Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 46 (2015) 1593 – 1600

Procedia Computer Science

International Conference on Information and Communication Technologies (ICICT 2014)

Online and Offline Signature Verification: A Combined Approach

K S Radhika[a], Gopika S[b]

[a]*Dept. of Computer Science and Engineering, Rajagiri School of Engineering and Technology, Kerala, India*
[b]*Dept. of Computer Science and Engineering, Rajagiri School of Engineering and Technology, Kerala, India*

Abstract

Handwritten signature verification is an emerging area. In this paper, an automatic signature verification system has been proposed. This work focuses on both online and offline features of handwritten signatures and aims at combining their results to verify the signature. Signatures are collected for both online and offline. Online data collected is the signing process captured using a webcam and offline data collected are the scanned signatures. Initially both data undergoes appropriate preprocessing steps. Then feature extraction is done where features based on pen tip tracking are used in case of online and gradient and projection based features are used in case of offline method. Later the online and offline method verifies the signature separately and finally their results are combined and the signature is verified using SVM. Paper also compares the results of online, offline and combined approach.

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)
Keywords: Dynamic time warping; Gradient feature; Pen tip tracking; Projection feature; Signature Verification; Support Vector Machine;

1. Introduction

Even with lot of advancements in technologies, handwritten signatures remain the most widely accepted means of authentication when it comes to legal documents, cheques etc. The manual verification based on signatures get tougher and time consuming when there is a large number of documents. This overload can be reduced by automating the signature verification process. Thus the task of an automatic handwritten signature verification system will be to confirm the identity of a person based on his/her signature.

Handwritten signature verification is a challenging task as the possibility and easiness of forging ones signature is very high. Forgeries can be of different types based on the details accessible or available to the forgerer. These are described in[1]. Based on how the data is collected the signature verification system can be classified as two: online and offline. In online systems we use pressure sensitive tablets, cameras etc. and for offline systems we use scanned or photographed images of signatures.

* Corresponding author. Tel.: +91-989-539-7566.
E-mail address: radhikaks91@gmail.com

Peer-review under responsibility of organizing committee of the International Conference on Information and Communication Technologies (ICICT 2014)
doi:10.1016/j.procs.2015.02.089

Several researches are available for both online and offline signature verification system. In [1] several offline signature verification methods have been covered. In [2,3,4] are researches on online signature verification system. In [2,4], data is collected using a tablet and stylus and in [3] a webcam is used for the same. In [5], author has proposed an offline signature verification system using gradient feature and later improved it by adding projection feature to it in [6]. Several researches are being done by combining different features together. In [7,8] authors have presented survey on various offline approaches and have also classified and evaluated them based on different classifiers.

A combination approach is being proposed in this paper. Here online and offline feature based verifications are being combined. The online approach follows the idea presented in [3] and the offline approach follows the idea presented in [6]. The sections of the paper are as follows: Section 2 describes the proposed approach in detail where each phase is described in separate subsections, Section 3 gives the experiment settings and performance evaluation and finally Section 4 concludes the paper.

2. Proposed approach

The proposed approach is an automatic signature verification system that aims at combining the results of two different systems. One among them verifies the signature based on its offline features and the other one verifies the signature based on its online features. Fig. 1 is the block diagram of the proposed approach.

