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Research Article

A New Intelligent System for Predicting Gender from Fingerprint

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ABSTRACT

This paper proposes a new method for predicting genders from only fingerprints based on Artificial Neural Network (ANN) model. The modelling tasks are achieved by capturing fingerprints, analyzing an obtained fingerprint part (for example cropping 5x5mm part from a fingerprint image), determining ridges crossed by the diagonal of the obtained fingerprint part automatically, finding the ridge counts, ridge thicknesses, average fingerprint ridge counts of individuals, combining these features in a model, preparing and setting the structure of it and finally testing the model. The results of proposed model have shown that the best model achieves the task within 72% accuracy.

Keywords: *Biometrics, Fingerprint, Gender prediction, Intelligent system, Ridge density*

Parmak İzinden Cinsiyet Tahmini İçin Yeni Bir Zeki Sistem

ÖZET

Bu makale, sadece parmak izlerinden cinsiyetlerin tahmin edilmesi için Yapay Sinir Ağları (YSA) modeli tabanlı yeni bir metod önermektedir. Modelleme işlemleri parmak izlerinin alınması, elde edilen bir parmak izi bölümünün (örneğin 5x5mm) farklı boyutlarının analiz edimesi, köşegen çizgisinin çizilmesi, köşegen çizgisi üzerindeki tepe çizgilerinin otomatik belirlenmesi, tepe sayılarının hesaplanması, tepe kalınlığı ve bireylerin parmakizi ortalama tepe sayılarının bulunması, bu özniteliklerin bir model içerisinde birleştirilmesi, bunun yapısının hazırlanması ve ayarlanması ve son olarak modelin test edilmesi ile elde edilmektedir. Önerilen modelin sonuçları en iyi modelin %72 başarıyla elde edildiğini göstermektedir.

Anahtar Kelimeler: *Biyometri, Parmak izi, Cinsiyet tahmini, Zeki sistem, Tepe yoğunluğu*

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I. INTRODUCTION

Biometrics is the science of identifying or recognizing identity of individuals. Fingerprint, signature, face, voice, deoxyribonucleic acid (DNA) and retina are the most preferred biometric properties because they cannot be stolen, lost or forgotten [1, 2]. Biometric systems are used for establishing identity in various commercial, civilian and forensic applications. Also, researchers are intensively working on the design of interpretation-based intelligent recognition systems [3].

Biometric systems have a wide variety of application areas today. These areas are airport entrance/exit operations, credit card applications, insurance transactions, e-commerce, e-signature, e-banking, tax processes, forensic identification and detection applications, network and data security, social security, automated teller machines (ATMs), personnel tracking, call centers, patient follow-up, etc. Biometric systems are also used in computers, personal digital assistant computers (PDAs), mobile phones and home locking systems. For example, a user cannot reach and process the data in a biometric system-installed computer if he/she cannot authenticate his/her identity [4].

Biometric systems are categorized into two main groups as physical and behavioral biometrics. Physical biometrics consists of iris, face, fingerprint, DNA, facial thermogram, retina, hand geometry and vein markings whereas behavioral biometrics consists of voice, gait, keystroke and handwriting [5, 6, 7, 8]. Age, health or mental condition of a subject should be removed from the test while physical/behavioral characteristic is being measured [9].

The characteristics of an identity such as fingerprint, face, retina, etc. taken from samples are recorded into the system as translated into numerical values in biometric systems. If a user wants to enter the system, initially saved characteristic is compared with the current one. The most important factor that determines the reliability of the system is the number of reference points. The more they are, the higher the reliability of the system is. In this case, feature selection must be made to decrease the amount of reference points.

External factors may prevent biometrics from matching. For example, fingerprint from current user may not always exactly match to the one taken from the user before he/she is trying to log in a system. Sounds coming from outside while voice recognition is being made or a high blood pressure of a subject during an experiment of iris recognition are also some other problems. Because of such problems, biometric properties must be entered securely so that nobody can modify the saved data while features are being recorded. For this reason, biometric system must protect templates of users stored in a database. Nandakumar et al. [27] presented a fully automatic implementation of the fuzzy vault scheme based on fingerprint minutiae to solve this problem.

One of the most commonly used biometric techniques is fingerprint-based recognition systems in automatic identity recognition [10, 11]. Hardware and software developments in fingerprint recognition systems have increased performance of these systems and facilitated their utilization in various applications like access control, computer access, attendance, recognition of criminals and so on [12].

