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AN INTELLIGENT AND

8**AUTOMATIC FACE** SHAPE **PREDICTION SYSTEM FROM FINGERPRINTS**
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ss@gazi.edu.tr, neclaozkaya@erciyes.edu.tr ABSTRACT

7**—This paper presents an intelligent system for generating face shapes from only fingerprints without knowing any information about faces. The**

7**proposed system based on artificial neural network has got a**

number of modules including two biometric data acquisition

> 1**modules, two feature extraction modules, an** artificial neural network **module, a** face re-construction **module and a** test & evaluation **module.**

Experimental

> 1**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

> 18**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

> 1**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

> 1**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

> 1**that an unknown biometric feature can be achieved from a known biometric feature.**

309 Some biological and physiological evidences were motivated to us to investigate the relationships among fingerprints and faces. These evidences can be explained as follows:

> 1**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.**

> 4**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

1**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

11**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,

1**two important attributes including end points and bifurcations**

were used [1]. Feature-based AFRSs mainly consist

1**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

1**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].

1**Detailed information about MMBSs can be found in [13]**

and [17].

1**3. ARTIFICIAL NEURAL** NETWORKS **Artificial Neural Networks** (ANNs) **have been applied to solve many problems**

[1],

25**[14], [18]-** [20]. **Learning, generalization, less data requirement** and **fast computation**

1**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

22**MLP consists of three layers: Input, output and hidden layers.**

The

2**neurons in the input layer can be treated as buffers and distribute** xi **input signal to the neurons in the hidden layer. The output of** the **each neuron** yj **in the hidden layer is obtained from sum of the multiplication of all input signals** xi **and weights** wji **that follow all these input signals. The**

2outputs 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

1ANN 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.

1Feature 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.

2In 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]. Biometric Data Acquisition Modules

1Feature Extraction Modules ANN Module Test & Evaluation Module Face Re-construction Module

Figure 1. Architecture of the FP2FSPS Biometric data acquisition

1modules help to store biometric data of individuals into the system database.

1A real multi-modal database that includes Fs&Fs belonging to 120 people was established.

Only a frontal face image and a fingerprint that was

1index 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.

1Fingerprint 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.

1To 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

> 2**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

> 1**used to analyze the existence of any relationship among Fs&Fs** was implemented with **the**

> 1**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

> 1**ANN module** is **the most critical and important module of the system. Because, all** other **modules**

> 1**are on duty, either in pre-processing or post-processing of** this **main process. The**

> 1**training process** is **started with applying the feature sets** of Fs&Fs **to the system as inputs and outputs,**

> 2**respectively. The system achieves the training** process **with these feature sets according to the learning algorithm and the ANN parameters.**

> 1**Even if the feature sets of Fs&Fs** are **required in training, only fingerprint feature sets** are **used in test.**

The

> 1**outputs of the system for** these **unknown test data indicate the**

> 2**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

> 2**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:

> 1**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

> 1**average of the absolute** percentage **errors per each** coordinate **of the feature sets of the faces.**

Similarly,

1**MAE is an average of the absolute errors per each** coordinate **of the feature sets of the faces.**

These metrics were explained in [24].

1**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**

1**to convert the ANN outputs and desired outputs to visual face**

shapes.

1**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

1**all of the system parts to be controlled properly. The**

experimental data

1**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

1**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

23**ROC curve of the** test results **is** given **in Figure 3. ROC**

1 0.8 0.6 TPR 0.4 0.2 0 0 0.2 0.4 0.6 0.8 1 FPR Figure 3. ROC curve of the test results

24**(TPR: True Positive Rate, FPR: False Positive Rate)** According **to**

the test results the

2**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

1**test results and desired values of them have been drawn** on **the same platform** as shown **in Figure**

4. Dark continuous

2and light dashed lines in the figure represent the desired and the generated face features, respectively.

In addition, to show the overall system performance graphically,

1APE, 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.

21CONCLUSION AND FUTURE WORKS The principal objective of this paper is to generate automatically the

2face 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

1an 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

1confirmed 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,

2investigations 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. 7.

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(a) APE Values (b) MAE and MAPE Values Figure 5. Error values for generated faces.

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