Novel Approach for Fingerprint Recognition Using Sparse Representation

Rohit Thanki
PhD Research Scholar, Faculty of Technology & Engineering, C U Shah University, Wadhwan City
Email: rohitthanki9@gmail.com
Komal Borisagar
Assistant Professor, Department of Electronics & Communication, Atmiya Institute of Technology & Science, Rajkot
Email: krborisagar@aits.edu.in

---ABSTRACT---

This paper presents novel approach for fingerprint recognition using sparse representation provided by compressive sampling theory. In this paper, fingerprint feature is extracted in term of sparse measurements vector using Compressive Sampling (CS) theory framework. CS theory is provided unique solution to generation of sparse measurement vector of image based on measurement matrix and sparse coefficients. The sparse measurement vector of query fingerprint image is compared with sparse measurement vector of authenticate fingerprint image in store database. SSIM is used as matching score between query measurement vector values and authenticate measurement vector values of fingerprint. The experimental results show that proposed recognition algorithm is used for fingerprint feature extraction and matching.

Keywords – **CS Theory, Feature Extraction, Fingerprint, Pattern Recognition, SSIM**

I. INTRODUCTION

Today world, automatic biometric recognition based system is used for human verification and authentication based on its biometric characteristics [1, 2]. This automatic biometric recognition based system is used more compared to traditional identification system like knowledge of password and ID card [3]. Fingerprint is accepted in worldwide because of fingerprint is easy to available for recognition [4]. So fingerprint based recognition system is used for verification and authentication of individual in worldwide. The basic fingerprint verification system is shown in figure 1. The first stage of system is fingerprint acquisition in which fingerprint image of individual is taken by a sensor. Then next stage is preprocessing stage in which enhances fingerprint image by removing noise which is introduced by sensor. Then extract feature of enhance fingerprint image using feature extraction stage. Finally, this extracted feature of query fingerprint image is compared with enrolled feature of fingerprint image which is stored at system database using matching stage. Based on matching results, individual is deciding as authenticated or unauthenticated.

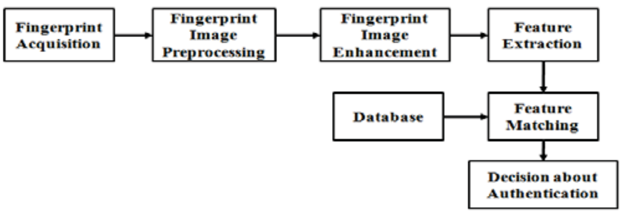


Fig.1. Block Diagram of a Fingerprint Verification System (adapted from [5])

Any fingerprint image can be representation by different level features like level 1 features, level 2 features and level 3 features which is shown in figure 2. Level 1 feature contains ridges and valleys. This features having different patterns like loop, arch, whorl and tented arch. Level 2 feature contains ridge endings, bifurcation, ridge terminations, eye, spur and cross-over. Level 2 features which is referring as minutiae points and minutiae is most famous features of fingerprint which is generally stable and robust. The minutiae point of fingerprint is unique for every individual and used for automatic fingerprint identification. Level 1 and 2 fingerprint features are used in many commercially application like individual recognition, security, ATM, credit card, electronic banking and network & Laptop access, etc.

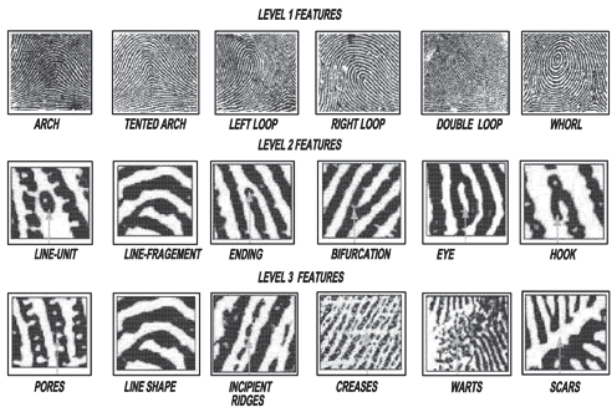


Fig.2. Fingerprint Features at Level 1, Level 2, Level 3 (adapted from [5, 15, and 16])

Level 3 feature contains pores and ridge details of fingerprints. Level 3 features require very high quality image sensor for acquisition, so that this features is limited used by researcher.

