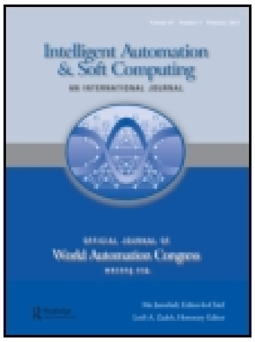

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AN INTELLIGENT AND AUTOMATIC FACE SHAPE PREDICTION SYSTEM FROM FINGERPRINTS

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ABSTRACT—This paper presents an intelligent system for generating face shapes from only fingerprints without knowing any information about faces. The proposed system based on artificial neural network has got a number of modules including two biometric data acquisition modules, two feature extraction modules, an artificial neural network module, a face re-construction module and a test & evaluation module. Experimental results have shown that the faces can be successfully generated from only fingerprints. Although the proposed system is an initial study, the performance of the system is very promising for the future developments.

Key Words: Intelligent systems, biometrics, artificial neural networks.

1. INTRODUCTION

Biometrics is a well known technology and deeply studied research field especially to support reliable personal identification systems. Recently, most of the works in this area have focused on improving the accuracy and processing time of the biometric-based systems. For achieve this improvement more effective, fast and robust techniques have been developed [1]. Obtaining a biometric feature of a person from another biometric feature of the same person is a challenging idea and it is a useful transformation for many applications. There has been no study on investigating relationships among the biometric features or obtaining one feature from another except the authors have recently reported in the articles [2]-[10] for the first time. The authors proposed novel approaches for generating the face borders [2], the face contours including face border and ears [3], the face models including eyebrows, eyes and mouth [4], the inner face parts including eyes, nose and mouth [5], the face parts including eyes, nose, mouth and ears [6], the face models including eyes, nose, mouth, ears and face border [7], the face parts including eyebrows, eyes, nose, mouth and ears [8], only eyes [9] and the face parts including eyebrows, eyes and nose [10] from only fingerprints without any need for face information or images. The results in the articles have clearly demonstrated that an unknown biometric feature can be achieved from a known biometric feature.

Some biological and physiological evidences were motivated to us to investigate the relationships among fingerprints and faces. These evidences can be explained as follows: It is known that the phenotype of the biological organism is uniquely determined by the interaction of a specific genotype and a specific environment [11]. Physical appearances of faces and fingerprints are also a part of an individual's phenotype. In dermatoglyphics studies, the maximum generic difference in fingerprints has been found among individuals of different races [11]. Unrelated people of the same race have very little generic similarity in their fingerprints; parent and child have some generic similarity as they share half of the genes, siblings have more similarity and the maximum generic similarity is observed in the identical twins, which is the closest genetic relationship [12]. This similarity distribution is very similar for faces of the people. The general characteristics of fingerprints and faces were determined by the genes [11]. These truths have indicated that there could be some relationships among biometrics. In order to investigate and support this assumption an intelligent face prediction system from only fingerprints has been developed and introduced in this study.

2. OVERVIEW OF BIOMETRICS

A biometric system operates its task by getting biometric data from a person, extracting a feature set from the acquired data and comparing this feature set against the template feature sets in the database [13]. The most used biometric systems are Automatic Fingerprint Identification Systems (AFISs) and Automatic Face Recognition Systems (AFRSs). Good surveys about these techniques were given in [1] and [14], [15], respectively. This study focuses on fingerprints and faces (Fs&Fs). To acquire feature sets of Fs&Fs in the literature, feature-based approaches have been mostly used. In the feature-based AFISs, two important attributes including end points and bifurcations were used [1]. Feature-based AFRSs mainly consist of three steps. These steps cover detection and localization of the faces, feature extraction and finally recognition tasks [16]. Both fingerprint and face recognition processes are really complex and difficult tasks [1], [14] and [16]. Recently, multi-modal biometric systems (MMBS) have gained acceptance among designers due to their performance superiority over the uni-modal systems that have some limitations about accuracy, processing time and vulnerability to spoofing [15]. Detailed information about MMBSs can be found in [13] and [17].

3. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANNs) have been applied to solve many problems [1], [14], [18]-[20]. Learning, generalization, less data requirement and fast computation features have made ANNs very attractive for applications [18]. These fascinating features have also made them popular in biometrics [1]-[10], [14], [19] and [20]. Multilayered perceptron (MLP) structure was used in this study. The MLP consists of three layers: Input, output and hidden layers. The neurons in the input layer can be treated as buffers and distribute x_i input signal to the neurons in the hidden layer. The output of the each neuron y_j in the hidden layer is obtained from sum of the multiplication of all input signals x_i and weights w_{ji} that follow all these input signals. The outputs of the neurons in other layers are calculated in the same way. The weights are adapted with the help of a learning algorithm according to the error occurring in the calculation. The error can be calculated by subtracting the ANN output from the desired output [18]. There have been many learning algorithms to train ANNs. The scaled conjugate gradient (SCG) algorithm is one of them. It is based on conjugate directions and adjusts the weights of ANNs [23].

4. AUTOMATIC FACE SHAPE PREDICTION SYSTEM FROM FINGERPRINTS

Unlike to the previous studies [2]-[10], the proposed ANN based intelligent system generates the face shape including *eyes, mouth* and *face border* of a person from only one fingerprint of the same person. The architecture of the developed Fingerprint to Face Shape Generation System (FP2FSPS) covering main modules is given in Figure 1. Implementation steps of the FP2FSPS to establish a relationship among fingerprints and faces (Fs&Fs) can be mentioned as follows:

1. A real multi-modal database was established from Fs&Fs.
2. Feature sets of Fs&Fs were obtained.
3. Training and test data sets were established.
4. Suitable ANN structure and its optimal parameters were determined. The ANN structure is finally established.
5. ANN based FP2FSPS was trained to generate face shapes more realistically until achieving certain accuracy in learning.
6. In order to test and evaluate the accuracy of the FP2FSPS, the test results were compared against to a variety of state-of-the-art methods [1].

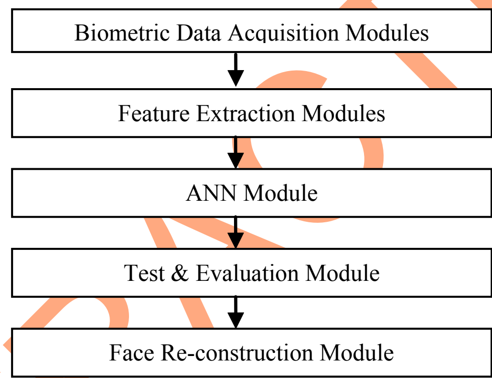

Figure 1. Architecture of the FP2FSPS

Biometric data acquisition modules help to store biometric data of individuals into the system database. A real multi-modal database that includes Fs&Fs belonging to 120 people was established. Only a frontal face image and a fingerprint that was index finger of the right hand were used in this study. An example of biometric feature set in the database is given in Figure 2.

Figure 2. An example for F&F set in the multimodal database

The feature extraction modules extract the discriminative feature sets from the acquired biometric data. Fingerprint feature sets were computed using a SDK developed by Neurotechnologija [21]. The reason of this preference is to establish an objective assessment for face shape prediction via the FP2FSPS. To obtain the feature sets of faces, a feature-based face feature extraction algorithm was borrowed from Cox et al. [22] and it was fundamentally modified and adapted to this application. In comparison to the approach proposed in [22], increasing the number of the reference points from 35 to 53 points helped to represent the faces more accurately and sensitively. In addition, face feature sets were shaped from x-y coordinates of the face reference points, not distances or average measures as in [22].

The ANN module that was used to analyze the existence of any relationship among Fs&Fs was implemented with the help of 3-layered MLP structure that was trained with SCG algorithm. The SCG algorithm adjusts the weights and biases of the ANN according to its learning strategy. The details of SCG algorithm was given in [23].

