i - b_i| \qquad 4.4$$

The results with facial normalization for CBR paradigm are shown in Figures 4.1 and 4.2.

Radial Base Function ANN Verification

When an individual stands in front of the face recognition system, he never stays in the same spatial position or with the same facial expression. There are differences between the taken picture and the picture stored in the machine. The machine system must be prepared to accept these changes without any identification error.

As opposed to the CBR paradigm, where is important normalize the face database, ANN systems need to use the most extreme face cases for its training. This is necessary because ANN interpolate between the learned cases [Bar01a].

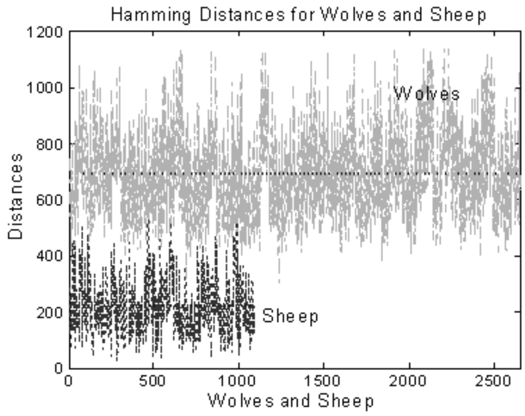

Figure 4.1 CBR classification's data for a desired person with face database optimization.

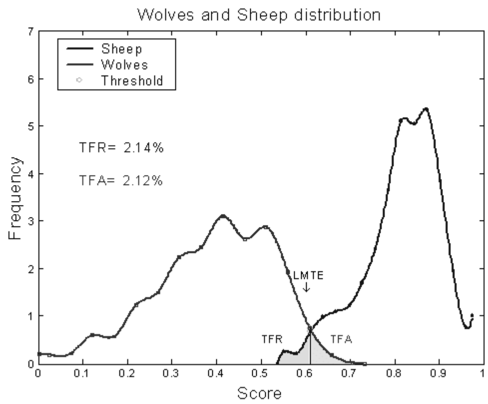

Figure 4.2 FAR and FRR in CBR classification for a desired person with face database optimization

A RBF ANN was chosen due its theoretical qualities such as:

1. Short learning time during the learning procedure.
2. Easy configuration, generally a RBF ANN has only one hidden layer
3. Its learning paradigm, generally a not supervised learning associated with a supervised method, that enables an easy comprehension of how the RBF paradigm works in relation with other NN's models

The learning algorithm used here was the Orthogonal Least Squares developed by Chen [Che83a]. This training algorithm starts with a minimum number of centers and goes increasing until reaching the desired error.

The activation function $j(r)$ is given by a Gaussian with radius represented by the Equation 4.5 and where ||.|| represents an Euclidean norm between the centers and the inputs.

$$r = \frac{\| \mathbf{c}_j - \mathbf{x} \|}{c_{j0}} \quad 4.5$$

The outputs values correspond to a score between "0" and "1". The "0" means the face does not correspond to the wanted face with 100% of confidence, and the output value "1" means the face correspond to the wanted face with 100% of confidence. Output scores between "0" and "1" are treated like linear approximations to these extreme values.

The score results can be seen in Figures 4.4 and 4.5. For the validation set, the two populations are completely separated, indicating that the verification system with this set of 52 individual's faces had a good response. Furthermore, with a threshold range between 0.45 and 0.80 the FAR and FRR are null.

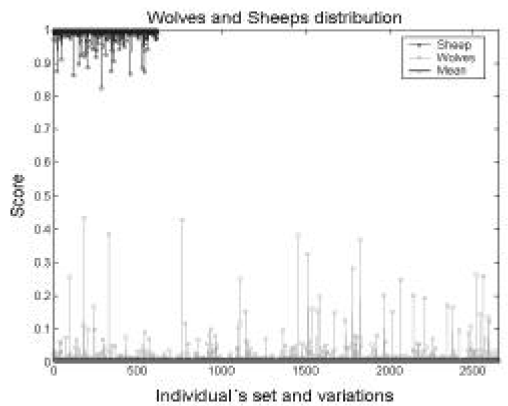

Figure 4.4. NN classification's data for a desired person.

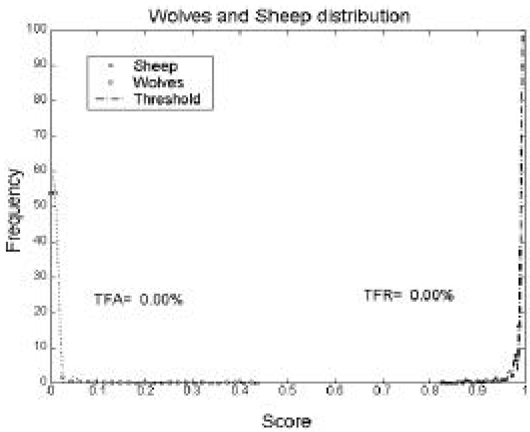

Figure 4.5. FAR and FRR in NN classification for a desired person.

5. CONCLUSIONS

With all subsystems presented here, it is possible to get a clear view of the SORFACE project, its advantages and disadvantages.

The shape extraction paradigm, Fourier Profilometry, has the simplicity as the main advantage because the face acquisition is performed by one face image, providing fast acquisition time.

However, in the fringes processing some improvements have to be done, especially in cases where the fringes are obstructed.

The dimensionality reduction gave a complete understanding about the relation quantity of information by recognition time. What proves that the entire face database can be reduced into 30% its dimension, increasing the recognition system efficiency.

In terms of the Verification subsystem, as RBC as ANN had a good performance, then, the use of each paradigm is directly associated with the face database characteristics. If the face database has normalization characteristics then RBC is faster. But, if robustness is necessary, ANN is the best approach to 3D face recognition.

Thus, this non conventional optic system for 3D human face recognition has promising features, what makes it a good choice in verification problems, like bank access.

6. ACKNOWLEDGEMENTS

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