Chapter 15
Finger Knuckle Print Feature Extraction Using Artificial Intelligence Algorithm

Chander Kant, Sheetal Chaudhary, Sukhdev Singh, and Parvinder Singh

Abstract Recently, the smart use of biometric traits, i.e., fingerprints, face, finger knuckle print, etc., in user authentication system seems to be integral part because of their user-friendly and robust behavior. All of these traits present different degrees of uniqueness, permanence, durability, performance, user acceptance, and robustness and are valuable according to their need in respective application. The proposed approach illustrates finger knuckle print biometric (FKP) for the authentication of user as it avoids latent FKP and criminal investigation stigma associated with printing the surface of the knuckles. The proposed approach used public database and the preprocessing carried out on the images collected, in order to separate the index finger, middle, and ring fingers of the hand. Bayesian network is used to extract the feature of FKP for the authentication and identification of user. The image processing is carried out using MATLAB R2014 software.

15.1 Introduction

Automated personal identification systems have become a very important component of information systems with the wide range of security applications. The benefits of personal identification are far too great, as they improve the reliability and security

C. Kant (✉) · S. Chaudhary
Kurukshetra University, Kurukshetra, Haryana, India
e-mail: ckverma@rediffmail.com

S. Chaudhary
e-mail: sheetalkuk@rediffmail.com

S. Singh
D.A.V. College (Lahore), Ambala City, Haryana, India
e-mail: sukhdev_kuk@rediffmail.com

P. Singh
Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Haryana, India
e-mail: parvindersingh.cse@dcrustm.org

R. Kountchev et al. (eds.), *New Approaches for Multidimensional Signal Processing*, Smart Innovation, Systems and Technologies 216,
https://doi.org/10.1007/978-981-33-4676-5_15

of electronic commerce transactions that often overcome privacy-related concerns in the use or implementation of these technologies [1]. In order to identify a person, the biometric authentication can be a promising alternative with convenient personal identification as it is free from something to carry or remember [2].

The purpose of this paper is to investigate the biometric feature of the knuckle surface for the identification of user, because of its various abilities over other traits. The benefits of this paper have obtained better result for the identification of user by applying it in security systems, in addition to having a high social acceptance, another advantage is that it does not use invasive capture systems for the user, unlike others biometric systems.

Biometric systems are planned for consistent and precise identification/authentication. In recent years, the knuckle surface image pattern (FKP) has been found to be unique and can be used in personal authentication systems [3]. Due to the intrinsic skin patterns of the outer surface about the finger phalanx joint, the knuckle surface is very distinctive due to the amount of skin folds; it has high ability to discriminate different persons; in addition, it is not easily destroyed and is therefore considered a typical biometric verification system. FKP biometric has a high acceptance by users, since it does not contain criminal investigation as in the fingerprint. Therefore, the function of the fingerprint knuckles has a high probability of being identifier in general terms as a biometric authentication system [4].

This paper reflects the use of Bayesian networks, that mock-up a phenomenon using a set of variables and the dependency associations between them. These models can have various functions, for organization, forecast, diagnosis, etc. [5]. Furthermore, they can give interesting information regarding how domain variables are related, that can occasionally be interpreted as cause–effect associations.

The extraction of biometric characteristics is carried out in the digital image processing of the upper part of the hand, using Bayesian networks, which will identify and extract from the region of interest (knuckle surface) the biometric characteristics. It later on will be compared in a reference database in order to be able to make a decision and know if the type to be identified is known or unknown and then carry out a control action.

