An Effective Card Scanning Framework for User Authentication System

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***Abstract*—Exponential growth of fake ID cards generation leads to increased tendency of forgery with severe security and privacy threats. University ID cards are used to authenticate actual employees and students of the university. Manual examination of ID cards is a laborious activity, therefore, in this paper, we propose an effective automated method for employee/student authentication based on analyzing the cards. Additionally, our method also identifies the department of concerned employee/student. For this purpose, we employ different image enhancement and morphological operators to improve the appearance of input image better suitable for recognition. More specifically, we employ median filtering to remove noise from the given input image. Next, we apply the histogram equalization to enhance the contrast of the image. We employ Canny edge detector to detect the edges from this equalized image. The resultant edge image contains the broken characters. To fill these gaps, we apply the dilation operator that increases the thickness of the characters. Dilation fills the broken characters, however, also add extra thickness that is then removed through applying the morphological thinning. Finally, dilation and thinning are applied in combination to Optical character recognition (OCR) to segment and recognize the characters including the name, ID, and department of the employee/student. Finally, after the OCR application on the morphed image, we obtain the name, ID, and department of the employee/student. If the concerned credentials of the employee/student are matched with his/her department, then access of the door is granted to that employee/student. Experimental results illustrate the effectiveness of the proposed method.**

Keywords—Dilation, Image Enhancement, Morphological Thinning, Optical Character Recognition, User Authentication.

I. Introduction

The advancement in modern day sophisticated image forgery algorithms led to increased tendency of image manipulation that poses several security and privacy issues. Organizations security concerns regarding confidentiality of their employee's working environment led to the usage of various automated solutions to testify the entrance of authorized employees in relevant departments/buildings. Organizations frequently use various devices such as surveillance cameras [1], lock systems [1], RFIDs [2], [3], iris recognition systems [3], [4], fingerprint recognition systems [5], etc. for employees' authentication. However, the current state-of-the-art image processing and artificial intelligence algorithms can be used to exploit the authentication systems. To address this issue, there exists a dire need to propose more effective and secure authentication systems that are robust to these forged/manipulated input data (i.e. images, videos, etc.).

There is a common practice of using different biometric solutions [8] – [12] i.e. thumb print identification, facial recognition, iris recognition, etc. for user authentication. These solutions are effectively used by organizations to authenticate the identity of their employees. However, user identification in real-time using these biometric solutions is a challenging task due to variation in human pose [6], facial expressions [7], hair styles [8], illumination conditions [9], user distance from the camera [10], etc. These conditions affect the identification process and leads to the generation of false alarms.

There is a common practice of identifying users through employee card verification. Employee card verification is largely used in various organizations in Pakistan for user identity verification [11]. Currently, organizations either used RFID card scanners [13] or manual card verification for user authentication. Manual card verification is a taxing and time-consuming activity and become less effective in case of large number of users entering in a building in short time span. Many educational institutions prefer the use of simple identification cards without RFID that the employee or student has to wear as a part of their dress code in order to reduce the cost of user identification. However, this manual verification process is unreliable and leads to security loop holes due to reliance on guards for manual verification where image tampering can be used to generate false cards that are hard to detect from naked eye.

To address these challenges, we propose an automated low-cost solution to authenticate the identity of the employees/ students. More specifically, we analyze the captured frames of the card via cameras and employ OCR to detect the department of the concerned person. We propose a non-learning-based technique to reduce the computational complexity of our solution. We employ different enhancement and morphological operators to obtain the image better suited for OCR processing. This image is finally fed to the OCR algorithm that recognize the employee's identity and department for authentication purposes. The main Contributions of the proposed work are as follows:

- We propose an effective user identification system through applying different morphological and image enhancement techniques.
- We present an economical and efficient user authentication system where a low-cost camera is required to capture the video.
- Our system is robust to variations in illumination conditions, glare, noise, contrast, and shadows.

II. Literature Review

This section provides a critical analysis of existing state-of-the-art user authentication systems. Existing techniques have proposed either biometric systems [14] – [20] or RFID based systems [22] – [25] for user authentication.

