Journal of ISMAC (2021)
Vol.03/ No.01
Pages: 16-30
http://irojournals.com/iroismac/
DOI: https://doi.org/10.36548/jismac.2021.1.002

Evaluation of Fingerprint Liveness Detection by Machine Learning Approach - A Systematic View

Dr. Edriss Eisa Babikir Adam,

Assistant Professor / EEE,
Mainefhi College of Engineering and Technology,
Mainefhi, Eritrea.
bonzoga20@gmail.com

Prof. Sathesh,

Department of EEE,
Eritrea Institute of Technology,
Eritrea.
sathesh4you@gmail.com

Abstract- Recently, fake fingerprint detection is a challenging task in the cyber-crime sector in any developed country. Biometric authentication is growing in many sectors such as internet banking, secret file locker, etc. There spoof fingerprint detection is an essential element that is used to detect spot-on fingerprint analysis. This article focuses on the implementation and evaluation of suitable machine learning algorithms to detect fingerprint liveness. It also includes the comparative study between Ridge-let Transform (RT) and the Machine Learning (ML) approach. This article emphasis on research and analysis of the detection of the liveness spoof fingerprint and identifies the problems in different techniques and solutions. The support vector machine (SVM) classifiers work with indiscriminate loads and confined grayscale array values. This leads to a liveness report of fingerprints for detection purposes. The SVM methodology classifies the fingerprint images among more than 50K of real and spoof fingerprint image collections based on this logic. Our proposed method achieves an overall

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

high accuracy of detection of liveness fingerprint analysis. The ensemble classifier approach model is proving an overall efficiency rate of 90.34 % accurately classifies samples than the image recognition method with RT. This recommended method demonstrates the decrement of 2.5% error rate when compared with existing methods. The augmentation of the dataset is used to improve the accuracy to detect. Besides, it gives fake fingerprint recognition and makes available future direction.

Keywords: *Fingerprint liveness, Ridgelet Transform, SVM classifier*

1. INTRODUCTION

In many developed countries turns into fully automated with smart home and lifestyle. Biometric authentication is one of the effective methods for unlocking or running any smart devices in the environment. Also, many spoofing fingerprints are happening in developed countries. So the liveness detection is the only solution for anti-spoofing [1]. The living moment of the individual or any functional information will be detected by the addition of liveness detection. There are three ideas used to acquire the sign of live moment at present as follows;

1. **Use of additional external hardware module**
2. **Use of trained software processing algorithm**
3. **Use of previous trained or captured of physique moment**

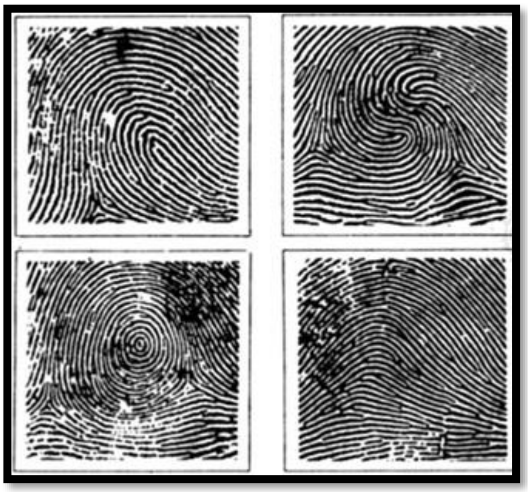

Figure 1 Ridges in fingerprints

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

Figure 1 shows the presence of the ridges in fingerprints. Since there are more ridges in the images, the ridgelet transform is chosen to transform one domain to another domain data [2].

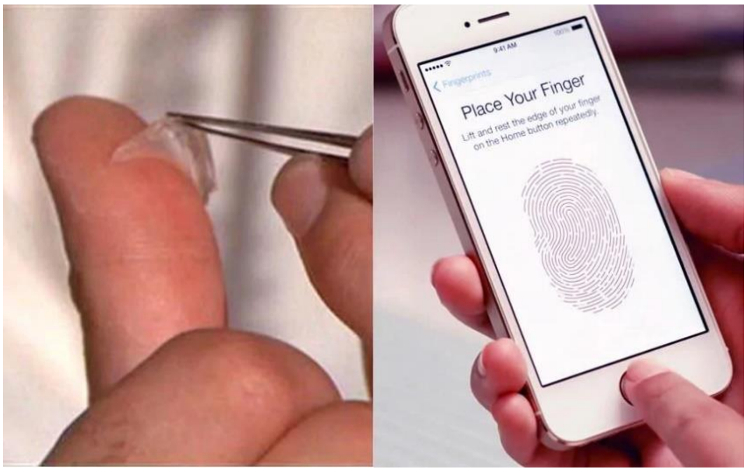
Place Your Finger
Lift and rest the edge of your finger on the Home button repeatedly.