Each person has a different fingerprint. Even twins do not have identical ones. Furthermore, as fingerprints do not change even when people grow old, they are preferred for identity determination [13]. They have been used to determine identity for over a hundred years [14].

Fingerprints play an important role in determining identity. Especially, security forces use fingerprints for criminal determination because fingerprints do not change from a person's birth to death unless there is a significant wound or cut. Detail points (minutiae), which are also called as feature points, are examined in each finger to distinguish fingerprints. The frequency and arrangement of ridge lines of fingerprints vary in each person. (Black lines in a fingerprint are called ridges). As a result of the studies in which ridges were examined, the presence of relationship between fingerprint and gender has been identified [15-19]. This topic is new, so there are a small number of studies about this hypothesis. The current state of literature makes it possible to study on this generally accepted hypothesis. Many fingerprint auditors indicate that women have better fingerprint ridge details than men [20]. Thus, gender prediction can be made by looking at details of ridges on fingerprints. A sample for ridges is showed in Figure 1. By looking at the ridge density, which is taken from a determined area of a fingerprint, it can be identified that the fingerprint has been taken from a male or a female person.

Figure 1. *Ridges of a fingerprint.*

In order to count ridges automatically, ANN based model has been implemented. ANNs are known as processing information like a physiological structure of a human brain. They learn from examples and make generalization. ANNs are used in both engineering and practical applications in computers, machines, electric vehicles, electronics, industries, biomedical engineering, medicine, mathematics, physics and social sciences, etc. They can provide reasonable solutions to problems that have multidimensional, complex and unknown data [21].

K-fold cross validation technique is used for testing the system. In this technique, data are separated to k piece data sets which have equal number of data and different from each other. One of these sets is chosen for testing the data set and the other (k-1) sets are chosen to train ANN models. Testing is done by changing the training data set k times for each fold. Due to this change, the fold data in the data set is tested at least once. The system is checked by all data sets and accuracy is calculated by the average of these k piece accuracy ratios [22].

Even if the studies for gender classification from fingerprints are available in the literature, intelligent system has not been used to classify genders from fingerprints automatically before us. The available studies before our studies provide the statistical experiments. In this study, we have also achieved the statistical experiments. In order to design intelligent system, we used all available data provided in the literature for development and test. The literature review is given in Section II. In Section III, the steps of automatic gender prediction from only fingerprints are presented. Finally, Section IV summarizes our findings and recommendation about the developed and presented intelligent system.

II. Gender Prediction From Fingerprints

The statistical analysis of gender classification from only fingerprints taken from subjects with different ethnic backgrounds in America, India and Spain [15, 16, 23] can be achieved properly within acceptable accuracies. Similarities of these studies are as following:

- The ratio of men and women used are equal,
- The examined sections of fingerprints are almost same,
- Same statistical methods are used to process the obtained data from fingerprints,
- The core of fingerprints is taken as a reference point, and
- The ridge density is used to determine the gender of individuals.

Other features reported in the studies are also given below:

- Fingerprints of women have more ridges than fingerprints of men.
- Women have higher ridge density if a certain area of a fingerprint is considered.
- Ridge density is a significant feature in gender classification.
- Ridges are important for minutiae extraction.

In order to achieve the tasks, image enhancement techniques are often used for reducing noise and finding ridges. Therefore, local ridge orientation must be found for gender classification. Normalization is used for this problem. *PI_N (i,j)* represents the normalized grey level value used for normalization at pixel *(i, j)*. To normalize the fingerprint image, the equation is used as *M* [26],

$$PI\_N(i,j) = \begin{cases} M_0 + \sqrt{\frac{VAR_0(I(i,j)-M)^2}{VAR}}, & if\ I(i,j) > M \\ M_0 - \sqrt{\frac{VAR_0(I(i,j)-M)^2}{VAR}}, & Otherwise \end{cases} \tag{1}$$

In Equation (1), M_0 and *VAR* are the desired mean and variance. A grey level fingerprint image of *I(.)*'s mean and variance in NxN size is given as *M* in [26],

$$M(I) = \frac{1}{N^2}\sum_{i=1}^{N-1}\sum_{j=1}^{N-1} I(i,j) \tag{2}$$

$$VAR(I) = \frac{1}{N^2}\sum_{i=1}^{N-1}\sum_{j=1}^{N-1}\left(I(i,j) - M(I)\right)^2 \tag{3}$$

The formulas given as *M* (4)-(6) are also used to find local ridge orientation. Dividing a fingerprint image into blocks of NxN, computing the gradients $\delta_x(i,j)$ and $\delta_y(i,j)$ at each pixel *(i,j)* and estimating each block's local orientation centered at pixel *(i,j)* are shown in formulas (4)-(6) [26].

