# New Prototype of Hybrid 3D-Biometric Facial Recognition System

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**Abstract**: *In the last decades, a lot of 3D face recognition techniques have been proposed. They can be divided into three parts, holistic matching techniques, feature-based techniques and hybrid techniques. In this paper, a hybrid technique is used, where, a prototype of a new hybrid face recognition technique depends on 3D face scan images are designed, simulated and implemented. Some geometric rules are used for analyzing and mapping the face. Image processing is used to get the two-dimensional values of predetermined and specific facial points, software programming is used to perform a three-dimensional coordinates of the predetermined points and to calculate several geometric parameter ratios and relations. Neural network technique is used for processing the calculated geometric parameters and then performing facial recognition. The new design is not affected by variant pose, illumination and expression and has high accurate level compared with the 2D analysis. Moreover, the proposed algorithm is of higher performance than latest's published biometric recognition algorithms in terms of cost, confidentiality of results, and availability of design tools.*

**Keywords**: *Image processing, face recognition, probabilistic neural network, photo modeler software.*

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## 1. Introduction

In the last three decades, face recognition researches are becoming an active research area that having many real-life applications such as: Identification and verification for terrorists, criminals and missing children [9]. Face recognition is also useful in human computer interaction, virtual reality, database recovery, multimedia, computer entertainment, information security and biometrics [6]. First face recognition researches are depending on face illumination and 2D information analysis for the face images [7].

Although, the first researches achieved successful results and performances, other biometric recognitions like fingerprint identification systems and retina and iris identification are considered to be more accurate than the face recognition and that due to the fact that the 2D facial recognition systems are relied on human pose and expressions [3, 5, 16] and those two factors are varied according to the human age, psychology and face illumination (which depends on the surrounded place where the face photos are taken). Recently, engineers and researchers tend to use a new face recognition technique which depends on 3D face scan images and analysis and is not effected by variant pose, expression and face illumination [1, 3, 10], but still not commonly used in ordinary security applications due to the high cost system recognition equipments and tools such as 3D sensors, scanners and special cameras [1, 2, 17]. Because face recognition is important in Many applications, therefore, different 3D face recognition methods are proposed by several studies [4]. In this paper, a new prototype of hybrid 3D Biometric [8, 12, 15] face recognition system is designed, simulated, and implemented, that combines 3D geometric close range analysis of photo modeler software and Probabilistic Neural Network (PNN) recognition process [13].

## 2. Related Works

As mentioned above, in the last three decades, a number of 3D and 3D+2D new face recognition techniques have been proposed. These techniques can be divided into three parts: Holistic matching techniques feature based techniques and hybrid techniques [6, 11].

In holistic approach, the complete face region is taken into account as input data into face catching system. For example, Satonkar *et al.* [14] have used two holistic approaches for facial images, the Principal Component Analysis (PCA) and the Linear Discriminant Analysis (LDA).

In feature-based approach local features such as eyes, nose and mouth are first of all extracted and their locations and local statistics (geometric and/or appearance) are fed into a structural classifier [16].

In hybrid approach, a combination of both holistic and feature extraction methods are used. This approach consists of detection, position, measurement, representation and matching processes [6]. The detection process is capturing a face either a scanning a photograph or photographing a person's face in real time. The position process is determining the location, size and angle of the head. The measurement process is assigning measurements to each curve of the face to make a template with specific focus on the outside of the eye, the inside of the eye and the angle of the nose. The representation process is converting the template into a code (numerical representation of the face) and finally, the matching process is comparing the received data with faces in the existing database. In this paper, a hybrid technique is used where a 3D geometric close range analysis of PhotoModeler software and a PNN recognition process are combined to form the proposed hybrid facial recognition system.

## 3. The Proposed System Design

Figure 1 shows the flowchart diagram of the proposed design, where detection, position, measurement, representation and matching processes are all involved in the system design. The diagram shows four steps, in the first step (the detection and the positions processes), a digital camera is used to capture at least three overlapping photos for a human phase, from different angles (right, left and front side views) as shown in Figure 2.