Figure 2 Fingerprint spoof chances

The fingerprint spoof changes made with different materials possible which are shown in figure 2. The additional attachment of the hardware module provides perfect or the highest accurate detection results. There are many types of additional attachments available to detect various physiological information as follows;

1. Temperature, pressure, and current vision of the person
2. Optical information
3. Electro Cardio Gram, pulse information
4. Blood pressure units and etc.

The current vision of the person will provide the best detection rate. But it is a bit too bulky and more expensive in the existing system [3, 4]. The software processing algorithms provide better results with the absence of various components. Figure 3 shows the different hardware and software methods used to detect liveness in fingerprint techniques. The feature representation is compact for liveness fingerprint detection with the assistance of spectral characteristics of input test images [5].

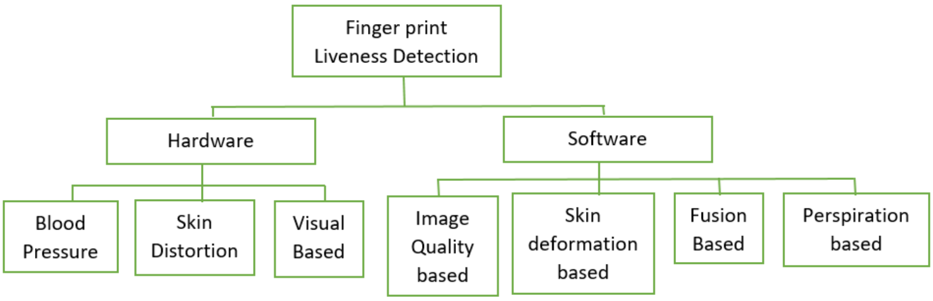

Figure 3 Methods of finding fingerprint liveness

Many materials such as gelatin, wood glue, Eco flex, silgum, latex, etc. can be made with fake fingerprints.

2. ORGANISATION OF THE RESEARCH

The structure of the research article organized as follows; Section 3 gives a literature survey of recent research approaches to the detection of liveness in a fingerprint. Section 4 presents the proposed methodology. Section 5 delivers a description of the results and discussion. Finally, Section 6 concludes the research work along with the future scope.

3. RELATED WORKS

Tan and Schuckers [6], the authors differentiated between wavelet-based liveness detection method and ensemble classifier method along with the optical fingerprint scanner. They calculated energy signatures for assist occurrence and energy signatures.

Zhifan Gao et.al. [7] deals with handling noisy data for the detection of the fingerprint. They investigated with a fingerprint using graphical pixels with the region of interest in a pattern. Also, they succeed to obtain the EER of 5.6% from 3.5% with the FVC2002 dataset. Zin Mar Win et al. [8] proposes the Gabor filters techniques to extract the fingerprint features. The current method is compared with the existing method and obtained higher accuracy of 97% is reported. Zhu Le-Qing [9] investigates the knuckle print recognition scheme based on a speeded-up robust features algorithm. The test results also show a good accuracy rate of 96.91% and computation time is very minimum to match the fingerprint for identification. Jucheng Yang et al. [10] conducted the test for fingerprint evaluation with the help of

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

assembled moment by FVC2002 dataset. They achieved less execution time and EER 2.27% for fingerprint match detection.

Nikam and Agarwal introduced several methods to detect fingerprints from the scanner. Also, the Local Binary Pattern method is used to detect fingerprint that is implemented along with wavelet transform. But this method is used to find whether the fingerprint is real or fake [11]. Another method known as Gray Level Co-occurrence Matrices (GLCMs) is concurrent with various techniques such as Gabor filter techniques [12], wavelet transform [13], and curvelet transform [14]. Nogueira et al introduce learning method implementation for this fingerprint detection task. The Support Vector Machine (SVM) and Principal Component Analysis (PCA) are the methods used to reduce the dimension in the process [15]. The liveness detection is done by Local Phase Quantization (LPQ) which is a distortion insensitive pattern classification method [16]. Ghiani et al [17] introduced the Binarized Statistical Image Feature (BSIF) method which is used to detect spoofing fingerprints. Here, face recognition is also performed with a different dataset. Also, the test is conducted for the detection of fingerprint by machine learning method with the minimum number of datasets LivDet2011.