In this paper, we have described novel fingerprint extraction and matching algorithm for individual recognition based on CS theory framework. In this algorithm, first step is generated sparse measurement vector using of authentic fingerprint image using measurement matrix and sparse coefficients of authentic fingerprint image. This sparse measurement vector of authentic fingerprint image is stored in database. Second step is that when query fingerprint image is come at sensor level, generate sparse measurement vector of query fingerprint image and compared this sparse measurement vector of query fingerprint image with stored sparse measurement vector of authentic fingerprint image. Based on comparing result, decision is made about query fingerprint image is authenticate or not.

The rest of paper is organized such that section 2 gives brief literature review on fingerprint matching algorithm. Section 3 gives description of compressive sensing theory; section 4 gives proposed fingerprint extraction and matching algorithm. Section 5 gives experimental results. Finally, section 6 gives conclusion and future work.

II. LITERATURE REVIEW

Any fingerprint recognition algorithm, two steps like fingerprint feature extraction and matching is very important. This section is give brief literature review on fingerprint feature extraction and matching algorithm. Author in [3] proposed a biometric template selection and cased study of fingerprint recognition. Author in [4] proposed fingerprint recognition algorithm based on filter bank. This algorithm is used by many researchers for fingerprint recognition because of its gives distance between query image and its closet match image in database. Author in [5] described three feature extraction techniques like pores contour, ridge contour and minutiae points. Author in [6] proposed pore extraction of fingerprint image based on skeletonization method or a unitary scale isotropic pore model. Author described that pore of fingerprint is not always isotropic and proposed model is worked on pore extraction because model parameters can adjustable according to fingerprint ridge direction and period.

Author in [7] described modified fingerprint recognition algorithm based on minutiae point feature extraction technique. In this algorithm, authors are combined different methods of minutia extractor and minutia matching to improve performance of recognition. Author in [8] described 3 level features based fingerprint matching algorithm. They described that fingerprint feature is given in hierarchical order of three level like level 1 is pattern, level 2 is minutiae points and level 3 is pores and ridge shape. Author in [9] proposed fast fingerprint recognition algorithm by combining level 2 and level 3 features of fingerprint. Author in [10] proposed fingerprint recognition algorithm based on canny and sobel edge detection algorithm. In this proposed algorithm, some edge feature of fingerprint is used for matching of individual.
Author in [11] shows Gabor filter based fingerprint recognition algorithm. In this proposed algorithm, Gabor filter is used fingerprint image enhancement. Author in [12] described normalized cross-correlation based fingerprint matching algorithm. But this technique is not work for low quality fingerprint images. Author in [13] proposed fingerprint matching algorithm based on a local correlation of fingerprint features. Author in [14] proposed a fingerprint verification system based on correlation approach. In this algorithm, find correlation between authentic and query fingerprint image and based on correlation results, individual recognition is performed.

III. COMPRESSIVE SENSING THEORY

Any image or signal can be exactly reconstructed by its few Fourier coefficients are described by Donoho and Candès [17, 18]. Basic on this concept, they are described new signal processing theory which is called “Compressive Sensing or Sampling (CS) Theory”. The necessary condition for application of CS theory on image is that image must be sparse in its own domain [17, 18]. Most of images are sparse when different image transform applied on it.

Any image f can be represent in term of sparse measurement vector using CS theory described by below equation 1 and 2.

$$x = \psi \times f \tag{1}$$

$$y = A \times x \tag{2}$$

In equation (1) and (2), y = Sparse Measurement Vector of Image with size of M × 1; A = Measurement Matrix with size of M × N; Ψ = Image Transform; x = Sparse or Transform Coefficients of Image; f = Original Image.

IV. PROPOSED FINGERPRINT RECOGNITION APPROACH

This section describes proposed fingerprint recognition approach based on Compressive Sensing (CS) theory. The proposed fingerprint recognition approach is divide into two step like feature extraction and feature matching. The proposed architecture of fingerprint recognition system is shown in figure 3. In figure 3, blue outline box is shown proposed enrollment process and red outlined box is show proposed verification process.

