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Software Based Biometric Liveness Detection using Convolutional Neural Network

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Abstract: ***Identifying a person based on some set of unique features is an important task. The human identification is possible with several biometric systems in which fingerprint and sclera recognition are the promising ones because of their individuality, uniqueness and reliability. A fingerprint image consists of a pattern of the valleys & ridges on human fingertips. The sclera is the white portion in the eye. The vein pattern seen in sclera and minutiae points in fingerprints is unique to each person. However the biometrics can be easily spoofed using several means. Pre-trained networks such as convolutional neural networks (CNN) can be explored for spoof biometric detection purpose. CNNs can achieve state-of-the-art performance even by training with natural images (such as animals, car, people etc.). A software based approach is adopted in the work in which fake traits can be identified once the images are loaded and processed using software. Dataset Augmentation, process of increasing dataset, can be used to increase the classifiers (Support Vector Machine) performance. Single classifier is trained using all available dataset for improved accuracy and robustness.***

Keywords: Minutiae points, sclera vein, convolutional neural networks**.**

1. Introduction

A biometric system is a technological system that uses information about a person to identify that person. In biometric systems, iris/sclera vein and fingerprint technologies are widely accepted as they have reliability and possess uniqueness. However biometric are relatively vulnerable to some sophisticated forms of spoofing. A fingerprint verification system can be deceived by submitting artificial reproductions of fingerprints. Differentiating human beings based on eye parts is another most challenging biometric work. The vein patterns in sclera are unique to each person in and hence it is made as a biometric tool for human identification [5]. The patterns do not change with age, alcohol consumption, allergies, or redness.

A suggested solution to spoofing attack is known as liveness detection. Biometric liveness detection algorithms can be broadly divided into two approaches: Hardware and Software. Whilst the hardware based solution are the most expensive, the software-based ones attempt to measure liveness from characteristics of images themselves by simply integrating image processing algorithms. The features used to distinguish between real and fake ones are extracted from the image of the fingerprint/sclera. Some works use general feature extractors such as Weber Local Descriptor (WLD) [6], which is a texture descriptor composed of differential excitation and orientation components. Rodrigo Frassetto Nogueira et al. [2] implemented and evaluated two different feature extraction techniques for software-based fingerprint liveness detection: Convolutional Networks with random weights and Local Binary Patterns. Rodrigo Frassetto Nogueira et al. [1] studied the use of Convolutional Neural Networks (CNN) for software-based fingerprint liveness detection. They compared four different models: two CNNs pre-trained on natural images and fine-tuned with the fingerprint images, CCN with random weights, and a classical Local Binary Pattern approach. A hierarchical matching system was proposed in the paper that utilizes features at all the three levels extracted from 1,000 ppi fingerprint scans. Level 3 features, including pores and ridge contours, are extracted using Gabor filters and wavelet transform and Iterative Closest Point (ICP) algorithm [3] is used to locally match.

Due to its distinctiveness, compactness, and compatibility with features used by human fingerprint experts, minutiae-based representation [3] has become the most widely adopted fingerprint representation scheme. In recent years, everyone have become increasingly good at training deep neural networks to learn a very accurate mapping from inputs to outputs, whether they are images, sentences, label predictions, etc. from large amounts of labeled data. In this work, Convolutional Neural Networks (CNN) are used for both fingerprint and sclera vein liveness detection. A variety of optional preprocessing techniques such as contrast normalization, frequency filtering, and region of interest (ROI) extraction can be tested and the most promising ones can be selected. Augmented datasets are successfully used to increase the classifiers robustness against small variations. Pre-trained CNNs can yield state-of-the-art results on benchmark datasets.

2. Proposed System

Transfer learning is considered as the transfer of knowledge from one learned task to a new task in machine learning. State-of-the-art liveness detection is possible by using models that were actually designed and trained to detect and distinguish objects in natural images (such as animals, car, people etc.). In this work, fingerprint and eye images are used, which has significant difference from those of other domains.