Gragnaniello et al. [18] perform the liveness fingerprint detection with a local discriminatory pattern called Weber Local Descriptor (WLD). There are two blocks were constructed called as differential excitation and coordination. With the support of a visual histogram of the images, discriminatory features can be initiated. Finally, Artificial Intelligence (AI) method is used for classifying the dataset LivDet2009 [19] and LivDet2011 [5]. The authors conducted a hybrid test, which merged two algorithms and yielded better accuracy results [16].

Galbally et al [20] used the ridge of the fingerprint to find the liveness detection process. The strength, continuity, and clarity of the fingerprint edges were calculated. Moreover, a local angle and pixel density were measured for the power spectrum of the input images. They conducted classifier analysis for better output response. This method achieved an overall rate of 90% suitably categorized sample patterns with around 10K real and fake images.

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

3.1 RESEARCH GAP

There may be a lot of research about liveness fingerprint detection. The existing procedure and algorithms lack in finding or identifying liveness of fingerprint detection. Figure 7 shows the same fingerprint but one is real; another two are fake with different material. The background of the image represents the region of the image and symbolized in LPB, GLCMs, etc. The combination of RT and classification algorithms can provide effective and accurate identification for liveness fingerprint detection. There may be two steps in the suggested approach. Initially, image features are extracted by RT and the liveness detection features in the images can be defined by the classifier process.

4. PROPOSED METHODOLOGY

The following steps proposed an effective and high accuracy identification of the liveness of fingerprint analysis.

Step 1:

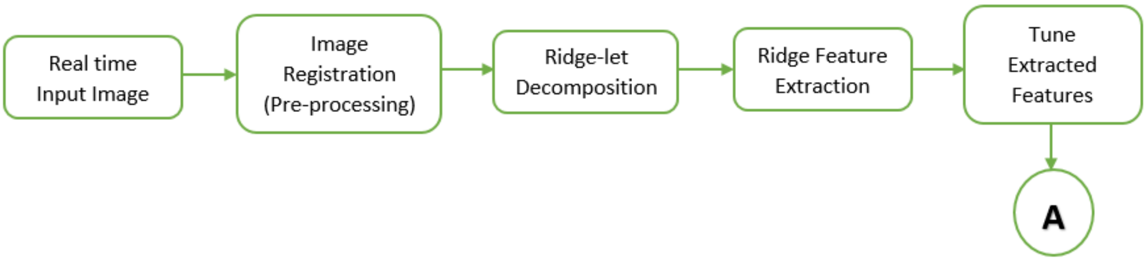

Figure 4 Ridge-let Decomposition

The discrete Ridge-let transform is defined with radon transform as follows;

$$R_s([p,q],b) = \sum_{(x_1,x_2)\epsilon L_{[p,q],b}} s(x_1,x_2)$$

Where

$$L[p,q],b = \{(x_1,x_2)\epsilon[0,N-1] * [0,N-1]: qx_1 - px_2 - b = 0\}$$

Here p, q are the normal vector.

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

Step 2:

Computing F(u,v) from the original image

Step 3:

Conversion from Cartesian

Compute with Fast Fourier Transform and the values are obtained on square lattice on a polar lattice. This process is called polar conversion from Cartesian.

Step 4:

Reduction in Dimension

PCA is the one of the effective method to reduce or tune the dimension in the images. Here, it is calculated for lower dimensional basis to signify the data [21].