3. 1.Fingerprint Feature Extraction

The fingerprint feature extraction steps are described below:

- Take fingerprint image with size of N × N.

- Convert fingerprint image into vector with size of $N^2 \times 1$.
- Applied 2D Discrete Cosine Transform (DCT) on Vector of fingerprint image and convert into sparse coefficients which is denoted as *x*.
- Generate measurement matrix A with size of M × N using random seed. Here M is used for deciding size of extracted fingerprint feature.
- Then generate sparse measurement vector *y* of fingerprint image using equation 1 and 2.
- Then sparse measurement vector is converting into bit 0 and 1 using uniform quantization process.
- This binary version of sparse measurement vector is stored as authentic fingerprint feature at system database and used for feature matching at later. This feature is denoted as Authentic_Feature.

3. 2.Fingerprint Feature Matching

This above mentioned process of fingerprint feature extraction applied on the entire fingerprint database to generated sparse measurements vector to each fingerprint image and stored at system database as enrolled database. This process is applied when any fingerprint image is come for individual recognition.

- Any query fingerprint image is come for individual recognition and then convert query fingerprint image is converting in to sparse measurements vector using fingerprint feature extraction process. This feature is denoted as Query_Feature.
- Then find similarity between Query_Feature with all Authentic_Feature using Structural Similarity Index Measure (SSIM) [19]. Here we have described two conditions for individual recognition based on fingerprint.
- **Condition 1:** Individual is Recognized and Authenticate if $SSIM(Authentic\_Feature, Query\_Feature) > \tau$
- **Condition 2:** Individual is not Recognized and Unauthenticate if $SSIM(Authentic\_Feature, Query\_Feature) < \tau$