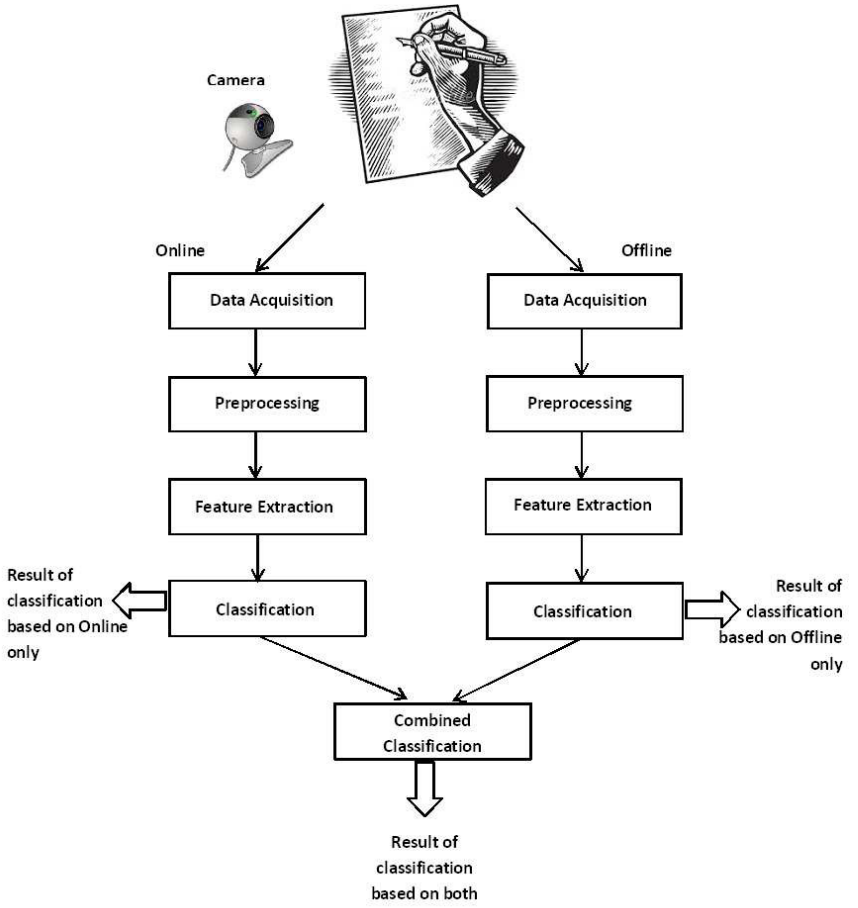

Fig. 1. Block diagram of proposed approach.

This approach can be viewed as three phases. First phase is the online signature verification, second phase is the offline signature verification and the third phase is the combined verification of the signature. Online signature verification works on the videos of signing process and offline signature verification works on the scanned signatures. Both these phases follow same steps, i.e. data acquisition, preprocessing, feature extraction and classification. First step is data acquisition where signing videos and corresponding scanned signatures are collected. Next they are preprocessed so that noises present in the data are removed and they are converted to the form suitable for feature extraction. The preprocessing methods applied are different for online and offline. In the next step unique and relevant features are extracted. For feature extraction online approach makes use of the pen tracks and for offline approach the gradient and projection features are used. Next is the classification phase where the feature vectors are analyzed and classified as genuine or forged. During classification online approach uses dynamic time warping and offline approach uses Euclidean distance. The third phase is the combination of online and offline approach where classification is done using Support Vector Machines (SVM). In the following subsections all the three phases are described in detail.

2.1. Online signature verification

2.1.1. Data acquisition

Here, data used is in the form videos. Using a webcam the signing process is captured i.e. the motion of the pen is captured. If the writer is right handed then the webcam is placed to the left side of the hand facing the palm and if the writer is left handed then the webcam is place to the right side of the hand facing the palm.

2.1.2. Preprocessing

Following are the preprocessing steps performed on the signing videos:

- Background subtraction: Our region of interest is the pen and in this step we detect the pen from each frame and all other background regions (including the hand and surroundings) are removed.
- Noise removal: Filters noises i.e. unwanted pixels from the video frames.
- Binarization: Represents the pen region in white pixels and all other regions in black pixels.
- Area opening: Small white regions left in the frames other than the pen region are removed.

Fig. 2 shows the various preprocessing steps involved.

Fig. 2. Example of online preprocessing.

2.1.3. Feature extraction

Pen tip tracking is done so that we get the position of pen tip in each frame. Here, we have considered the lowest white pixel in the frame as pen tip. As feature we find the velocity of the pen as:

$$V_t = sqrt\left[(x_{t+1} - x_t)^2 + (y_{t+1} - y_t)^2\right] \tag{1}$$

Min max normalization is then applied to these values.

2.1.4. Training and testing

This is the classification phase where we train and test our classifier. For each writer 5 signatures are kept as reference signatures. For training the online signature verification system we used 5 genuine and 5 forged signature videos. The difference between these signatures and the 5 reference signatures are found. Based on their differences a threshold value is set for each writer. Since the feature size of each video varies, we use dynamic time warping for finding the difference.

Whenever a new signature is given for testing, its difference with the reference signatures are found and a score is computed which is equal to the mean of the differences. The signature is accepted as genuine if this score < threshold for that particular writer. Otherwise, the signature is rejected i.e. it is identified as forged.