Multiple biometric identification techniques make use of the waves emerging out of the human body for human biometric identification and authorization. For example, [14] – [16] makes use of EEG signals coming out of brain for this purpose which are then classified using neural network algorithm for user classification. I. Assadi, A. Charef, N. Belgacem, A. Nait-Ali, and T. Bensouici [14] used the ECG signals which are classified using K-Nearest Neighbors Classifier. Behavioral biometrics-based methods have also been proposed by researchers [18] – [20] in order to identify and authenticate the users. Y. Chemla and C. Richard [22] used smart card along with biometric profile recognition method for personal identification. The method in [21] includes the use of client-server-based architecture that helps in identifying and matching the smart card holder with his biometric data, making the system fool proof.

Existing systems have used both deep learning and conventional machine learning algorithms [26] – [29] for user identification and classification. Deep learning approaches are employed due to potential benefits of achieving better accuracy [30], [31]. Additionally, existing literature also achieved better accuracies using non-learning-based techniques. For example, A. Nosseir and O. Adel [32] used SUFE extraction algorithm along with template matching technique to identify a person from his ID card in multiple environmental conditions.

OCR based algorithms are also now-a-days commonly used by many firms and researchers for user identification. For example, C. Wick, C. Reul, and F. Puppe [33] proposed an OCR based algorithm using LSTM based network. On the other hand, R. Baran, P. Partila, and R. Wilk [34] proposed a non-learning-based OCR method. This method used connected component labelling algorithm to reduce the distortions in the input image and later fed to OCR for authentication.

III. Proposed Method

This section provides a comprehensive discussion on the proposed method. Shown in Fig. 1 is the process flow of the proposed method.

A. Image Pre-processing

We used the 16MP resolution camera to capture the input color frame. The pre-processing stage transforms the acquired color image into grayscale image as follows:

$$I_{GS}^{(i)}(x,y) = I_R^{(i)}(x,y) \times 0.298 + I_G^{(i)}(x,y) \times 0.587 + I_B^{(i)}(x,y) \times 0.114 \quad (1)$$

where $I_{GS}^{(i)}(x,y)$ represents the grayscale image, $I_R^{(i)}(x,y)$, $I_G^{(i)}(x,y)$ and $I_B^{(i)}(x,y)$ represent the red, green, and blue components of the input color image respectively.

B. Noise Removal

We observed after watching massive number of images in our dataset that card images contain spiky black dots/patches due to placing cards in transparent covers. These patches generate impulse noise in the captured images. Median filtering is most effective method to reduce the density of impulse noise in the images as it also preserves the edges of the image. Therefore, in this paper, we employed the median filtering to reduce the impulse noise from the image as follows:

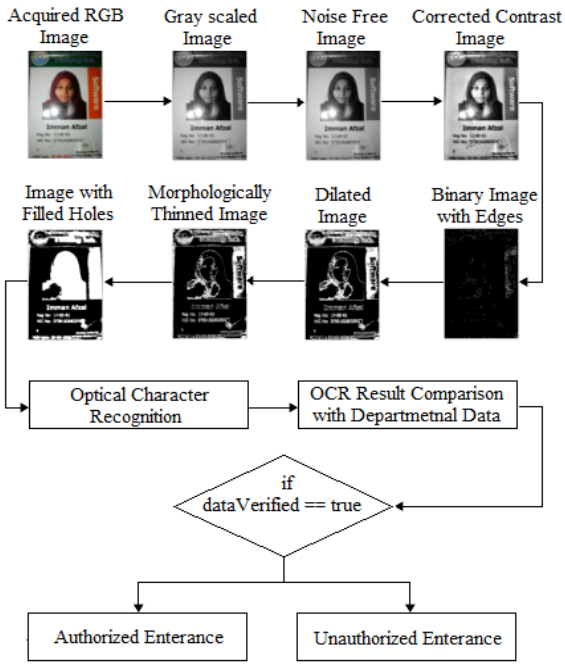

Fig. 1. Block Diagram of Proposed System

$$I_M^{(i)}(x,y) = \text{median}\left\{I_{GS}^{(i)}(x,y),(x,y) \in w\right\} \quad (2)$$

where $I_M^{(i)}(x,y)$ is the resultant median image obtained after applying median filtering and w is the size of window that is set to 3x3 in our case.

C. Histogram Equalization

We observed that the images captured at low illumination conditions also experience poor contrast. Therefore, after noise reduction, we employed the histogram equalization method to improve the contrast of the image. The histogram equalization process enhances the image contrast by adjusting the image intensity distribution.