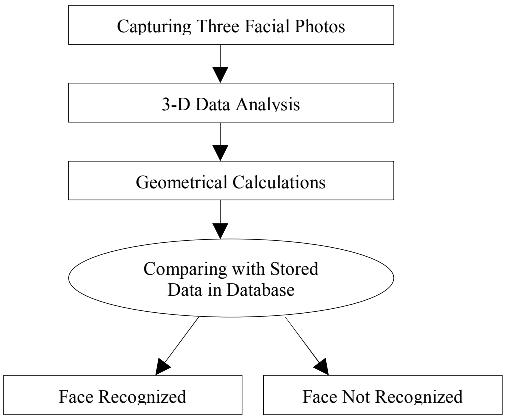
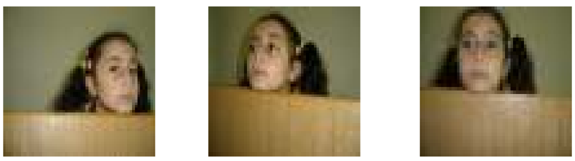



Figure 1. System design diagram.



a) Right side view. b) Left side view. c ) Front side view.

Figure 2. The three captured photos.

In the second step (the measurement process), the captured images are processed using software programming and that include marking and referencing, where marking includes the universally and the uniqueness of face points and referencing represents the fundamental idea of matching, where, each marked point in the reference photo is matched with the equivalent marked point in other photos. The minimum face points needed for the proposed system to construct any 3D model are six. Figure 3 shows seven points and that includes the eye terminal-points, the upper middle sections of eye sockets, one point at the nose-top, the mouth terminal-points and lower chin point. The previous face points (except the mouth points) are not affected by face gesture, motion of face itself and existence or absence of sunglass or lenses. Mouth points are only considered to create the 3D face model; in the following stages those two points will be omitted.

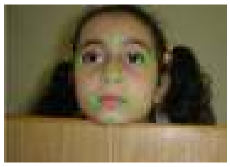


Figure 3. The required seven facial points.

The used processing algorithm is an iterative process, where, sequence steps repeated many times to determine the location of each point in three dimensions and to minimize the total error. Finally, a specific software programming tool is used to convert the predefined two-dimensional mark points (X, Y) into a three-dimensional mark points (X, Y, Z). In the third step (the representation process), the previous 3-D facial points are used to calculate the predefined and the predetermined geometrical parameters. In the fourth step (the matching process) a PNN of two layers is used for processing the calculated geometric parameters and then performing facial recognition. The third and the fourth steps will be explained in the following subsections.

### 3.1. Geometrical Face Difference Distance and Distance Ratio Parameters

If Point *a* is located at ($x_a$, $y_a$, $z_a$) and b Point is located at ($x_b$, $y_b$, $z_b$), then the Face Difference Distance (FDD), which represents a 3-D distance, can be calculated from the following relation: FDD=Length of $P = |P| = \left(P_1^2 + P_2^2 + P_3^2\right)^{1/2}$. Where the points $P_1$, $P_2$ and $P_3$ are equal to ($x_a$-$x_b$), ($y_a$-$y_b$), and ($z_a$-$z_b$) respectively. The Distance Ratio (DR) between the distances (2, 7) and (1, 3) determines whether the face is circular or cylindrical, where:

$$DR = \frac{Distance\ (2,7)}{Distance\ (1,3)} \quad (1)$$

If *DR*>1, then the face is approximately cylindrical, otherwise the face is approximately circular. The value of *DR* is a good parameter to make first view of the face shape. Figure 4 illustrates two calculated vertical and horizontal FDDs and their ratio.

a) Vertical FDD= 9.953cm. b) Horizontal FDD= 7.571cm.

Figure 4. Vertical and horizontal geometrical distances and the calculated DR.

$$DR = \frac{Distance\ (2,7)}{Distance\ (1,3)} = \frac{9.953\ cm}{7.571\ cm} = 1.315 \tag{2}$$

$$FATR = \frac{A(1,3,7)}{A(1,3,4)} = 2.9755 \tag{3}$$

$$FDA = |47.7212 - 37.7343| = 9.9869^{\circ} \tag{4}$$

$$AR = \frac{Angle(1,3,4)}{Angle(1,3,7)} = \frac{47.7212}{37.7343} = 1.2646637 \tag{5}$$

### 3.2. Geometrical Face Area Triangular Ratio Parameter

The Face Area Triangular Ratios (FATR) can also be considered as a good parameter to distinguish between humans. The ratio can be calculated using the following formula:

$$FATR = \frac{A(a,b,c)}{A(d,e,f)} \tag{6}$$

Where $A(a, b, c)$ and $A(d, e, f)$ represent the areas of the triangles *abc* and *def*, respectively. Figure 5 shows two different triangles (1, 3, 7) and (1, 3, 4), the calculated areas and the calculated *FATR*.

a) A(1,3,4)= 15.9213cm$^2$. b) A(1,3,7)= 47.3734cm$^2$.