$$\Delta_x(i,j) = \sum_{u=1}^{w} \sum_{v=1}^{w} 2\delta_x(u,v)\delta_y(u,v) \tag{4}$$

$$\Delta_y(i,j) = \sum_{u=1}^{w} \sum_{v=1}^{w} \delta_x(u,v)^2 - \delta_y(u,v)^2 \tag{5}$$

$$\Theta(i,j) = tan^{-1} \frac{\Delta y}{\Delta x} \tag{6}$$

In the study [16], authors used the fingerprints taken from a police department. The fingerprints belong to 100 Caucasian men, 100 Caucasian women, 100 Afro-American men and 100 Afro-American women ranging in ages from 18 to 67. Totally 400 data were obtained. The fingerprints were taken from criminals. The authors indicate that the fingerprint worked on may belong to a man if the ridge density on a fingerprint is 11 ridges/25 mm^2 or lower. On the other hand, the finger worked on may belong to a woman if the ridge density on the fingerprint is 12 ridges/25 mm^2 or higher.

In [23], fingerprints of 250 men and 250 women from Karnataka were used. Ages of subjects were between 18-60. They observed that the average ridge density of the fingerprints of men is 12.8 ridges/25 mm^2 whereas it is 14.8 ridges/25 mm^2 in women.

In another study [15], fingerprints of 100 men and 100 women were obtained. The fingerprints were taken from Caucasian-origin people. Ages of subjects were between 20-30. According to the results obtained from this study, it may belong to a man if the ridge count of fingerprint is 16 ridges/25mm^2 or lower and it may belong to a woman if the ridge count of fingerprint is 17 ridges/25mm^2 or higher. Unlike the other studies, in this statistical study, fingerprints from 10 fingers were used to determine gender.

The main features of the above-mentioned studies [15, 16, 23] are as following:

- They are based on statistics,
- They do not find automatic results in a certain system approach,
- They have subjects from different ethnic backgrounds, and
- The most important one is that they use only ridge density.

The main aim of the studies described above was creating a statistical database. In the current state of the technique, when this study was done, there is no system to analyze genders from the data of a fingerprint.

In our previous studies, we collected 750 fingerprints (375 Turkish women and 375 Turkish men). We selected right index fingers of those people. From core point of these fingers, we selected 5x5mm^2 area from the upper right area. In this area, the ridge counts were counted for comparing the fingerprints of different genders. We found that average ridge density of women is 13.91 ridges/25mm^2 and average ridge density of men is 11.51 ridges/25mm^2 in the chosen area. Thus, we used this information in our intelligent system as there is a difference between fingerprints of men and women [25].