Process Flow in Second Phase

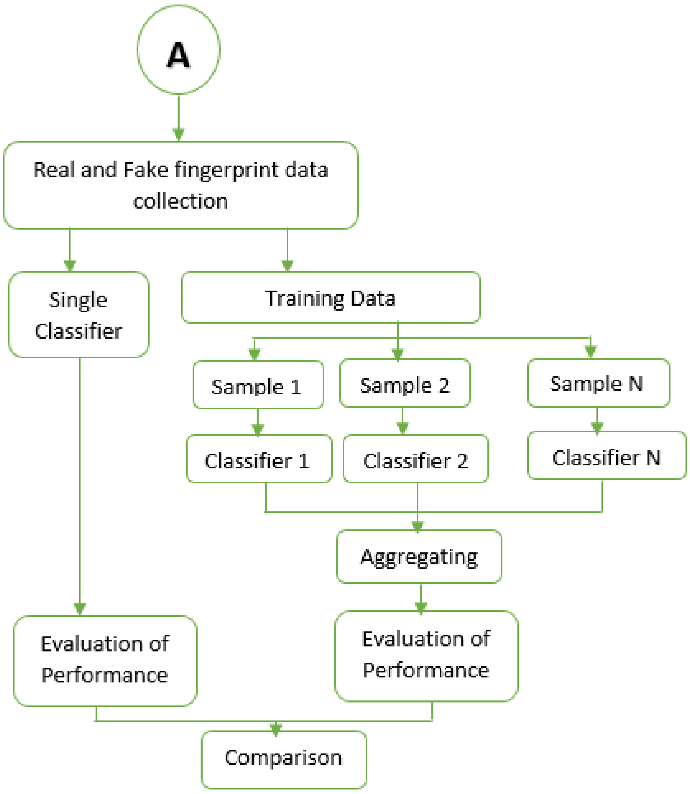

Figure 5 Process of Ensemble and single classifier

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

The data collection for the images, training data for the classifier, and aggregating and detecting the liveness of fingerprint images are the pipelines of the second step of our proposed algorithm. Finally, the performance will be measured using a range of measures, including precision, accuracy, F measure, and recall.

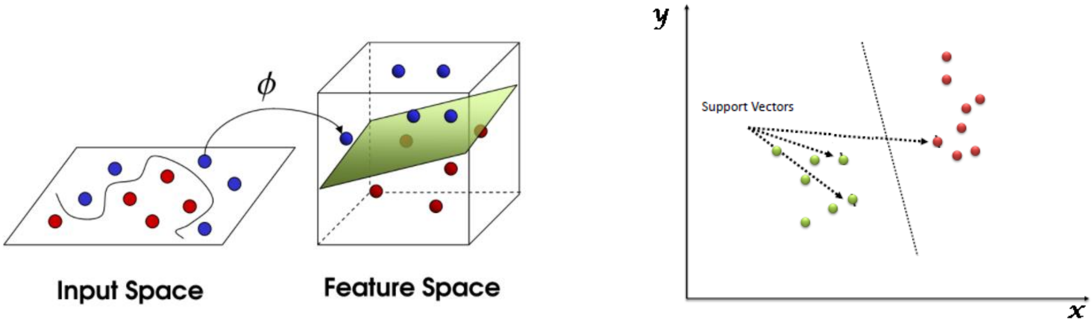

Figure 6 Support Vector Machine approach

Step 5:

To determine complex feature space mapping,

$$\varphi(x)\epsilon R^M$$

For each input features are transformed as

$$\varphi(x): R^D \to R^M$$

Step 6

The model class is separating the points with the hyperplane is shown in figure (a)

$$H: w^T(x) + b = 0$$

Step 7

All separated and represented data points can be segregated with separate class after the measurement of distance between the points is defined as,

$$d_H(\varphi(x_0)) = \frac{|w_T(\varphi(x_0) + b|}{\|w\|_2}$$

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

Where,

$$\|w\|_2 = \sqrt{w_1^2 + w_2^2 + w_3^2 + \cdots + w_n^2}$$

Step 8:

Generally, hyperplane by SVM focuses to have huge boundary with nearest point; and for the perfect separation is defined as,

$$w^* = arg_w max\left[min_a \frac{|w^T(x_n)) + b|}{\|w\|_2}\right] = arg_w max\left[min_a \frac{y_n|w^T(x_n)) + b|}{\|w\|_2}\right]$$

The pre-processing is involving dimension reduction and filtering with the assistance of Region Of Interest (ROI). The equalization of contrast in the image also will be considered in this section. The final model in this research depends on validation time and error calculation of executing the single operation. During the cross-validation process, hyperplane parameters are treated by an automated combination of processing [20].

One of the most important considerations in the classification of liveness fingerprint detection is spatial resolution. To check certain functions in different scales of the interpolation function, the image reduction technique is used.