The ANN module is the most critical and important module of the system. Because, all other modules are on duty, either in pre-processing or post-processing of this main process. The training process is started with applying the feature sets of Fs&Fs to the system as inputs and outputs, respectively. The system achieves the training process with these feature sets according to the learning algorithm and the ANN parameters. Even if the feature sets of Fs&Fs are required in training, only fingerprint feature sets are used in test. The outputs of the system for these unknown test data indicate the success and reliability of the system and it must be clearly shown by evaluating the ANN outputs against to the proper metrics.

The traditional metrics of an ordinary biometric system are no longer appropriate to characterize the performance of the FP2FSPS. So, in addition to the ROC curve, the results of the system are evaluated by considering the following numerical metrics: mean squared error (MSE), sum squared error (SSE), mean absolute error (MAE), absolute percentage error (APE) and Mean APE. APE is the measure of accuracy of the system as a percentage for a test face. MAPE shows mean APE that is average of the absolute percentage errors per each coordinate of the feature sets of the faces. Similarly, MAE is an average of the absolute errors per each coordinate of the feature sets of the faces. These metrics were explained in [24]. To evaluate the system results comprehensively a visual evaluation platform was also created by drawing the ANN outputs and their desired outputs in the same page as overlapped. In order to achieve the visual evaluation effectively, a face re-construction module was developed to convert the ANN outputs and desired outputs to visual face shapes.

Consequently, for a more objective comparison, the performance and accuracy of the system have been evaluated and presented on the basis of the combination of these metrics for illustrating the qualitative properties of the proposed methods as well as a quantitative evaluation of their performances.

5. EXPERIMENTAL RESULTS

The proposed FP2FSPS discussed in previous section was implemented to conduct the experiments efficiently. The dedicated and developed software supplies all of the system parts to be controlled properly. The experimental data sets used in the test contain only feature sets of fingerprints of the test people. The face feature sets of these people were never used in training processes of ANN. They were used for evaluation of the system performance. The inputs and the outputs of the system were vectors sized 298 and 106, respectively. Producing the faces as close to the real one as possible is critical for this study. The metrics MSE, SSE, mean APE, mean MAE and mean MAPE were 0.00044, 1.90770, 4.29903, 0.01572 and 0.04056, respectively. The ROC curve of the test results is given in Figure 3.

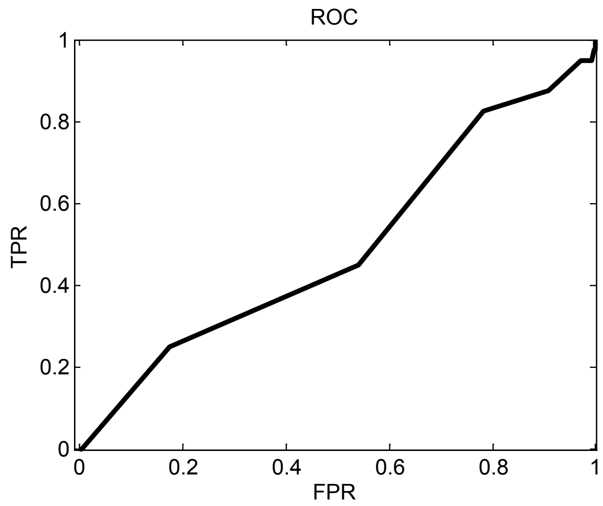

Figure 3. ROC curve of the test results (TPR: True Positive Rate, FPR: False Positive Rate)

According to the test results the proposed system performs the tasks with high similarity measures to the desired values. For the purpose of more realistic and visual evaluation, all of achieved test results and desired values of them have been drawn on the same platform as shown in Figure 4. Dark continuous and light dashed lines in the figure represent the desired and the generated face features, respectively. In addition, to show the overall system performance graphically, APE, MAE and MAPE values belonging to all test results were demonstrated in Figure 5. Based on the results and observations, the presented FP2FSPS can be used as an intelligent model to predict face shapes from fingerprints, effectively.