More specifically, we applied the global histogram equalization method for contrast enhancement as follows:

$$I_k^{(i)} = C \times \sum_{j=0}^{k} (n_j / N), \quad \text{for } 0 \le k \le L\text{-}1 \quad (3)$$

where $I_k^{(i)}$, n_j, *N*, *C* and *L* represent the new intensity value, frequency of intensity *j*, sum of all frequencies up to intensity *k*, constant value, and highest frequency respectively.

D. Edge Detection

After contrast enhancement, we transform this image into edge image to extract the text from the image. For this purpose, we employ the canny edge detector as canny operator extracts maximum edges as compared to other edge detection techniques. Additionally, canny edge detector retains important information by keeping all important major and minor edges while discarding rest of the unnecessary details in the image. We obtain the edge image as follows:

$$I_{edge}^{(i)}(x,y) = \text{canny}\left\{I_{HE}^{(i)}(x,y),(x,y) \in w\right\} \quad (4)$$

E. Dilation

The edge image obtained in the last step contains broken characters or gaps that must be filled before feeding image to OCR. Therefore, we applied the dilation operator on the edge image as follows:

$$I_{dil}^{(i)}(x,y) = I_{edge}^{(i)}(x,y) \oplus SE \quad (5)$$

where $I_{dil}^{(i)}(x,y)$ represents the dilated image and *SE* represents the structuring element which is set to a window of size 3 for both horizontal and vertical dilation.

Dilation operation successfully fills the broken characters; however, thickness of the characters is increased significantly. Therefore, we need to reduce the extra thickness of characters added after dilation.

F. Density Reduction

The density reduction stage removes the extra thickness of the edges by applying the morphological thinning operation. Thinning operator is used to truncate the outliers. After applying the thinning operator on the dilated image, we obtain the characters with actual thickness. Morphological thinning is applied as follows:

$$I_{thin}^{(i)}(x,y) = I_{dil}^{(i)}(x,y) \otimes SE \quad (6)$$

where $I_{thin}^{(i)}(x,y)$ represents the thinned image. We used *SE* of square shape which had the size equal to a 3x3 window.

G. Hole Filling

After density reduction, we observed that the body of characters contains small holes that need to be filled. We achieved hole filling step as follows:

$$I_{filled}^{(i)} = \left(I_{filled}^{(i-1)} \oplus SE\right) \cap {I_{thin}^{(i)}}^{c} \quad (7)$$

where $I_{filled}^{(i)}$ and ${I_{thin}^{(i)}}^{c}$ are the filled image and complement of thinned image respectively.

H. Optical Character Recognition

To recognize the contents of the card, we apply the tesseract OCR method [35] on this filled image obtained after applying the morphological operators. We obtain the recognized characters and use spacing detection mechanism to extract different words. Later, we convert the recognized characters/words into computerized characters. We fed the entire frame to the OCR method without manual image cropping to specify any region of interest (ROI). The results obtained from OCR are then compared with the departmental data. If the department of the employee matches with the record in the database, then that employee is authorized to enter from the door.

IV. Performance Evaluation

A. Dataset

For the performance evaluation of the proposed system, we created a dataset of 1000 university card images that belong to different departments. We ensured to create a diverse dataset. Our dataset is captured in different environmental and lighting conditions, containing glare, shadow, and low contrast images. The resolution of each image in the dataset is 3120 x 4160 pixels.

B. Experimental Results

Performance of the proposed system is evaluated in images taken at a real-time. The effectiveness of the proposed system is evaluated by the detection of correct credentials of the employee/student. Shown in Table I are the results of the proposed system for user identification. From the results (Table I), we can observe that our system achieves an average accuracy of 96.4%. We captured the frames for testing in real-time environmental conditions with poor contrast, low illumination, shadow over image, background distortion and glare. Despite the presence of multiple distortions in the captured images, our system provides remarkable performance. It is worth mentioning that the system gives greater than 95% accurate results for six environmental conditions out of total 7 conditions under consideration. Tilt in the scanned image affects the system accuracy due to the fact that the proposed system is designed to scan images from an anterior view with the angle of inclination of camera parallel to the plane of identification card.