5. RESULTS AND DISCUSSION

The filtering technique is performed to remove the noise and unwanted details in the image by low pass filtering. The hypothesis conditions of fake and true fingerprint liveness analysis were tested in the real-time scenario. The real-time image is normally influenced by noise all of the time; a low pass filtering method is applied for a continuous search. The filter techniques are low pass and high pass filtering techniques. The high pass filtering techniques are implemented in the subtraction of the original noise-free images to obtain the pure image.

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

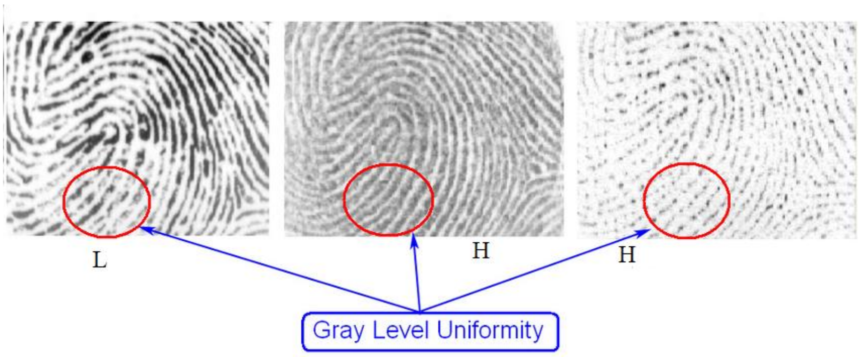

Figure 7 Grey level uniformity

Low-frequency features are present in real fingerprint images. High-frequency components such as Fun-Doh and Gummy images respectively which are shown in figure 7. This is the reason for choosing the High Pass (HP), Low Pass (LP) frequency filters in the first phase of our proposed method. The SVM classifier classification is depicted in figure 8. It displays the maximum number of information separated by the shortest distance.

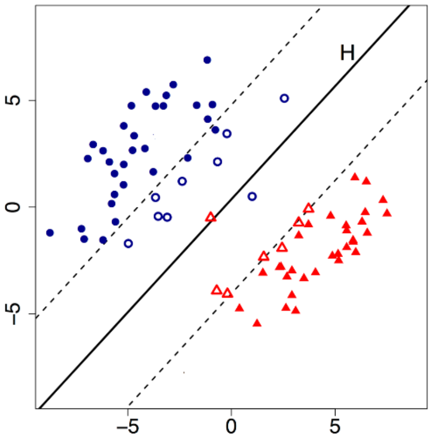

Figure 8 Classification by SVM classifier

The region of interest is also essential for the huge amount of dataset. This is because of these images are having details in not cantered at the image. The morphological approach is undertaking this operation. The contrast equalization is very important to find the liveness in fingerprint analysis. The adaptive histogram equalization is providing the lightness value of the image based on the surrounding. The performance comparison graph chart is shown in

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

figure 9. LivDet 2013 consists of 16K images from various sensors. There 2K images from spoof fingerprint images.

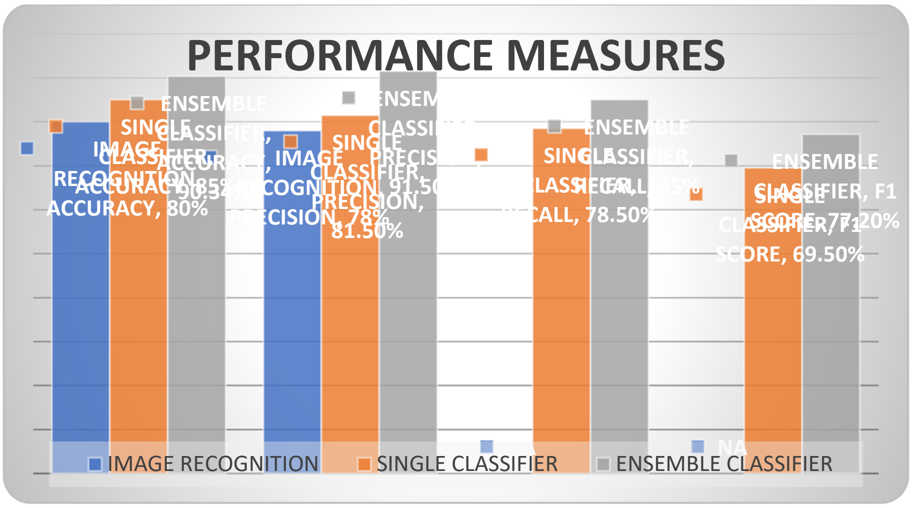

Figure 9 Performance measures between identification methods

The above chart represents that the ensemble classifier techniques provides good accuracy in the liveness identification of spoof fingerprint. The process of splitting the datasets contributes high speed in the computation. The datasets are classified as 80% for training and 20% for testing. The SVM classification and a single classifier are also applied for processing. But the results obtained in the SVM ensemble classifier method is improved rather than the single classifier algorithm.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