6. CONCLUSION AND FUTURE WORKS

The principal objective of this paper is to generate automatically the face shapes including eyes, mouth and face border from only fingerprints with high accuracy. This article successfully presents an approach to predict face shapes from only fingerprints. The relationships among biometrics and achieving an unknown biometric feature from a known biometric feature are also experimentally shown in the proposed study. When each of the results was visually elaborated, it is very clear to see that there are very close matches among ANN outputs and their desired values. The results presented in this work reports that there are more than twelve close matches considering mouths and face borders and also more than fifteen close matches at eyes. The experimental results provided very encouraging and successful results in achieving the face shapes from fingerprints automatically. These results confirmed once more that there are close relationships among Fs&Fs. It is expected that this study will lead to create new concepts, research areas, and especially new applications in the field of biometrics and forensics.

In future studies, investigations will be conducted to enhance the face generation processes. It is also studied on modeling the relationships among Fs&Fs to prove not only experimentally but also mathematically. In addition, the performance and accuracy of the system should be shown by using a larger multi-modal database including biometric features of people from different countries.

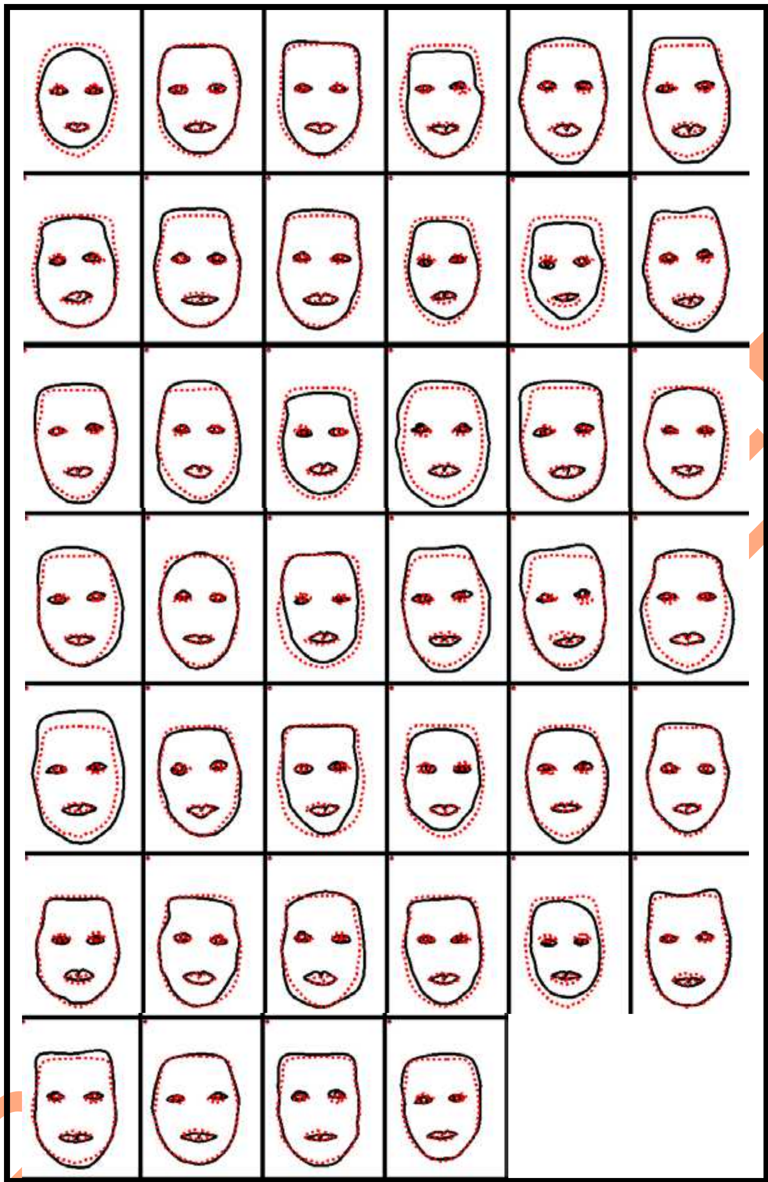

Figure 4. Representing the test faces achieved from the FP2FSPS and their desired values.