2.2. Offline signature verification

2.2.1. Data acquisition

The signatures put corresponding to each of the videos collected in the online approach are scanned and cropped. Here data considered are the signature images.

2.2.2. Preprocessing

Following are the preprocessing steps used in offline phase:

- Binarization: The image is binarized i.e. signature is represented in black pixels and other areas are in white pixels.
- Noise Removal: Here unwanted pixels are eliminated from the images using median filter.
- Cropping: Our area of interest is the signed region; hence we crop the extra white spaces surrounding the signature.
- Thinning: Signature strokes are represented with minimum cross- sectional width by eliminating few foreground pixels.
- Normalisation: Here, the image is resized to 256 x 256 pixels so that each signature will have a standard size.

Fig. 3 shows the various preprocessing steps involved.

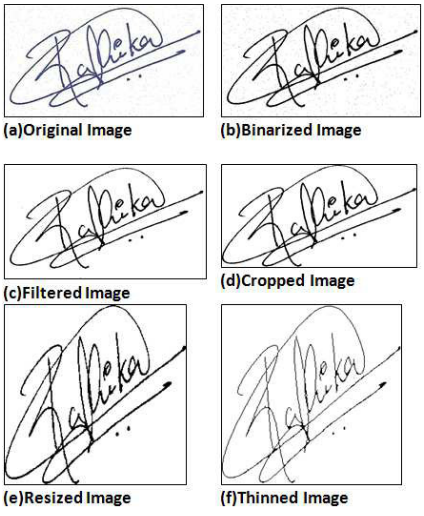

Fig. 3. Example of offline preprocessing.

2.2.3. Feature extraction

From every signature images the following feature are being extracted:

- Gradient feature: For each pixel in the preprocessed image the gradient directions and the gradient magnitudes are computed as follows:

$$g_v(i,j) = f(i-1,j+1) + 2f(i,j+1) + f(i+1,j+1) - f(i-1,j-1) - 2f(i,j-1) - f(i+1,j-1) \quad (2)$$

$$g_h(i,j) = f(i-1,j-1) + 2f(i-1,j) + f(i-1,j+1) - f(i+1,j-1) - 2f(i+1,j) - f(i+1,j+1) \quad (3)$$

$$\theta = arctan[g_v(i,j)/g_h(i,j)] \quad (4)$$

$$Gmag = \sqrt{g_h(i,j)^2 + g_v(i,j)^2} \quad (5)$$

Each of the gradient direction is mapped to a 12 direction code as shown in Fig. 4(a). The mean of the magnitudes corresponding to each direction code is found. The image is divided into 4x4 blocks as shown in Fig. 4(b) and the count of each direction count is taken for each block. These values i.e. mean and counts form the gradient feature.

- Projection feature: The means of vertical and horizontal projection profiles are computed. And along with this two ratios namely, aspect ratio and diagonal ratio are computed as follows:

$$A = L/W \quad (6)$$

$$R = L/D \quad (7)$$

These four values form the projection feature.

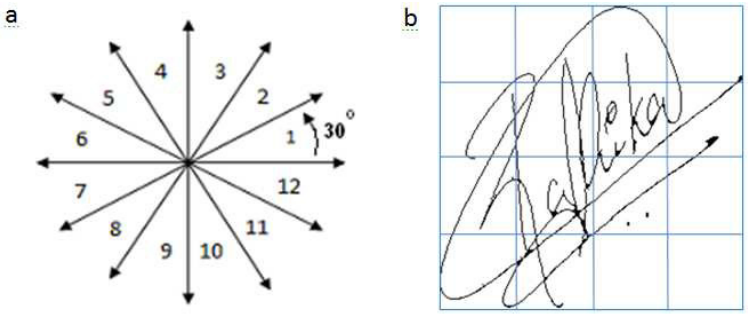

Fig. 4. (a) 12 direction code; (b) 4x4 block partition.

2.2.4. Training and testing

Training and testing is same as in case of the online phase. Here, the signature images corresponding to the 5 reference videos are used as reference signatures. 5 genuine and 5 forgeries are used for training. A threshold is computed for each writer during training and during testing decision is made based on the score computed for the test signature and the threshold of that particular writer. In the offline phase distance calculation is done base on the Euclidean distance formula.