In our second experiment, we perform a confusion matrix analysis for user authentication based on different departments. The results of confusion matrix analysis are provided in Table II. From the results presented in Table II, we can observe that the proposed system achieves 100% true positives for seven departments out of total 11 classes. In the remaining four categories, the highest error is just 0.2 that signify the effectiveness of our system in terms of user authentication based on automated card verification. Hence, we can argue that the proposed system is effective in terms of classifying the employee/student as an authorized or unauthorized personnel. The results also show that the system

TABLE I. EMPLOYEE/ STUDENT UNIVERSITY CARD IDENTIFICATION RESULTS

Image Type	True Positive	True Negative	False Positive	False Negative	Precision Rate	Recall Rate	Accuracy Rate	Error Rate	F1 Score
Poor Contrast	49	5	0	1	100%	98%	98.18%	1.82%	0.9899
Low Illumination	30	3	0	0	100%	100%	100%	0%	1
Shadow	33	5	0	2	100%	94.29%	95%	5%	0.9706
Background Distortion	50	5	0	0	100%	100%	100%	0%	1
Glare	49	3	0	1	100%	98%	98.11%	1.89%	0.9899
Slight Tilt	8	2	1	1	88.89%	88.89%	83.33%	16.67%	0.8889
Normal Image	45	10	0	0	100%	100%	100%	0%	1
Average					98.41%	97.02%	96.37%	3.63%	0.9770

TABLE II. CONFUSION MATRIX ANALYSIS FOR DEPARTMENT BASED IDENTIFICATION

Departments / Category	SE	IE	CE	EE	ME	ENC	ENV	CS	CP	TE	X
Software Engineering (SE)	1	0	0	0	0	0	0	0	0	0	0
Industrial Engineering (IE)	0	0.9	0	0	0	0	0	0	0	0	0.1
Civil Engineering (CE)	0	0	1	0	0	0	0	0	0	0	0
Electrical Engineering (EE)	0	0	0	1	0	0	0	0	0	0	0
Mechanical Engineering (ME)	0	0	0	0	1	0	0	0	0	0	0
Electronics Engineering (ENC)	0	0	0	0	0	0.8	0	0	0	0	0.2
Environmental Engineering (ENV)	0	0	0	0	0	0	0.9	0	0	0	1
Computer Science (CS)	0	0	0	0	0	0	0	1	0	0	0
Computer Engineering (CP)	0	0	0	0	0	0	0	0	0.9	0	1
Telecom Engineering (TE)	0	0	0	0	0	0	0	0	0	1	0
Unauthorized (X)	0	0	0	0	0	0	0	0	0	0	1

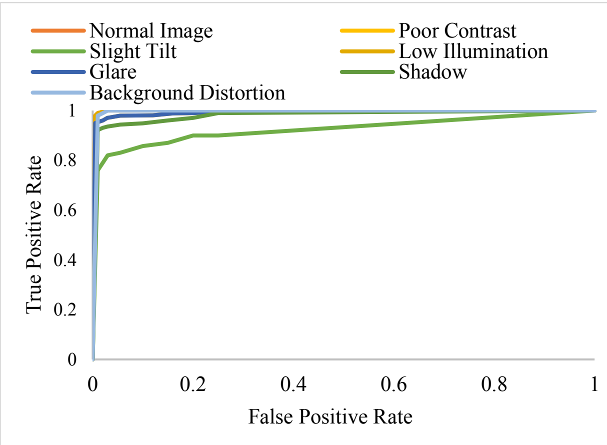

Fig. 2. ROC Curve for University Card Identification

is independent of the changes in major environmental condition.

In the last experiment, performance of the proposed system is measured using the receiver operating curve (ROC) analysis. We created ROC curves for images acquired in multiple conditions and results are plotted in Fig. 2. From the Fig. 2, it is evident that the proposed system attains remarkable classification accuracy for all conditions except the tilted acquired images.

V. CONCLUSION

In this paper, we propose an effective and efficient employee authentication method based on card verification. The proposed method is robust to variations in illumination conditions, glare, noise, contrast, and shadows. Additionally, our method is economical and require any low-cost camera for video/image capturing. Performance of the proposed method is evaluated on a diverse dataset of real time scanned images. Our method achieves an average accuracy of 96% that demonstrates the effectiveness of the proposed method for employee authentication. Under the condition of slight tilt in image acquisition process, the accuracy drops to some extent. Currently, we are examining this problem and planning to extend our method that can also achieve remarkable performance under tilt image acquisition condition.

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