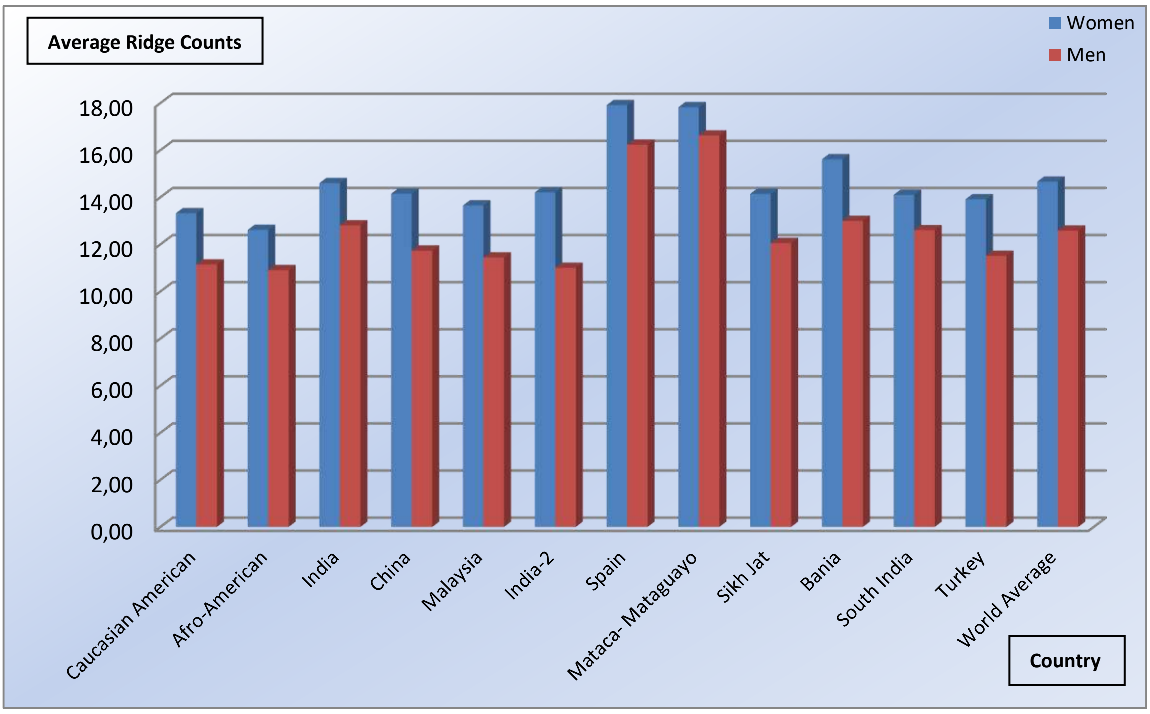

Figure 2. *Average ridge count difference of men and women from different ethnic backgrounds [25].*

Average ridge count of men and women from different ethnic backgrounds collected from the literature and calculated for Turkey in our previous study are shown in Figure 2.

III. THE PROPOSED SYSTEM: AN AUTOMATIC SYSTEM FOR GENDER PREDICTION FROM FINGERPRINTS

The proposed system is an intelligent model which learns the relationship between genders and fingerprints from the fingerprint database. The relationship is established with the help of Artificial Neural Network (ANN) architecture. This developed model is used for the data which have not been known before or not found in the database. In the first step, appropriate number of data cluster is created and the system is trained. Inputs of the system are ridge density, ridge count and the parameters that belong to them and output is the numeric correspondence of gender depending on the fingerprint. As a result, the intelligent system determines the relationship between fingerprint and gender. After identifying the relationship between the input and the output, fingerprint of a desired person is conveyed to the system with a scanner in real time. Gender information is created automatically by using the learnt or trained information in the system or by the developed intelligent model.

Our intelligent gender prediction system works through the steps explained below:

First, we established the system to obtain the fingerprint from any number of different fingers through the reader. We took equal numbers of male and female fingerprints and adjusted them to different ages. We took fingerprints with the help of an Automated Fingerprint Recognition System (AFIS) which is available on the market in order to have a database that includes an appropriate number of fingerprints belong to men and women.

We observed from these steps and from our studies that women have higher ridge density than men in our country [24, 25, 28]. We developed a software for determining the finger we get the fingerprint from and cropped a 5x5mm area from the taken fingerprint. Upper-left part of the core point is acquired if right fingerprint is taken (Figure 3.a) and upper-right part of the core point is acquired if left fingerprint is taken. Then ridge density on this area is found, and we have created an intelligent system which is based on artificial neural networks. Quantitative ridge density is considered from the state of fingerprint ridges that are “thick” or “thin”. The system models the relationship between genders and fingerprints from ridge values and their variations.

The system transforms the cropped region of fingerprint shown in (Figure 3.a) to black-white state (binary state) and then applies improvement and noise reduction procedures (Figure 3.b). Then the system looks to the diagonal line from the core point to the upper-left corner of the sample 5x5mm part of the fingerprint and prepares a bit string line (Figure 3.c). It calculates ridge count and ridge thickness values on this linear array and obtains average ridge values of men and women in our country through the procedures specified above.

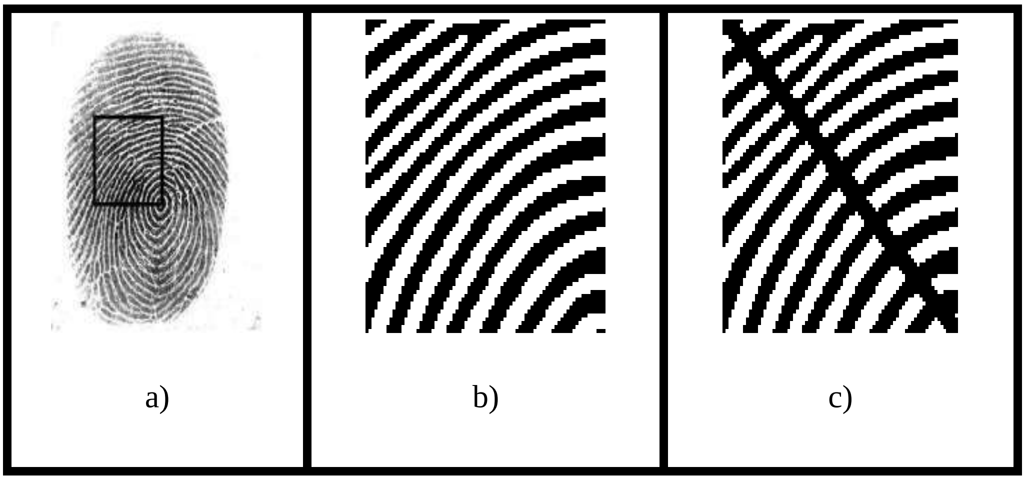

Figure 3. *Acquiring ridge information of a fingerprint for gender prediction.*

a) *A sample of fingerprint region that is cropped for finding the fingerprint ridge information.*