2.3. Combined approach

Here, we make use of the test results from online and offline signature verification. That is, the score value being computed in phase 1 and phase 2 are combined to form the feature vector for phase 3. Here for classification we use

SVM. Since SVM is a binary classifier, we need n SVMs where n is the total number of writers. The features used for training the SVM is formed as follows: for each of the genuine and forged signature used for training in online and offline phase, their differences with the reference set is concatenated. That is, for a signature the online phase will result in 5 difference values and offline phase results in another 5 values. These are concatenated to form the feature vector to be given to the SVM. Thus the SVM is trained for 5 genuine and 5 forged signatures.

3. Experiment settings and result analysis

The dataset used is collected from 13 different writers. For each person 30 genuine and 25 forged signatures are collected. Forgeries considered here are skilled forgeries collected from different writers. The signatures are collected from writers of different age group. For each signature we have a signature image as well as the signing video as data. In the proposed approach 5 genuine signatures (image and video) are kept as reference set. Another 5 genuine and 5 forged signatures are used for training and for testing rest of the 20 genuine and 20 forged signatures are used. Here, a signature will correspond to its image and its signing video. Table 1 shows the dataset partitioning for training and testing for each writer.

Table 1. Dataset partitioning.

	Reference	Training Set	Testing Set	Total
Genuine Signatures	5	5	20	30
Forged Signatures	-	5	20	25
Total	5	10	40	55

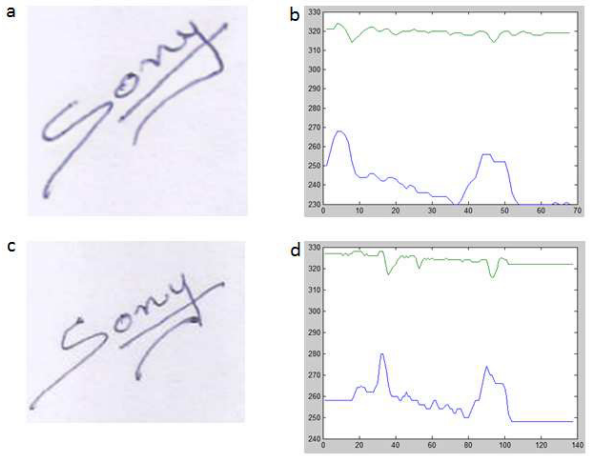

Fig. 5. Dataset samples; (a) genuine offline;(b)genuine online;(c)forgery offline;(d)forgery online.

Fig. 5 show a sample signature set. (a) is a genuine signature image and (b) is its pet tip plot i.e. x and y values are plotted against the frame number. (c) is the forged signature of (a) and (d) is its corresponding x and y value plot.Here we have compared the performance of combined approach with the online and offline approaches being combined. Table 2 summarizes the average performance of these approaches based on accuracy, FAR, FRR and AER. FAR is the false acceptance rate computed based on the number of forged signatures being accepted as genuine and FRR is the false rejection rate computed based on the number of genuine signatures being rejected. AER is the average error rate equal to the average of FAR and FRR. Fig. 6(a), Fig. 6(b) and Fig. 7(a) summarizes the results of each approach for each writer. Fig. 7(b) shows the result of online approach alone for different features namely x, y, x+y and v where (x,y) is the pen tip position and v is the velocity of the pen. The approaches discussed are conducted using MATLAB tool.

Table 2. Average performance.

Approach	Accuracy	FAR	FRR	AER
Online	63.46	45.38	27.69	36.53
Offline	74.04	19.23	32.69	25.96
Combined	76.92	11.54	34.62	23.08