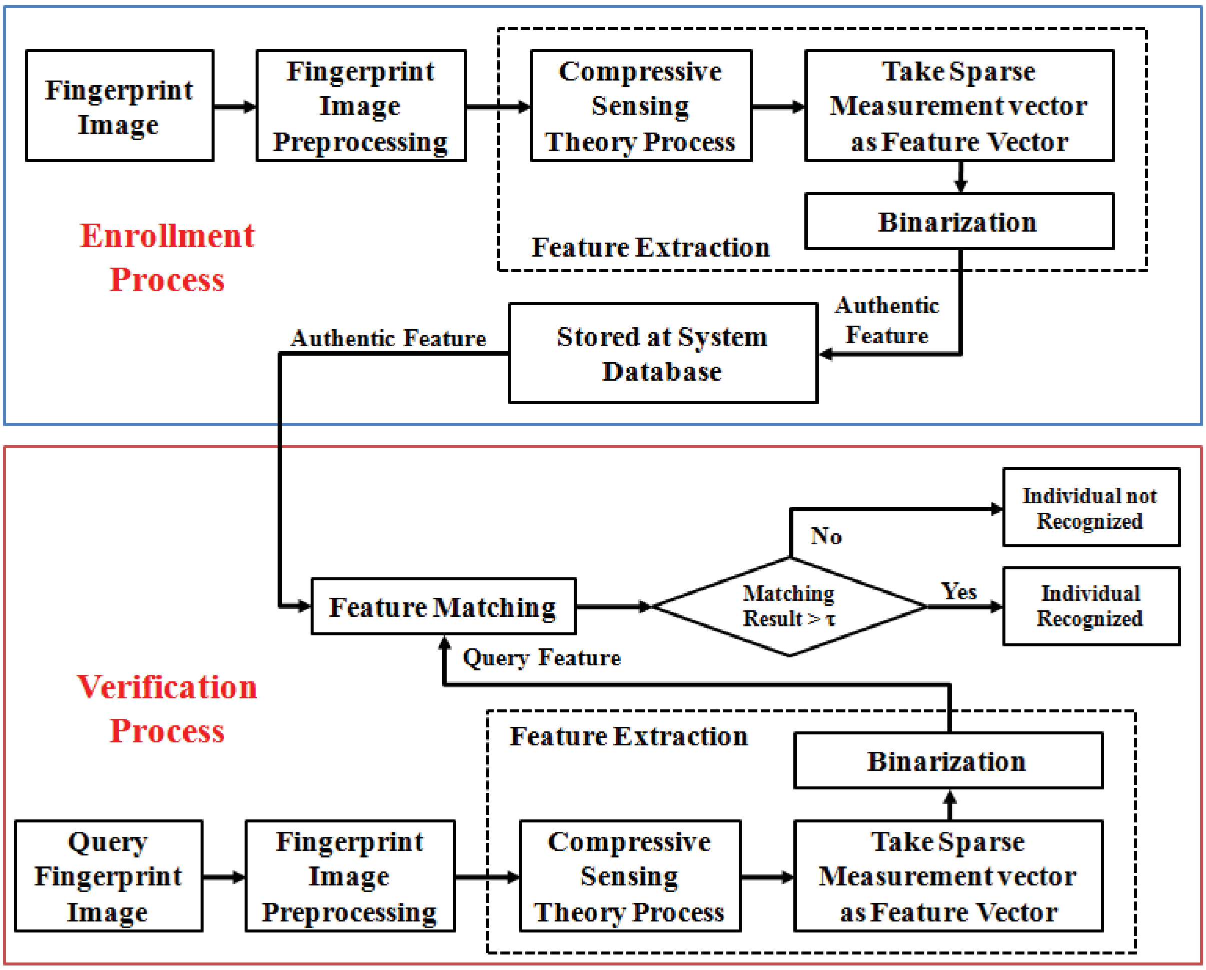
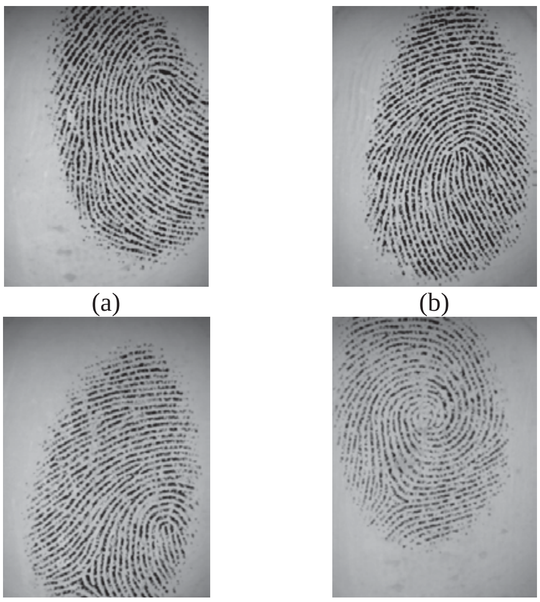


Fig.3. Proposed Architecture of Fingerprint Recognition System

V. EXPERIMENTAL RESULTS

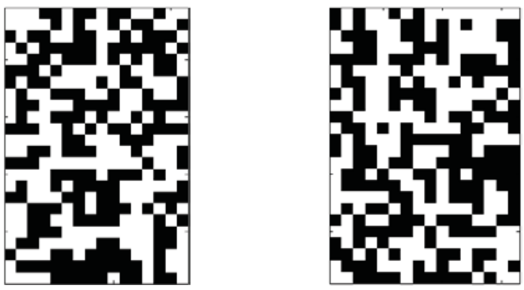
For testing of proposed fingerprint recognition algorithm, we have taken FVC 2002 db4 Set B [20] database. This database contains 80 different fingerprint image with size of 288 × 384 pixels. Figure 4 shows few fingerprint samples which is used for testing of proposed algorithm.

Fingerprint feature extract using below procedure followed. Applied 2D discrete cosine transform (DCT) on fingerprint image and convert transform coefficients into vector with size of 110592 × 1. These transform coefficients taken as sparse coefficients of fingerprint image. Then generate measurement matrix A with size of 384 × 110592. Finally, generate sparse measurement vector of fingerprint image with size of 384 × 1 using equation 1 and 2. Then convert this sparse measurement in term of bit 0 and 1 using uniform quantization process. This sparse measurement vector of fingerprint image is stored at system database and denoted as authentic or enrolled feature. Figure 5 shows authentic feature or enrolled feature of fingerprint image using CS theory which in term of sparse representation.

