Novel Optimization of Identified Palm Geometry Using Image Segmentation

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Abstract—Segmentation is one of the essential steps towards the identification of any object in the domain of image processing. In the area of hand-based biometric which is mainly deployed for a user authentication system, segmentation plays a critical role. A review of existing studies shows that there is a very less amount potential contribution in this regard. Therefore, this manuscript presents a novel optimization scheme towards palm geometry recognition system where segmentation process is the prime highlights for classification of hand and background considering a case study of finger recognition. Further, the proposed scheme uses masking operation where the Region-of-Interest section of hand is subjected to segmentation. Further proposed system uses machine learning approach (convolution neural network and Siamese Neural Network) to further assist in optimizing the segmentation performance. The experimental outcome of the study shows proposed system offers better accuracy compared to the existing system.

Keywords—segmentation, convolution neural network, Siamese neural network, Hand geometry, recognition

1 Introduction

There is increasing usage of biometric in an existing system over different ranges of devices [1]. The usage of biometric comes over various forms using e.g., voice, face thermogram, iris, fingerprint, handwriting, face geometry, retina, etc. Out of all, hand-based biometric is the most widely used in the majority of commercial as well as domestic applications [2]. The success rate of the hand-biometric depends upon the precise identification of an object while segmentation plays a critical role in this regard [3]. The prime target of the segmentation process is to perform simplification of a hand image in order to yield the resulting segmented image which can be claimed to be more logically simpler to analyze [4]. In this process of segmentation, a level is assigned to all the pixels of an image in such a way that there is a resemblance of characteristics for the pixels with similar labels [5]. At present, there is various work being carried out towards segmentation [6]-[10]; however, with respect to biometric, the challenges are yet the open end. In the process of biometric, the first problem is to deal with the en-

rollment and template preparation process. In this case, there is fair feasibility of yielding different segments of the same image by a different human observer. This will cause a significant problem at the time of authenticating the user, which is the sole goal of using hand-based biometric. Apart from this, it could also lead to bypassing the authentication of a user if an improper segmentation is used. Hence, it is necessary to deploy a better form of segmentation technique with a novel approach to offer better supportability of the futuristic hand-based verification system. The primary step to use a hand-based user verification system will be to create a biometric template itself. This step performs enrollment for recognizing hand geometry which is a combination of light-emitting diodes and prisms in the scanner by extracting the hand image in its raw form. The biometric template is constructed by considering the back, front, as well as the palm of the hand which optionally can also construct a three-dimensional image. Unfortunately, there are issues in this process itself that affects the authentication system. The captured raw images consist of various unnecessary parts (e.g., pegs), which are manually eliminated to generate input images. Due to this process, it's computationally difficult for an algorithm to find out discrete variance due to the rotation or positioning of the hand. Such images are then transformed into a binary file system. Apart from this, the inherent process of enrollment, as well as validation of the template, is also error prone. This causes the geometric feature of the hand to possess a slight amount of physiological equivalence with others which acts as an impediment towards the feature extraction process. At present, there are various techniques utilized in modernizing hand-based user authentication systems [11]. However, each process is witnessed with certain pitfalls [12]. At present, there is also the prevalence of using multi-modalities for user authentication systems in the perspective of biometrics [13]. However, they have their own boundaries of effectiveness that is specifically meant for application.

Apart from this, there are fewer studies being emphasized towards the segmentation process for hand images. Hence, the proposed study implements a unique hand image segmentation process that is meant for optimizing the palm geometry system with respect to the recognition system. This is carried out by masking the hand. The proposed system also uses a machine learning approach (convolution neural network and Siamese Neural Network) in a unique manner to accomplish this objective. The organization of this paper is as follows: Section II discusses about related studies towards the domain of study followed by the identification of the research problem in Section III. The proposed methodology is discussed in Section IV while result analysis is illustrated in Section V. Finally, Section VI offers the conclusion of the paper.