15.2 Literature Review

The literature has been reviewed to study the existing feature extraction methods for FKP proposed by various authors. Zhang et al. [6] discussed a novel feature set extraction approach to combine fisher-criterion with manifold-criterion which is known as (WLE) weighted linear embedding. Gaussian weights were employed to merge various types of information. The proposed approach intends to locate a map vector, that the ratio among weight class scatter to the weight within class scatter is maximized. It produces a recognition rate of 78.2% when applied on index finger of different persons. Yang et al. [7] used Gabor wavelets for image analysis and pattern recognition of FKP feature set extraction. The orthogonal linear discriminant analysis (LDA) transformation methodology in PCA is used and classified by nearest neighbor classifier thereby increasing the efficiency up to 98.14%. Jing et al. [8] used distances and angles concurrently between image data vectors to compute data similarities. To eliminate unnecessary information, orthogonal complex preserving locality projections method has been used. They achieved recognition rate of 88% for the left index finger. Zhun Lei Quin [9] devise a robust FKP feature extraction cum matching methods based on speed up features that is considered a good improvement over scale invariant transform. It defines a system that is based on local convex direction map of FKP for alignment of images and a ROI is cropped for feature set l extraction. For matching process, the relative distance of the closest neighbor with second closest neighbor is compared and distance ratio with less than 0.6 unit. It produces accuracy of 90.63% for verification and 96.91% for identification. Shen et al. [10] proposed an approach based upon results of neurophysiology studies which show that both local and global features are very important for image perception. It is suitable for images with plentiful line like structures and has the features like high accuracy, robustness to illumination variations, and fast matching. Rui Zhao et al. [11] proposed a novel approach that reduces the load of large database to train the classifier model where the edges of images are characterized at gray levels. The experimental work proves that FKP is consistent and appropriate trait for recognition rate of 95.68% with 30 threshold value. Shariatmadar and Faez [12] used a collection of Gabor filters to extract the orientation information from FKP images. Five different scales and eight different orientations were selected to keep the remaining parameters constant and PCA is applied to reduce their dimensions. Combination of PCA and LDA provides efficient feature selection method. The proposed algorithm was tested for 4-fingers l and concludes that right middle finger provides a better performance with 75.2% accuracy. Kumar and Ravikanth [13] proposed a personal authentication scheme by finger knuckle surface. The feature extraction for finger knuckle surface was performed with both texture and geometrical feature analysis methods. The texture information of knuckle surface was obtained by PCA, ICA, and LDA approaches. Scores were calculated by calculating Euclidean distance (ED) obtained from reference and input vectors.

15.3 Proposed Approach

The objective of this research is to identify and authenticate people through the use of FKP biometrics. An artificial intelligence methodology will be used through Bayesian networks by taking as a reference in database. The reference database used here is from Center for Biometric Research of the Polytechnic University from Hong Kong [14] made up of 165 samples, out of which 125 males and 40 females between the age of 18 and 50.

In the first practical stage of this paper, a model was designed and implemented to capture images of the knuckle surface, which consists of an acrylic box with a

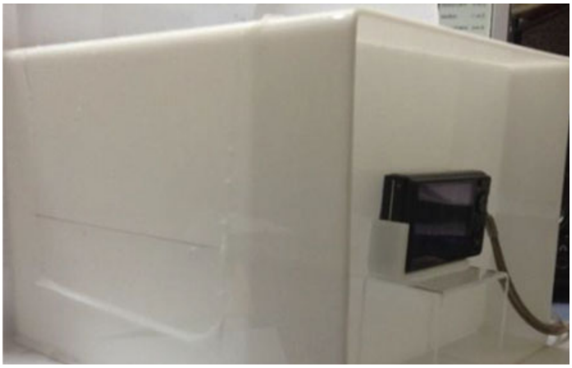

Fig. 15.1 Model for image capture

dimension of 30 cm × 25 cm × 20 cm, as shown in Fig. 15.1. The device includes a Sony Cyber-Shot model digital camera with a resolution of 14.1 megapixels; this external camera allows the capture of photographs from the user's hand when the user introduces them to the model.

The acrylic used in the model is white to prevent external lighting from affecting the capture of the images. At the bottom of the model, a plate was installed with posts that have the same location as a hand punch, so that the samples captured by the model always have the same shape and position, as shown in Fig. 15.2.

Once the images of the model have been captured, as shown in Fig. 15.3, the following is to carry out a preprocessing, that is, of the hand that was photographed, the index, middle, and ring fingers are separated and obtained the region of interest (ROI) from each of them on which the biometric characteristics will be extracted. It is important to note that in this paper, the image processing is carried out using MATLAB R2014 software.