$$F - Measure = \frac{2.TP}{2.TP + FP + FN}$$

The differences in the measurement metrics are calculated for the proposed models and attained the performance of the evaluated model. The overall performance of the proposed models can be determined by calculating accuracy (single classifier and ensemble classifier).

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

The precision is responsible for the model's positive prediction accuracy. The recall specifies the overall coverage of the actual positive sample. The F measure is used to compute for unbalanced classes.

6. CONCLUSION AND FUTURE SCOPE

Initially, the computation time efficiency was measured in the proposed work. The time efficiency is not equal during perfect identification of liveness fingerprint analysis. Due to feature extraction in many patterns, it can be inferred that the anti-spoofing method concentrates time efficiency for many sectors. The findings obtained are acceptable for our tests of the proposed algorithm. This approach extends by using any form of material used to spoof fingerprint images and other biometric properties. The proposed techniques have enhanced their recognition in the liveness detection fields, to the best of our knowledge. The context uncertainty of the spoof images was demonstrated. To assess the liveness of a spoof fingerprint, this analysis used two separate approaches such as single classifier and an ensemble approach classifier. As a consequence, in the first step, a lot of fake images in the database is mixed and checked for liveness detection.

Other measuring metrics' precision and low performance were achieved. The second step output detection is very reliable and metrics are higher performance in two different classifier approaches compared to ridge features extraction. Our proposed algorithm is not very practical for all forms of spoof fingerprinting materials. The two types of materials as Gelatin and wood glue were obtained and tested in real-time. The number of materials available is increased and assists to fine-tune our algorithm's parameters for a more effective test. Although using an unknown or different material for spoof fingerprint yields a lower accuracy and another factor. The ensemble classification method is used for identifying the liveness for fingerprint analysis. The single classifier shows inaccuracy for those unknown materials. A separate process is required to do sufficient evaluation in the robustness, vulnerability, and reliability of the liveness of spoof attacks by an intruder. Finally, the introduction of segmentation of the image can give better clarity in feature extraction.

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

REFERENCES

[1] Galbally J., Fierrez J., Ortega-Garcia J., Cappelli R. (2014) Fingerprint Anti-spoofing in Biometric Systems. In: Marcel S., Nixon M., Li S. (eds) Handbook of Biometric Anti-Spoofing. Advances in Computer Vision and Pattern Recognition. Springer, London. https://doi.org/10.1007/978-1-4471-6524-8_3

[2] L. Boutella and A. Serir, "Block ridgelet and SVM based fingerprint matching," *3rd European Workshop on Visual Information Processing*, Paris, 2011, pp. 247-251, doi: 10.1109/EuVIP.2011.6045518.

[3] L. Q. Zhu, ―"Finger knuckle print recognition based on SURF algorithm," in Proc. Eighth International Conference on Fuzzy Systems and Knowledge Discovery, IEEE, 2011.

[4] J. C. Yang, N. X. Xiong, A. V. Vasilakos and Zh. J. Fang, ―"A fingerprint recognition scheme based on assembling invariant moments for cloud computing communications," IEEE Systems Journal, vol. 5, no. 4, Dec. 2011.

[5] Yambay, D.; Ghiani, L.; Denti, P.; Marcialis, G.L.; Roli, F.; Schuckers, S. LivDet 2011 Fingerprint liveness detection competition. In Proceedings of the 5th IAPR International Conference on Biometrics (ICB), New Delhi, India, 29 March–1 April 2012; pp. 208–215.

[6] Bozhao Tan and S. Schuckers, "Liveness detection for fingerprint scanners based on statistics of wavelet signal processing," in Proc. of Computer Vision and Pattern Recognition Workshop, 2006.

[7] Z. F. Gao, X. G. You, L. Zhou, and W. Zeng, ―"A novel matching technique for fingerprint recognition by graphical structures," in Proc. the Wavelet Analysis and Pattern Recognition, Guilin, IEEE, July 10-13, 2011.