2 Related work

This section presents a brief about the contribution of existing literature towards hand geometry identification and classification emphasizing on segmentation process. The work carried out by Yang et al. [14], Pham et al. [15], and Van et al. [16] have recently presented a simplified form of implementation towards segmentation considering palm image. The idea is meant for performing identification of user hand for authentication purposes.

Zhang et al. [17] have investigated a study towards various techniques where smartphones have been used for the palmprint verification process. Another recent application-based study towards hand biometric has been carried out by Yang et al. [18] towards user identification. According to this model, a speaker, as well as commodity microphones, are used for sensing hand geometry. Interestingly, this model generates a specific form of the acoustic waveform which are particular for one user once the mobile device is held by the user. A study towards accuracy for assessing the performance of binary biometric detection is carried out by Deshpande et al. [19]. The work carried out by Staunch et al. [20] has presented an authentication technique using palm veins which is basically based on infrared wavelength. This technique also makes use of an ultraviolet wavelength followed by applying a convolution neural network meant of obtaining all essential features to be deployed for authentication purposes.

A recent work carried out by Bera et al. [21] has presented a spoofing attack detection technique based on evaluating the quality of hand images. The differentiation of the normal and counterfeited image is carried out on basis of thresholding using gradient magnitude. Oldal and Kovacs [22] have presented a contactless biometric authentication system that targets key point detection considering the geometric relation of palm images. Another interesting work is carried out by Chen et al. [23] where image intensity analysis is carried out for multiple lights over finger veins. Curve-fitting is used for analyzing the infrared images where the weighted pixel level is fused using the estimation of the quality of image blocks. Although this study is not directed towards an authentication system, its mechanism is fair enough to adopt for data augmentation as the first step in the authentication. The basic idea is to improvise accuracy using beneficial features. The work carried out by Zhang et al. [24] has used a deep convolution neural network for the purpose of recognizing the palmprint. Jaswal and Poonia [25] have emphasized optimizing the selected features by combining finger knuckle and palm print for the purpose of authentication. The study has also used a backtracking search algorithm and Latent Dirichlet Algorithm for extracting features facilitating the classification process. Wu et al. [26] have developed a unique feature extraction system considering the direction, gradient, and texture of palmprint followed by deploying an encoding mechanism. The study makes use of a block-wise histogram in order to formulate the essential features. Another unique study carried out by Gupta and Gupta [27] has presented an authentication system considering the combination of hand geometry, palm dorsal vein, and slap fingerprints. The idea of this model is to reduce the false positives by including the multi-modalities of hand-based biometrics. Another interesting implementation towards authentication is carried out by Wang et al. [28] where a generative adversarial network has been used. The study has exclusively focused on presentation attack and reconstruction attacks and this is mitigated by developing a false acceptance attack associated with palmprint biometrics. Further, a clustering approach is applied for assessment with diversified elements of counterfeited images. Adoption of finger knuckle is also seen in work carried out by Kusanagi et al. [29] where the idea is to identify the specific joint of finger knuckle using region of interest. Correspondence matching using explicit phases has been used for the region of interest for identifying any forms of abnormalities. Priesnitz et al. [30] have developed a recognition system for the two-dimensional fingerprint using a touchless system.

The work carried out by Afifi [31] has used a machine learning approach of convolution neural network where hand images were used for recognizing gender. Support vector machine has been used for classifying the extracted feature for hand images. The review carried out by Hussein et al. [32] has briefed about authentication techniques used for palmprint recognition systems in biometrics.

Therefore, there are various types of hand-geometry based authentication mechanisms in existing approaches. The next section outlines the identified research problem.

3 Research problem

This section highlights the problems explored after reviewing the existing literature:

- There is less work being carried out towards formulating a segmentation process for given hand images.
- There are various techniques based on the identification of hand-geometry on a multi-modal basis; however, the segmentation process is deemed less important.
- The existing machine learning approach is found to be highly iterative from a computational efficiency viewpoint while the accuracy factor associated with segmentation is not carried out.
- There are different types of features from hand viz. gradient, texture, directionality, etc. Similarly, different modalities will have their own features. Hence, developing an identification process on such scattered forms of features is highly challenging.
- Assessment of all the models is usually carried out on a similar form of a dataset. For segmentation to be effective, it should offer uniform performance irrespective of any dataset being used.