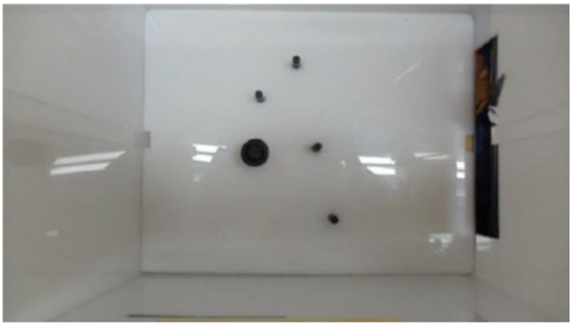

Fig. 15.2 Posts for hand position

Fig. 15.3 Sample image of the database

15.3.1 Digital Preprocessing

From the image of the database like the one shown in Fig. 15.3, which has a dimension of 1920 × 1080 pixels, the next step is to cut the index, middle, and ring fingers from the image (as shown in Fig. 15.3) and then each finger separately extracts biometric characteristics from the region of interest.

15.3.1.1 Detection of ROI

To crop the image along, it is necessary to binarize the original image, that is, convert it to black and white, as shown in Fig. 15.4. The next step to crop the image from left to right is to make a summation of each one of the pixels of the binarized image (to carry out the summation it is necessary to transpose the image), in order to derive the ROI. Figure 15.5 shows the graph of the summation of the binarized image.

In the summation graph (Fig. 15.5), the contour of the binarized image is observed (using MATLAB), rotated 90° to detect the cut point up to the tip of the middle finger, just enough to obtain the minimum point of the summation, knowing this point we

Fig. 15.4 Binarized image

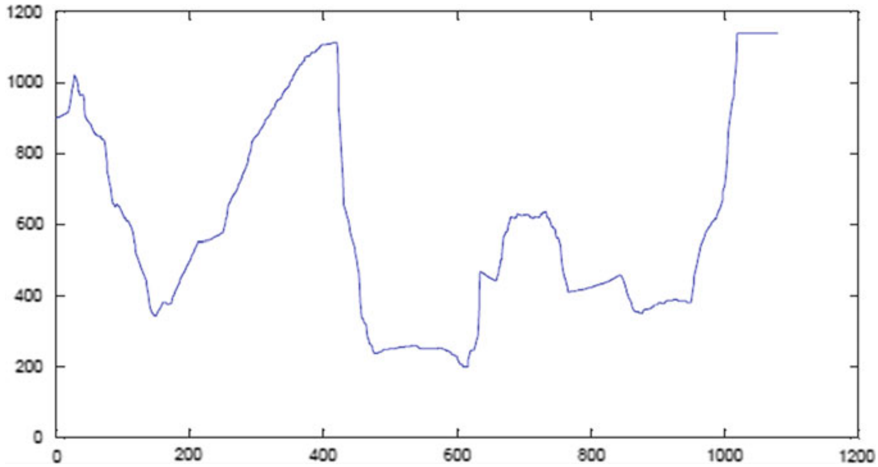

Fig. 15.5 Summation of the binarized image

proceed to cut the image up to the fingertips, but to have only the cut out of the fingers, a new sweep of the image is carried out starting from the center to the end of the same, to detect the pole of the base of the model located between the middle finger and the index, once you have the location of the post on the *X*-axis, the original and binarized image is cut, as shown in Fig. 15.6.

The width of the resulting image remains the same as that of the original 1080 pixel image; now with the resulting image, the next thing to separate is the index, middle, and ring fingers; this is done by dividing the image into three equal parts, with a 360 pixels wide, thus having an image for each finger. Figure 15.7 shows the fingers separately when cropping the previously cropped image.