2.1 Convolutional Neural Networks

Convolutional Neural Networks (ConvNets or CNNs) are a category of Neural Networks that have proven very effective in areas such as image recognition and classification. A Convolutional Neural Network (CNN) is comprised of one or more convolutional layers (often with a subsampling step) and then followed by one or more fully connected layers as in a standard multilayer neural network.

- **Convolutional:** Convolutional layer extracts patterns found within local regions of the inputted images that are common throughout the dataset. This is done by convolving a template or filter over the inputted image pixels. Output of this forms the feature map c, for each filter in the layer. A linear rectification f(c) = max (0; c), a non-linear function is applied element-wise to each feature map c: a = f(c). The resulting activations f(c) are then passed to the pooling layer thus aggregating the information within a set of small local regions, R. Result is a pooled feature map s (normally of smaller size).
- **Max pooling:** The pooling layer takes small rectangular blocks from the convolutional layer and subsamples it to produce a single output from that block. Here in the work pooling layers will always take the maximum of the block they are pooling.

2.2 Feature extraction for fingerprint

Features extracted for fingerprint is minutiae points. Minutiae (Figure 1) refer to specific points in a fingerprint. These are the small details in a fingerprint that are most important for fingerprint recognition.

There are three major types of minutiae features: the ridge ending, the bifurcation, and the dot (also called short ridge). The ridge ending is, as indicated by the name, the spot where a ridge ends. A bifurcation is the spot where a ridge splits into two ridges. Spots are those fingerprint ridges that are significantly shorter than other ridges.

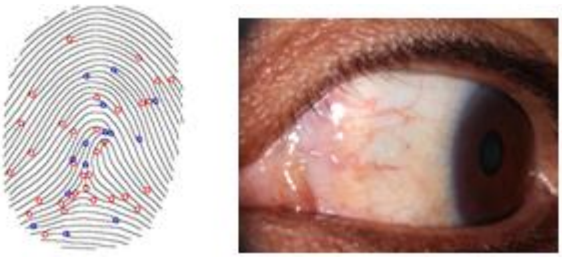

Figure 1: Minutiae points and sclera vein pattern

2.3 Feature extraction for sclera

The veins in the sclera-the white part of the eyes-can be imaged when a person glances to either side, providing four regions of patterns: one on each side of each eye (Figure 1). Eye veins are clear enough that they can be reliably imaged. The proposed sclera recognition consists of five steps which include sclera segmentation, sclera vein pattern enhancement, feature extraction, feature matching and matching decision.

2.4 Performance Metrics

Evaluation of the classification error was done by the Average Classification Error (ACE), which is the standard metric for evaluation in Liveness Detection competitions. It is defined as:

$$ACE = (SFPR + SFNR) / 2 \quad (1)$$

Where SFPR (Spoof False Positive Rate) is the percentage of misclassified live fingerprints and SFNR (Spoof False Negative Rate) is the percentage of misclassified fake fingerprints.

2.5 Dataset Augmentation

Dataset Augmentation is a technique which artificially creates slightly modified samples from the original ones. When used during training, the classifier will become more robust against small variations present in the data, thus forcing it to learn larger (and possible more important) structures.

3. Results & Discussion

Software used for complete work is MATLAB. MATLAB helps to interpret the data more easily for quicker decision making and is user friendly also. First required databases were created for both fingerprint and sclera images. These databases comprised of both real and fake images for training. Initially CNN was trained with lesser number of databases (200 images for each) in order to save considerable amount of time. By means of high speed online rental computers, however this problem can be combated. Optional pre-processing's were done for fingerprint images (filtering using Gaussian filters, enhancement) while several pre-processing's were used for sclera images (segmentation, decibel conversion, enhancement etc.).