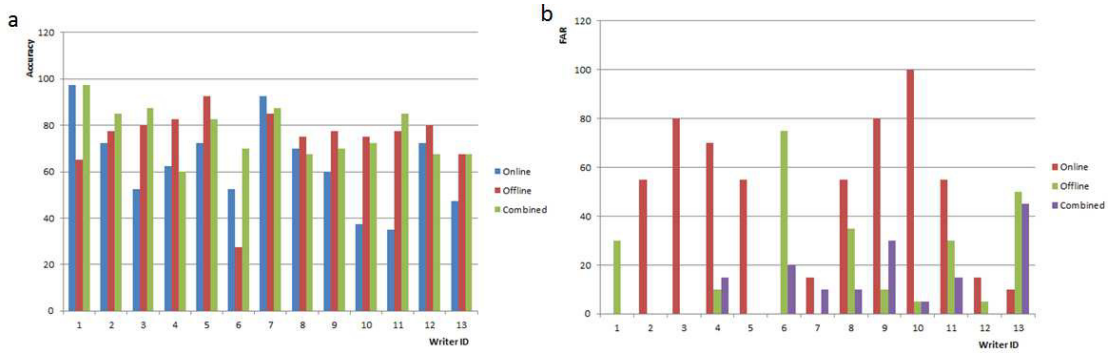

Fig. 6. . (a) Accuracy vs writer; (b) FAR vs writer.

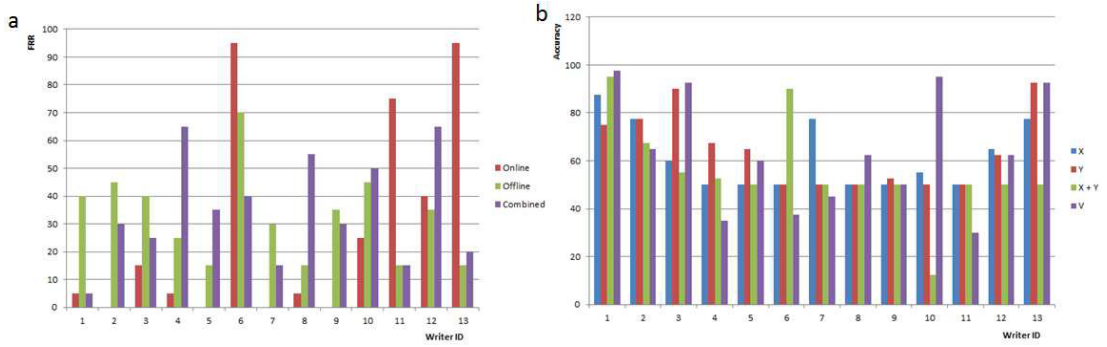

Fig. 7. (a) FRR vs writer; (b) Accuracy vs writer for various online features.

4. Conclusion

An approach that combines online and offline signature verification methods has been proposed. The online approach deals with the videos of signing process and the pen track is used for forming the feature vector. Whereas offline signature verification deals with the scanned images of the signatures and uses the gradient and projection features for forming the feature vector. Both online and offline approach verifies a signature based on comparison with a previously set threshold value. Finally the results of testing done in these approaches are combined and used by SVM for final verification. The performance of online, offline and combined approaches have been evaluated and the proposed approach works fairly well.

References

1. K S Radhika and Gopika S, *Offline Signature Verification - A Broad Visualization*, In proc. National Conference on Recent Trends in Knowledge Management(NCRTKM), pp. 70-74, February 2014.
2. Yumiko Kawazoe, Wataru Ohyama, Tetsushi Wakabayashi and Fumitaka Kimura, *Improvement of On-line Signature Verification based on Gradient Features*, 12th International Conference on Frontiers in Handwriting Recognition, 2010.

3. Daigo Muramatsu, Yasushi Yagi, *Silhouette based Online Signature Verification using Pen Tip Trajectory and Pen Holding Style*, International Conference on Biometrics Compendium, IEEE, June 2013.
4. Takashi Ito, Wataru Ohyama, Tetsushi Wakabayashi and Fumitaka Kimura, *Combination of signature verification techniques by SVM*, International Conference on Frontiers in Handwriting Recognition, 2012.
5. K S Radhika, Gopika S, *A Novel Method for Offline Signature Verification*, In proc. National Conference on Computer Competence, pp. 44-47, April 2014.
6. K S Radhika, Gopika S, *Gradient and Projection based features for Offline Signature Verification*, International Conference on Information Science, July 2014.
7. Madhuri Yadav, Alok Kumar, Tushar Patnaik, Bhupendra Kumar, *A Survey on Offline Signature Verification*, International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 7, January 2013.
8. Meenakshi S Arya, Vandana S Inamdar, *A Preliminary Study on Various Off-line Hand Written Signature Verification Approaches*, International Journal of Computer Applications (0975 8887),Volume 1 No. 9, 2010.