b) *An example of the selected region which is converted to usable form.*

c) *An example of finding the diagonal line based on the structure of the fingerprint from the selected region.*

After getting this information, we determined the input and output parameters for the intelligent system by considering the obtained data. Input parameters are obtained orthogonal pixel values, ridge count, ridge thickness and average ridge thickness and ridge count for fingerprints of men and women obtained from the taken part of the fingerprints. Output values are from “1” to “-1” numeric values which distinguish between men and women.

We selected Levenberg-Marquardt learning algorithm for training the proposed model. The system trains the proposed ANN model with the chosen algorithm by selected number of samples until getting targeted error rate or performance (0.01 RMS).

The system tests the intelligent model with the chosen number of fingerprint data after training step (test result is not bigger than 0.05 rms). We determined a threshold level that separates man and woman considering the obtained values. We classified the obtained value as a man if it is between 0 and 1, and we classified the obtained data as a woman if it is between 0 and -1.

We developed a stand-alone version for personal computer (PC) and a web-based version for web access to automatically realize the procedures mentioned above. These versions consist of a modules for selecting the size of fingerprint part, for taking a part of a fingerprint (5x5mm), for creating bit string for determining ridge count in selected fingerprint part, for finding ridge count and average ridge thickness in bit string and adding this to the system, for training and testing the developed intelligent model, accessing the system securely, logging the access to the system, informing users via email or sms, and developing web service for accessing to the intelligent model. We combined the developed modules in software platform and integrated the fingerprint-reader hardware to this developed platform. We added the tested ANN model to the developed platform for permanent use. We took the system into action after testing the system with various fingerprint data. We put the system into service for users who want to try it in their own right. An example of gender result obtained from the gender prediction system is shown in Figure 4.

Figure 4. *The interface that shows the gender of an obtained fingerprint in the system.*

IV. Results And Conclusions

The proposed intelligent system can predict genders from fingerprints in less than two (2) seconds. Our system works automatically after entering fingerprint images simultaneously. It realizes real-time gender prediction through pre-trained intelligent ANN model. The proposed method uses only fingerprints and predicts a person's gender in real-time in order to achieve the task automatically. The system is based on the theory that gender of a person can be predicted by checking fingerprint ridge information of a person. It is then predicted by the intelligent system.

The results of proposed model have shown that the best model achieves the task within 72% accuracy. While creating a data set, some of the fingerprint images in the database are of low quality or no core point. These are some reasons for the accuracy of the system is not as we expected. As we know from the literature and our previous experiences, it is not easy to create an own fingerprint database. Also, there are not many publications which collects and analyses more than 800 fingerprints. So, the accuracy is not enough as we expected, but it is acceptable.

The Turkish [29], European [30] and United States [31] patents of the system were taken by us. We used some parts of our patent in this paper.

This developed system is expected to reduce the number of suspects, to offer innovations for saving both time and energy spent in litigation and investigation process, to provide new opportunities and applications such as entrance and exit authentication systems by examining the fingerprint left on any object at the scene and by distinguishing the owner of the fingerprint in gender pool uniquely.

Our developed system can be used for determining gender from the data obtained from a fingerprint without having knowledge about any database. In this way, gender information can be predicted with the help of this system without any need for fingerprint identification and identity of a person. Using fingerprint image is enough for this prediction process.

It is expected that the proposed intelligent system that predicts gender from fingerprint will especially speed up catching the criminal process in criminal cases through fingerprints obtained from the crime scenes. Also it is expected that it will facilitate the entrance and exit control in places exclusive for men or women, pave the way for new studies to be done and enable different studies in this area.

DISCLOSURES: This paper is based on the MSc thesis of the corresponding author titled "Intelligent System that Estimates Gender from Fingerprint", also some parts from the Patents titled "System for estimating gender from fingerprints" obtained from Turkey, Europe and United States were used in this paper.

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