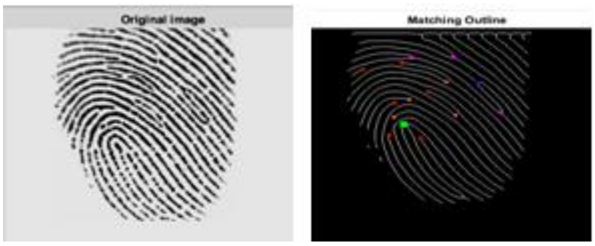

Figure 2: Input fingerprint and its minutiae feature

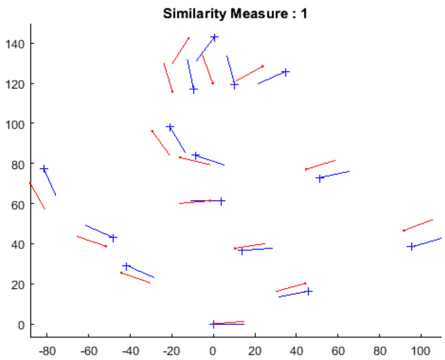

Figure 3: Similarity plot between inputted image and database original image

When the similarity plot lines (red lines for original dataset image minutiae point positions and blue lines for inputted image minutiae point positions) are either parallel or overlapped (Figure 3), then inputted image is interpreted as a genuine one otherwise fake. Minutiae points have the very advantage that their position changes for spoof ones. Result will be displayed on the window screen as either 'Genuine image' or 'Fake image'.

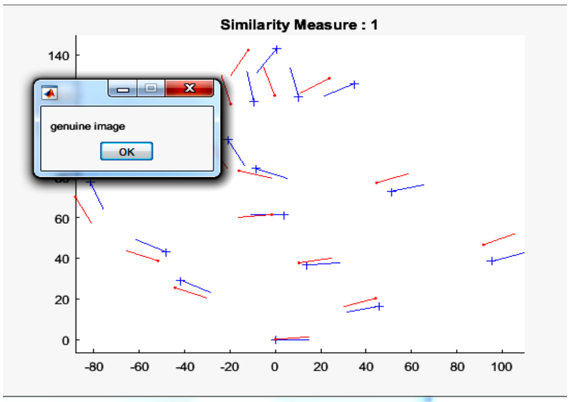

Figure 4: Final output for fingerprint liveness detection

Images of sclera veins will pass through several pre processing's and the result will be a 'Matched' or 'Not matched' display.

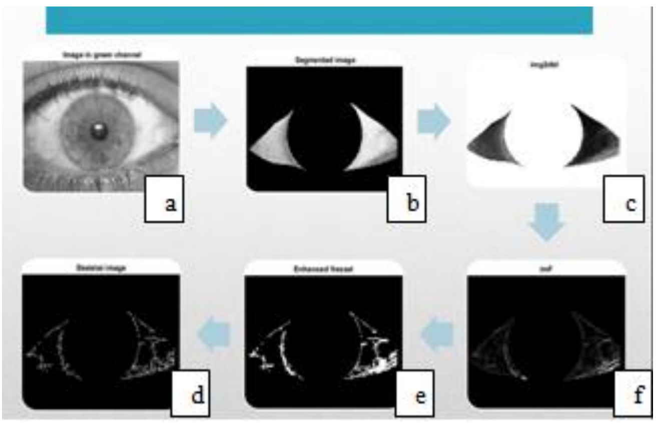

Figure 5: Inputted image in grey scale (a), segmented image (b), decibel conversion (c), filtering (d), enhancement (e), skeletal image (f) (veins are extracted)

Based on the skeletal image of veins classifier (SVM) classifies the image as either real or fake. The increase in factors like vulnerability to security and transaction process, then the need for secure identification and individual verification also increases. Biometric-based systems provide secure financial transactions and data confidentiality. Biometrics can be implemented in local, governmental, military and commercial applications also. Network security, ID proof, E-banking, Money transactions, retail sales and social services are already in benefit due to biometric technology.

4. Conclusion

Biometric authentication systems are vulnerable to several sophisticated spoofing attacks. Reliable spoofing detection tools are necessary for a good level of security, preferably implemented in software modules. Fingerprints and sclera veins provide promising results in good security level and hence that biometric spoof detection is carried out in the work using CNN. Even though training with small data sets CNN's provide state-of-the-art performance. Dataset augmentation implemented helps in improved accuracy. Using high speed online computers the task can be executed even faster with large data sets.

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