[8] Z. M. Win and M. M. Sein, ―"Fingerprint recognition system for low quality images," presented at the SICE Annual Conference, Waseda University, Tokyo, Japan, Sep. 13-18, 2011.

[9] L. Q. Zhu, ―"Finger knuckle print recognition based on SURF algorithm," in Proc. Eighth International Conference on Fuzzy Systems and Knowledge Discovery, IEEE, 2011.

[10] J. C. Yang, N. X. Xiong, A. V. Vasilakos and Zh. J. Fang, ―"A fingerprint recognition scheme based on assembling invariant moments for cloud computing communications," IEEE Systems Journal, vol. 5, no. 4, Dec. 2011.

[11] Nikam, S.B.; Agarwal, S. Texture and wavelet-based spoof fingerprint detection for fingerprint biometric systems. In Proceedings of the First International Conference on

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

Emerging Trends in Engineering and Technology (ICETET'08), Nagpur, India, 16–18 July 2008; pp. 675–680.

[12] Nikam, S.B.; Agarwal, S. Gabor filter-based fingerprint anti-spoofing. In Advanced Concepts for Intelligent Vision Systems; Springer: Berlin/Heidelberg, Germany 2008; Volume 5259, pp. 1103–1114.

[13] Nikam, S.B.; Agarwal, S. Wavelet energy signature and GLCM features-based fingerprint anti-spoofing. In Proceedings of the International Conference on Wavelet Analysis and Pattern Recognition (ICWAPR'08), Hong Kong, China, 30–31 August 2008; Volume 2, pp. 717–723.

[14] Nikam, S.; Agarwal, S. Fingerprint liveness detection using curvelet energy and co-occurrence signatures. In Proceedings of the Fifth International Conference on Computer Graphics, Imaging and Visualisation (CGIV'08), Penang, Malaysia, 26–28 August 2008; pp. 217–222.

[15] Frassetto Nogueira, R.; de Alencar Lotufo, R.; Campos Machado, R. Evaluating software-based fingerprint liveness detection using Convolutional Networks and Local Binary Patterns. In Proceedings of the IEEE Workshop on Biometric Measurements and Systems for Security and Medical Applications (BIOMS), Rome, Italy, 17 October 2014; pp. 22–29.

[16] Ghiani, L.; Marcialis, G.L.; Roli, F. Fingerprint liveness detection by local phase quantization. In Proceedings of the 21st International Conference on Pattern Recognition (ICPR), Tsukuba, Japan, 11–15 November 2012; pp. 537–540.

[17] Ghiani, L.; Hadid, A.; Marcialis, G.L.; Roli, F. Fingerprint Liveness Detection using Binarized Statistical Image Features. In Proceedings of the IEEE Sixth International Conference on Biometrics: Theory, Applications and Systems (BTAS), Arlington, VA, USA, 29 September–2 October 2013; pp. 1–6.

[18] Gragnaniello, D.; Poggi, G.; Sansone, C.; Verdoliva, L. Fingerprint liveness detection based on Weber Local image Descriptor. In Proceedings of the IEEE Workshop on Biometric Measurements and Systems for Security and Medical Applications (BIOMS), Napoli, Italy, 9 September 2013; pp. 46–50.

[19] Marcialis, G.L.; Lewicke, A.; Tan, B.; Coli, P.; Grimberg, D.; Congiu, A.; Tidu, A.; Roli, F.; Schuckers, S. First international fingerprint liveness detection competition - LivDet 2009. In Image Analysis and Processing—ICIAP 2009; Springer: Vietri sul Mare, Italy, 8–11 September 2009; pp. 12–23.

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021

[20] Galbally, J.; Alonso-Fernandez, F.; Fierrez, J.; Ortega-Garcia, J. A high performance fingerprint liveness detection method based on quality related features. Future Gener. Comput. Syst. 2012, 28, 311–321.

[21] W. Yongxu, A. Xinyu, D. Yuanfeng and Li Yongping, "A Fingerprint Recognition Algorithm Based on Principal Component Analysis," *TENCON 2006 - 2006 IEEE Region 10 Conference*, Hong Kong, 2006, pp. 1-4, doi: 10.1109/TENCON.2006.344032.

ISSN: 2582-1369 (online)
Submitted:14.12.2020
Revised: 21.01.2021
Accepted: 15.02.2021
Published: 01.03.2021