Figure 5. Two different geometrical areas and the calculated FATR.

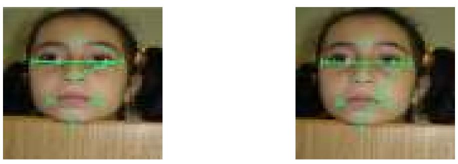
### 3.3. Geometrical FATR Parameter

Face Difference Angles (FDAs) and Angular Ratios (ARs) are two proposed parameters adopted for facial distinguishing. The following two formulas represent the two parameters:

$$FDA = |Angle(a,b,c) - Angle(d,b,e)| \tag{7}$$

$$AR = \frac{Angle(a,b,c)}{Angle(d,b,e)} \tag{8}$$

Figure 6 shows geometrical angles 134 and 137, the absolute values of their difference and ratio.



a) Angle(1, 3, 4)= 37.7343$^0$. b) Angle(1, 3, 7)= 47.7212$^0$.

Figure 6. Two different geometrical angles and the calculated AR.

### 3.4. Recognition (Matching) Process Using PNN

The recognition (matching) process for authentication is employing a suitable classification type of neural network, this type is called PNN [13] and it gives accurate output and deals with analog values. As known, PNN neuron consists of two layers; radial basis layer and competitive layer as shown in Figure 7. Radial basis layer measures the convergence between the input vector (*P*) and the stored weight vector ($W_1$), and uses the Radbas transfer function to limit each distance from unlimited value to a fraction value (0-1). ||*dist*|| algorithm takes $R$×1 input vector (*P*) and Q×R weight matrix ($W_1$) and produces $Q$×1 distance matrix. The ith row in the distance matrix represents the difference between test-person parameters (p) and the ith row enrolled-person in weight matrix ($W_1$). The bias b allows the sensitivity of the radbas neuron to be adjusted. *radbas* transfer function regulates the distance matrix. Thus, ||*radbas*|| acts as a convergence indicator between the input vector (*P*) and enrolled-user ($W_1$) parameters and a regulator (regulates each distance value from unlimited value to new limit value (0-1)), so the classification operation becomes easier and has limited recognition domain. In the competitive layer, the weight matrix ($W_2$) is multiplied by the $Q$×1 distance matrix, to form the $Q$×1 indicator matrix, where the number of columns in the indicator matrix is equal to the number of input vector.

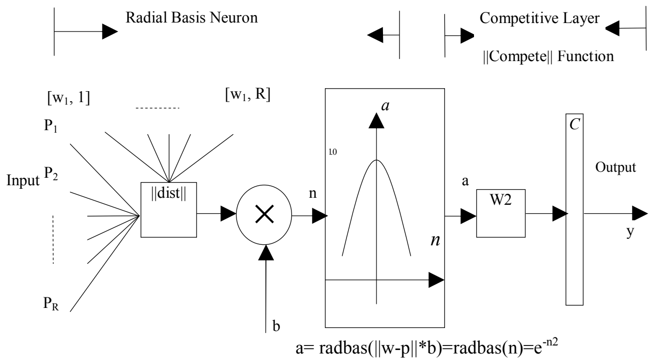



Figure 7. Architecture of PNN [17].

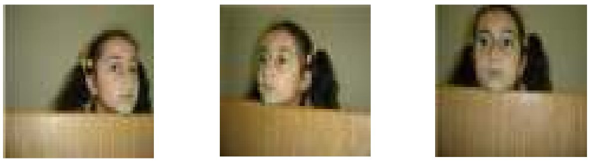
||*compete*|| transfer function calls $S$×1 indicator matrix, to return the index or number of the matched enrolled-sample, it works by finding out the maximum measuring closer value in the indicator matrix and gives out the index of the identical enrolled-person depending on the position of the maximum value.

## 4. Case Study: Implementation and Simulation Processes

In this paper, a case study is implemented and then simulated as follows:

- Three photos at least are taken from different angles as shown in Figures 8-a, b and c (in this paper only right, left and front views of the facial photos have been considered).
- Then, an image processing tool is used to get a two dimensional values for the marked three photos as depicted in Figures 8-a, b and c, respectively.