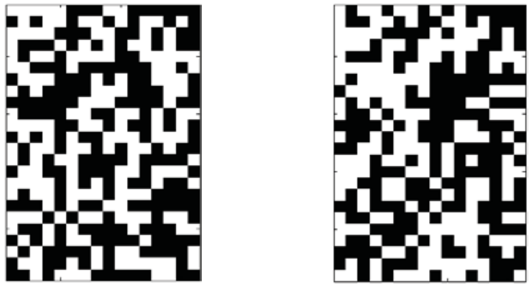


(a) (b) (c) (d)

Fig.4. Test Fingerprint Images (a) F1 (b) F2 (c) F3 (d) F4



(a) (b)



(c) (d)

Fig.5. Authentic Features of Fingerprint Images in term of Sparse Representation (a) F1 (b) F2 (c) F3 (d) F4

Now any fingerprint image is come for query at sensor level. Then first generate sparse measurement vector of query image and this sparse measurement vector is denoted as query feature. This query feature is compared with authentic feature of fingerprint image using SSIM [19]. If result of matching is threshold value then decide that query image is authentic image otherwise query image is not authentic. Here we have threshold value for matching of feature is 0.9 (90 %).

For performance analysis of proposed recognition algorithm, we have generated sparse measurement vector of 80 fingerprint images which is available in FVC 2002 db4 Set B which is stored as authentic feature of fingerprint in system database. Then taken one authentic feature as query feature of fingerprint and compared this query feature with entire authentic feature in system database. The matching result of features comparison is summarized in table 1.

Table 1. Matching Result of Proposed Algorithm for Test Fingerprint Image

Query Image	Similarity between Query Feature and Authentic Feature	Matching Percentage (%)
1	1.000	100
6	0.487	48.70
10	0.481	48.10
16	0.476	47.60
25	0.467	46.70
30	0.524	52.40
40	0.490	49.00
50	0.552	55.20

The results shown in table 1 indicated that similarity between query feature 1 and authentic feature 1 is 1.00 (100 %). Otherwise similarity between other query features and authentic feature 1 is less than 0.600 (60 %). This indicates that proposed algorithm is used for individual recognition.

VI. CONCLUSION

The paper proposed a novel feature extraction and matching technique for fingerprint recognition based on Compressive Sensing theory. The technique combines the field of pattern recognition and compressive sensing theory. This technique is explored unique solution of provide by CS theory based on measurement matrix and sparse coefficients. This technique can be used other biometric modalities recognition like iris and face. This proposed algorithm has good performance against spoofing attack because it is difficult to generate sparse feature by imposter without knowledge of correct measurement matrix and sparse coefficients.

ACKNOWLEDGEMENTS

The authors are highly thankful to BioLab, University of Bologna provide fingerprint image database.

REFERENCES

[1] A. Jain and A. Kumar, “Biometric Recognition: An Overview”, *Second Generation Biometrics: The Ethical, Legal and Social Context, Springer*, 2012, 49-79.

[2] A. Jain, A. Ross and S. Pankanti, “Biometric: A Tool for Information Security”, *IEEE Transactions on Information Forensics and Security*, 1(2), 2004, 125-143.

[3] U. Uludag, *Secure Biometric Systems*, Ph.D. Thesis, Michigan State University, USA, 2006.

[4] S. Prabhakar, *Fingerprint Classification and Matching Using a Filterbank*, Ph.D. Thesis, Michigan State University, USA, 2001.

[5] A. Rawat, *A Hierarchical Fingerprint Matching System*, M.Tech Dissertation Report, Indian Institute of Technology, Kanpur, India, 2009.