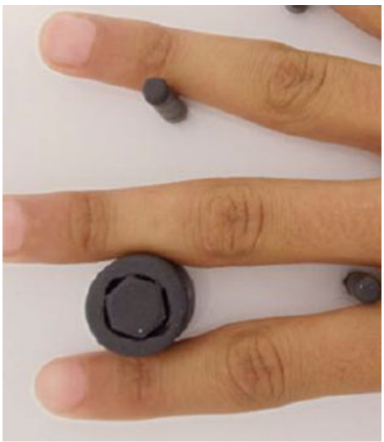

Fig. 15.6 Original image cropped with the new coordinates

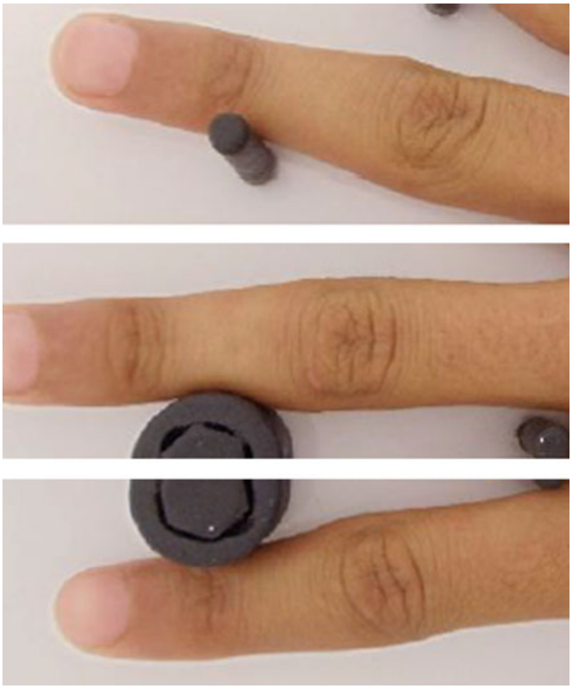

Fig. 15.7 Index, middle, and ring fingers trimmed separately

Due to the posts located at the base of the model, it is possible to know the angle of inclination of the index finger and the ring finger, for which the index finger is rotated with an angle of $-10°$ and the ring finger with an angle of 15°. Figure 15.8 shows the result of rotation to each of the images separately; note that the middle finger is not rotated because its orientation is in an optimal location for feature extraction.

Once the region of interest is completely isolated, techniques will be applied to extract biometric characteristics that can identify distinctive points of each image. By obtaining this information, the artificial intelligence algorithm will carry out a comparison between images, which is located in the database and that will be the new image entered by the user to identify; if the images have a high percentage of coincidence, the algorithm will determine that it is a genuine user, otherwise it will be marked as an impostor.

15.3.2 Proposed Architecture

Figure 15.9 shows the architecture or block diagram of proposed approach. The steps involved are discussed below:

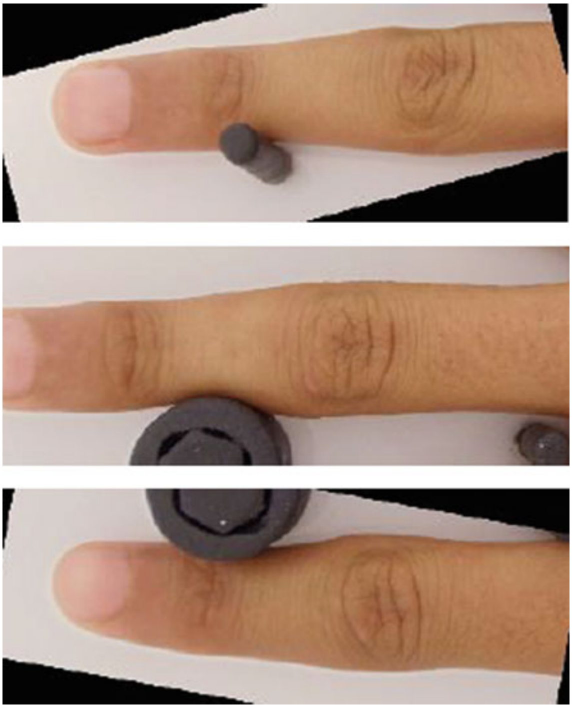

Fig. 15.8 Rotation of the index and annular method

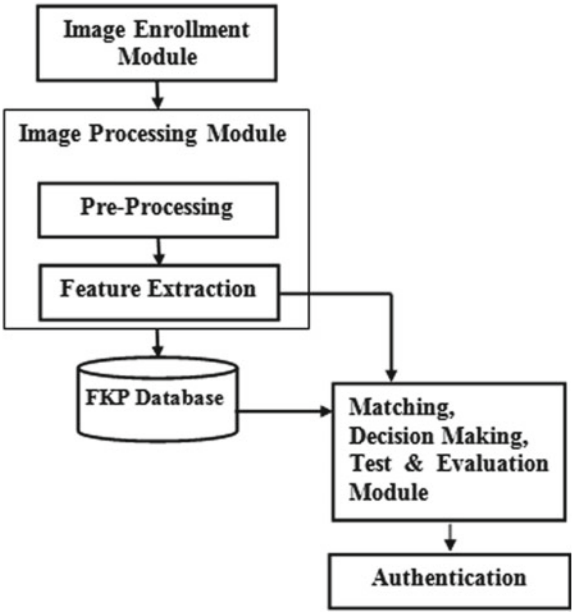

Fig. 15.9 Block diagram for proposed approach

Step 1: In image enrollment module, a digital camera with 14.1 megapixel was used for image acquisition of the index, middle, and ring finger knuckle with dimension of 1920 × 1080 pixel.
Step 2: In image preprocessing module, an image with dimension of 1920 × 1080 pixels was used to cut the index, middle, and ring finger from the image, and then each finger separately to extract biometric feature from the region of interest (ROI).
Step 3: This step performs feature extraction from the preprocessed image of index, middle, and ring finger knuckle with the help of the Bayesian network. Bayesian network is a directed acyclic graph (ADG) that has structure of network consisting of nodes and dependency probabilities.
Step 4: This step stores the extracted feature set in FKP database for authentication purposes, i.e., identification or verification.

15.4 Experimental Results

As seen along Figs. 15.3, 15.4, 15.5, 15.6, 15.7 and 15.8, initially having an image without processing, it was possible to separate the fingers of the hand. So far there is a (test) method to cut the knuckle of the index and ring fingers, this is achieved through the location of the resulting contours by rotating the image, that is, sweeps are made in the image in different lines and columns (of the contours) to detect color changes in the image; in Fig. 15.10, the cut points are marked to generate the new image, as seen in the column on the left side the image of the index and ring finger. The crosses made to separate the knuckle from these fingers are marked in red, and the result of the new cut is shown in the right-hand column.

It should be noted that this method is only a test (for the moment) for the extraction of the region of interest from the index and ring fingers, and currently, we are working on optimizing this algorithm so that it can detect the knuckle of the three fingers separately and can generate a unique and exclusive image of the region to which biometric features are desired.

15.5 Conclusions and Future Scope

It has been observed from the above proposed work that the feature set for FKP is obtained effectively using different effective steps and the efficiency of the approach is proven to be better than existing approach. After applying digital image processing to the database, it has also been possible to extract the region of interest and the next stage is to apply a technique for extracting image features. Once having this information, the third stage consists of developing the artificial intelligence algorithm using Bayesian networks, which makes the decision (based on how much similarity there is between one image and another) to accept or reject the user. In future,

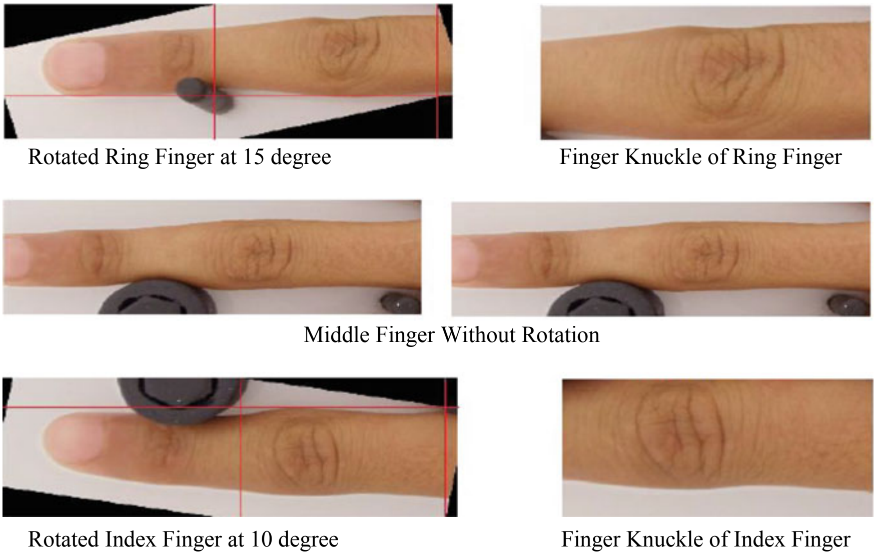

Fig. 15.10 ROI of the knuckle of the index and ring fingers based on the black outlines caused by the rotation of the image