The above-mentioned points are research problems that have been identified in order to address in the proposed study. The next section outlines the proposed system.

4 Proposed system

The proposed study introduces a novel mechanism that is capable of performing the segmentation of hand images. The core target of this work is basically to assist in the development and optimization of a palm geometry recognition system. In order to carry out this process, the proposed system makes use of the masking principle for the hand images. Figure.1 highlights the simplified block diagram of the proposed implementation, where the input image is subjected to Convolution Neural Network (CNN), which further make use of hand-image and tensors in order to construct an input mask followed by applying Siamese Neural Network.

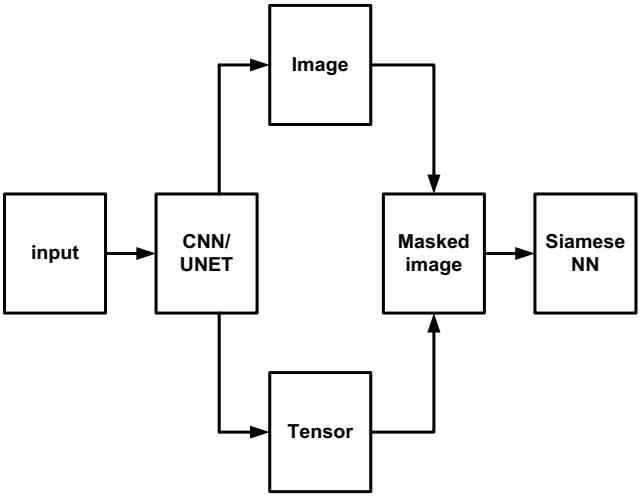

Fig. 1. Block diagram of the proposed system

According to the proposed concept, the presented image segmentation algorithm is meant for classifying each pixel of the image into either hand or background. This will add an additional layer before the standard preprocessing and help the final algorithm to perform better. Any image processing algorithm can perform better with image masking. The proposed system also hypothesize that the masking operation will significantly contribute to a better outcome since the preprocessing system presented in our prior version of model [33] is anticipated to work well only with the 11K hands dataset [32]. From the viewpoint of image processing, the concept of masking is utilized for limiting an arithmetic operator as well as point to hand area that is defined by the mask. It assists in narrowing down the investigation area furthermore. In the proposed system, the masking operation is represented as an optional input to a point operator, which further assists the operator to be applied automatically towards the pixels that are allocated by the mask region. In fact, the masking system makes it more robust and the system can be tested on several other datasets as well. The masking CNN system is being proposed to make the system to be able to work with multiple types of sensors and illuminations. Hence, this process always has benefits for solving identification problems and recognition problems associated with hand geometry. The next section discusses system implementation being carried out towards the proposed system.

5 System implementation

The implementation of the proposed system is carried out using various essential modules that built up a system viz. Input, CNN with image segmentation algorithm, tensors, main image, input mask, and Siamese neural network.

The first stage of the proposed model is to consider the input image from the dataset to be processed by the system. Some of these inputs are considered as sample images

for recognition in Siamese NN. For the purpose of an efficient assessment environment, the proposed system is required to be evaluated with the standard high-end dataset for hand images. Hence, the evaluation has been carried out considering two different standard datasets that are elaborated in next section. Apart from this, it is noted that the adopted dataset are completely of two different types on the basis of acquisition of an image. This will give a fair opportunity to assess the effectiveness of segmentation policy introduced in proposed study.

The core system design of the proposed system is showcased in Figure 2 that elaborates about the step-wise process of performing recognition.