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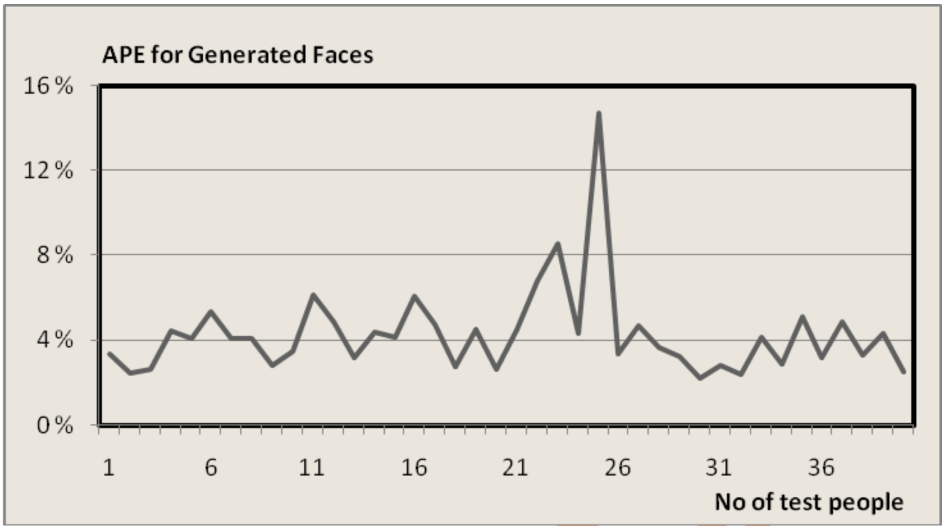
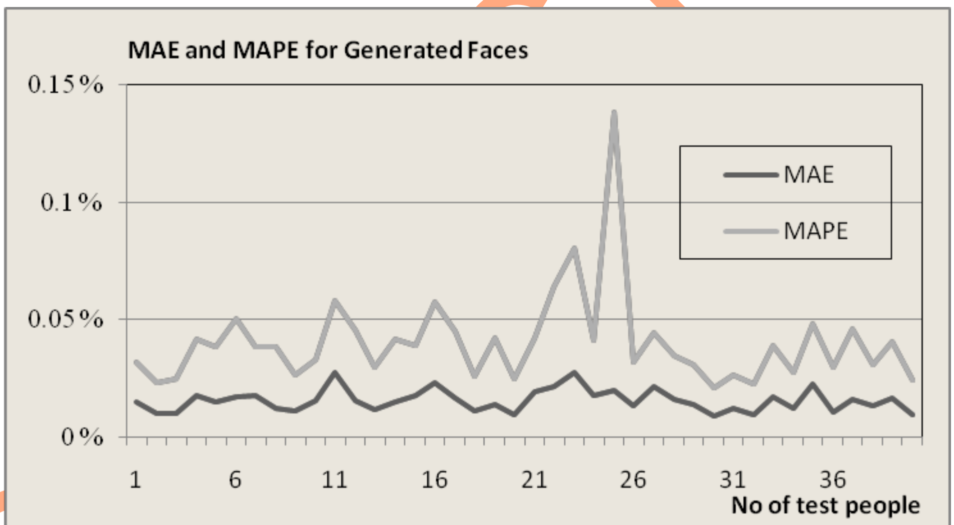


(a) APE Values



(b) MAE and MAPE Values

Figure 5. Error values for generated faces.

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