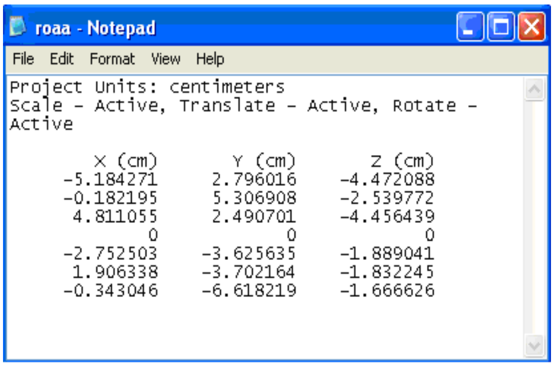
- Then, the auto-run programming feature of the photo modeler software is used to convert the 2D values of Figures 8-a, b, and c into 3D ones as shown at the notepad of Figure 9.
- After that the 3D values are then used to calculate the previous geometrical parameters as mentioned above.
- Then, the calculated geometrical values are used as an input to a PNN neural network and then compared to stored ones as shown in Figures 10 and 11, respectively.
- Finally, the non-zero neural output numbers determine the order number of the recognized stored person and the zero numbers mean that the person is not recognized or it is not found in the neural database. In the current case study, a person of number two in the database is recognized where its parameters are matched to input parameters of the PNN.



| X | Y | X | Y | X | Y |
|---|---|---|---|---|---|
| 575 | 881 | 575 | 881 | 367 | 1004 |
| 741 | 1185 | 741 | 1185 | 536 | 717 |
| 857 | 791 | 857 | 791 | 548 | 1324 |
| 1061 | 713 | 1061 | 713 | 672 | 996 |
| 1075 | 942 | 1075 | 942 | 905 | 838 |
| 1238 | 818 | 1238 | 818 | 908 | 1136 |
| 0 | 0 | 0 | 0 | 1085 | 988 |

a) The right side view photo. b) The left side view photo. c) The front side view photo.

Figure 8. Two dimensional representation of the right, left and front side view photos, respectively.



roaa - Notepad

File Edit Format View Help

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Project Units: centimeters
Scale - Active, Translate - Active, Rotate -
Active

     X (cm)       Y (cm)       Z (cm)
  -5.184271     2.796016    -4.472088
  -0.182195     5.306908    -2.539772
   4.811055     2.490701    -4.456439
          0            0            0
  -2.752503    -3.625635    -1.889041
   1.906338    -3.702164    -1.832245
  -0.343046    -6.618219    -1.666626
```

Figure 9. Three dimensional notepad text file.

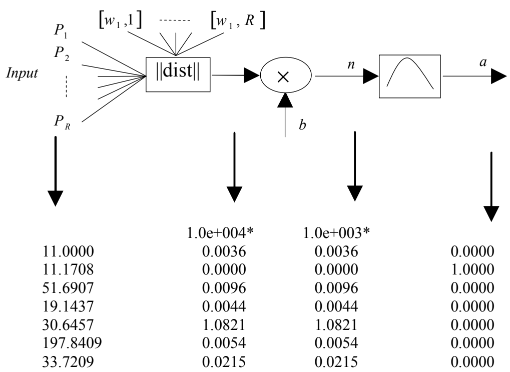


Figure 10. The block diagram of the radial basis layer and the processes of calculations.

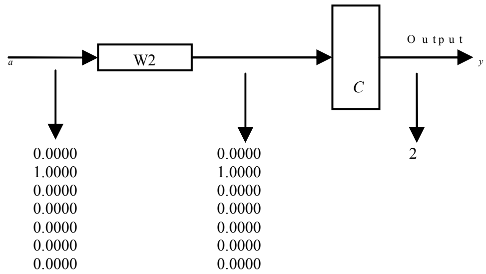


Figure 11. The block diagram of the competitive layer and the processes of calculations.

## 5. Results and Conclusions

In this paper, a geometrical 3D hybrid face recognition system are designed, implemented and then simulated, where, universality and uniqueness face points are selected to create a 3D module for a person, which is not affected by face gesture, motion of face itself, and existence or absence of sunglass or lenses. A special program like PhotoModeler is used to construct a 3D scale points from a 2D ones and then a three dimensional geometrical rules such as distances, areas, angles, volumes and their ratios are calculated and considered as geometrical parameters. A PNN of two layers is used for face recognition, where, the second layer is modified, so if the closer degree between the entry and stored persons is only 95% or larger an identical response of acceptance is shown. Finally, 3D face recognition system has lower cost respect with others, where cheap and available 3D geometry application like photo modeler is used instead of using high cost 3D scanners and sensors.

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