the approach may be used with fused templates with multimodal biometrics rather than individual biometric that of course further increase the efficiency and accuracy parameters of proposed approach.

Acknowledgements This work is part of bilateral Indian–Bulgarian cooperation research project between Technical University of Sofia (Bulgaria), Kurukshetra University Kurukshetra (Haryana) and DCR University of Science and Technology, Murthal, Sonepat, India under the title "Contemporary Approaches for Processing and Analysis of Multidimensional Signals in Telecommunications," financed by the Department of Science and Technology (DST), India and the Ministry of Education and Science, Bulgaria.

References

1. Kumar, M.N., Premalatha, K.: Finger knuckle-print identification based on local and global feature extraction using sdost. Am. J. Appl. Sci. **11**(6), 929–939 (2014)
2. de Luna-Ortega, C.A., Ramirez-Marquez, J.A., Mora-Gonzalez, M., Martínez-Romo, J.C., Lopez-Luevano, C.A.: Fingerprint verification using the center of mass and learning vector quantization. In: 2013 12th Mexican International Conference on Artificial Intelligence, pp. 123–127. IEEE (2013)
3. Liu, M., Tian, Y., Lihua, L.: A new approach for inner-knuckle-print recognition. J. Vis. Lang. Comput. **25**(1), 33–42 (2014)
4. Aoyama, S., Ito, K., Aoki, T.: A finger-knuckle-print recognition algorithm using phase-based local block matching. Inf. Sci. **268**, 53–64

5. Kulkarni, S.S., Rout, R.D.: Secure biometrics: finger knuckle print. Int. J. Adv. Res. Comput. Commun. Eng. **1**(10) (2012)
6. Zhang, L., Zhang, L., Zhang, D.: Monogeniccode: a novel fast feature coding algorithm with applications to finger-knuckle-print recognition. In: 2010 International Workshop on Emerging Techniques and Challenges for Hand-Based Biometrics, pp. 1–4. IEEE (2010)
7. Yang, W., Sun, C., Wang, Z.: Finger-knuckle-print recognition using Gabor feature and MMDA. Front. Electr. Electron. Eng. China **6**(2), 374 (2011)
8. Jing, X., Li, W., Lan, C., Yao, Y., Cheng, X., Han, L.: Orthogonal complex locality preserving projections based on image space metric for finger-knuckle-print recognition. In: 2011 International Conference on Hand-Based Biometrics, pp. 1–6. IEEE (2011)
9. Zhun Lei Quin: Robust palm print and knuckle print recognition system using a contactless approach. In: 2010 5th IEEE Conference on Industrial Electronics and Applications, pp. 323–329. IEEE (2010)
10. Shen, L., Bai, L., Ji, Z.: Hand-based biometrics fusing palmprint and finger-knuckle-print. In: 2010 International Workshop on Emerging Techniques and Challenges for Hand-Based Biometrics, pp. 1–4. IEEE (2010)
11. Zhao, R., Ouyang, W., Li, H., Wang, X.: IEEE international conference on computer vision and pattern recognition (CVPR) (2015)
12. Shariatmadar, Z.S., Faez, K.: A novel approach for Finger-Knuckle-Print recognition based on Gabor feature fusion. In: 2011 4th International Congress on Image and Signal Processing, vol. 3, pp. 1480–1484. IEEE (2011)
13. Kumar, A., Ravikanth, C.: Personal authentication using finger knuckle surface. IEEE Trans. Inf. Forens. Secur. **4**(1), 98–110 (2009)
14. PolyU, FKP Database. The Hong Kong Polytechnic University, Hong Kong (2014)