[6] Q. Zhao, L. Zhang, D. Zhang, N. Luo, “Adaptive Pore Model for Fingerprint Pore Extraction”, *In Proceedings of the IAPR 19th International Conference on Pattern Recognition (ICPR’08)*, Tampa, Florida, USA, December 2008,

[7] M. Kaur, M. Singh, A. Girdhar and P. Sandhu, “Fingerprint Verification System Using Minutiae Extraction Technique”, *World Academy of Science, Engineering and Technology*, vol. 2, 2008, 432-437.

[8] A. Jain, Y. Chen and M. Demirkus, “Pores and Ridges: Fingerprint Matching Using Level 3 Features”, *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 29(1), 2007, 15-27.

[9] M. Vatsa, R. Singh, A. Noore and S. Singh, “Combining Pores and Ridges with Minutiae for Improved Fingerprint Verification”, *Elsevier, Signal Processing*, 89(12), 2009, 2676-2685.

[10] W. Cui, G. Wu, R. Hua and H. Yang, “The Research of Edge Detection Algorithm for Fingerprint Images”, *In Automatic Congress 2008, WAC 2008, World, IEEE*, September 2008, 1-5.

[11] S. Li, M. Wei, H. Tang, T. Zhuang and M. Buonocore, “Image Enhancement Method for Fingerprint Recognition System”, *In Conference Proceedings: … Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, IEEE Engineering in Medicine and Biology Society Conference, vol. 4, 2004, 3386-3389.

[12] D. Karna, S. Agrawal and S. Nikam, “Normalized Cross-correlation Based Fingerprint Matching”, *In proceedings of 5th IEEE International Conference on Computer Graphics, Imaging and Visualization (CGIV’08)*, 2008, 229-232.

[13] K. Nandakumar and A. Jain, “Local Correlation based Fingerprint Matching”, *ICVGIP*, 2004, 503-508.

[14] A. Bazen, G. Verwaaijen, S. Gerez, “A Correlation Based Fingerprint Verification System”, *Workshop on Circuits, Systems and Signal Processing*, Veldhoven, Netherlands, November 2000.

[15] The Thin Blue Line, October 2006, http://www.plicensw.com/info/fingerprints/finger06.html

[16] H. Nieuwendijk, Fingerprints, October 2006, http://www.xs4all.nl/~dacty/minu.html

[17] E. Candès, “Compressive Sampling”, *Proceedings of the International Congress of Mathematicians*, Madrid, Spain, 2006.

[18] D. Donoho, “Compressed Sensing”, *IEEE Transaction on Information Theory*, 52(4), 2006, 1289-1306.

[19] Z. Wang and A. Bovik, “A Universal Image Quality Index”, *Journal of IEEE Signal Processing Letters*, 9(3), 2004, 84-88.

[20] For Fingerprint Database: http://bias.csr.unibo.it/fvc2002/databases.asp

Biographies and Photographs

Rohit M. Thanki has received B.E. degree in Electronics and Communication Engineering from Saurashtra University, Rajkot and M.E. in Communication Engineering from Sardar Patel University, Vallabh Vidyanagar. He is currently pursuing his Ph.D. in Electronics and Communication Engineering from C U Shah University, Wadhwan City, Gujarat, India. His area of research is to Design Watermarking Algorithm for Biometric Data Protection. He has guided more than 15 UG students in their project work. He has published 11 research papers in various high impact factor international journals. He has presented 7 research papers in various national and international conferences. He has published books titled Comparative analysis of digital watermarking techniques and Design of Operational Transconductance Amplifier with Lambert Publishing House, Germany. His area of interest is Digital Watermarking, Compressive Sensing, Pattern Recognition, Image & Signal Processing, and Digital VLSI Design.

Dr. Komal R. Borisagar received B.E. degree in Electronics and Communication from C. U. Shah Engineering College, Saurashtra University, Rajkot, Gujarat, India in 2002 and M.E. degree in Communication System Engineering from Changa Institute of Technology, Gujarat University, and Ahmedabad in 2008. In 2012, she received her doctoral degree from the Department of Electronics and Communication Engineering, JJT University, Rajasthan. She has teaching experience of over 10 years. She is working as Assistant Professor at Electronics & Communication Department, Atmiya Institute of Technology and Science, Rajkot. Her areas of interest are wireless communication, speech processing and signal & image processing.