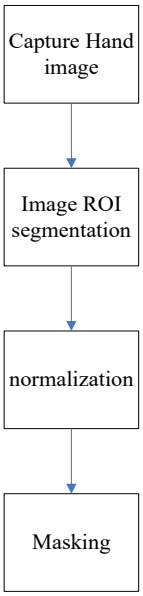

Fig. 2. Flow of proposed system

Figure 2 highlights the flow of the proposed system, where it can be seen the consequences of using the block processing on hand images. The proposed system also set up a target of using a use case of finger recognition, which is one of the most unique case studies from the recognition perspective of hand geometry. Figure 2 also highlights the mechanism used for masking hand images. The unique novelty of the proposed system design is also the usage of CNN in order to carry out the image segmentation process. The step-wise information of the complete process is as follows: i) the hand image from each dataset is considered as an input file to the proposed system, ii) in order to offer better accuracy, the proposed system also implements Region-of-Interest (ROI) for facilitating better segmentation performance by narrowing down the actual region of hand with fingers, iii) the next step is to carry out finger segmentation using CNN, iv) normalization operation follows the next step and v) finally CNN is also used for finger recognition. It should be noted that the input size and output size of this neural network is one and the same as shown in Figure 3.

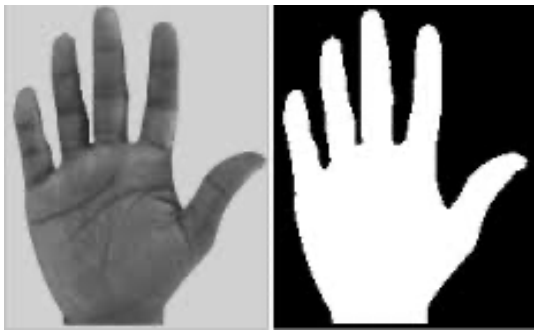

Fig. 3. Segmentation output of the hand image

The next part of the system design is to carry out tensor design considering the main image. This phase of system implementation calls for improving the performance of identification using the segmented image. The segmented image is used as a mask. In this part of the implementation, the background of the image is kept constant as it is while the contrast of the ROI is increased. At the same time, the contrast of the entire hand is increased whereas the contrast of finger segments is further increased. This operation significant contributes towards discretizing the entire hand from fingers facilitating the identification process. The mathematical expression for this is as shown below:

$$\overrightarrow{P_{i,J}} = \overrightarrow{P_{i,J}}(K_1.(1 + S1_{i,j})) \quad (1)$$

In the above equation (1), $\overrightarrow{P_{i,J}}$ will represent pixel value, while K1 represents constant 1 for ROI contrast, K2 will represent constant 2 for fingers contrast, S1i,j will represent segment 1 value that could be either 1 or 0, It should be noted that the input mask is basically an image that is created after performing the contrast adjustment according to the above equation. The proposed system makes use of the Siamese network which consists of multiple identical sub-networks that are mechanized for yielding significant feature vectors for all the input images followed by comparing them. For simplification, consider that A1 and A2 represent feature vectors of two objects (hand geometry), which are required to be matched. While applying Siamese Neural Network, these feature vectors A1 and A2 are modelled in the form of high-level design of the network that consists of CNN model, with explicit architecture for assisting in the identification process. In this case, the Siamese Neural Network contributes towards playing the role of yielding a generator model for the proposed CNN model in order to facilitate finger recognition of hand images. Additional benefits of applying the Siamese Neural network is that it could be also utilized for identification of the specific region of hand, exploring a discrete set of anomalies, as well as identifying duplicates.

Figure 4 and Figure 5 highlights the visual outcome before and after the adjustment. The contribution of the proposed system is that it introduces a unique and simplified mechanism to use the deep learning method for addressing the finger recognition system from hand geometry. This method is completely flexible for alignment factors and thereby it assists in a faster time of matching the hand from the dataset images. Further,

the Siamese Neural Network is used for learning the feature correspondence of the identified hand. Therefore, a simplified architecture for performing segmentation of hand ROI is presented resulting in finger recognition. The next section presents the discussion of the results.

Fig. 4. Before adjustment

Fig. 5. After adjustment

6 Results

The implementation of the proposed study is carried out in a python environment where two different datasets have been considered viz.

- 11K hands dataset [32]
- IITD hands dataset [34]

The first dataset consists of hand images of more than a hundred subjects while this dataset consists of multiple poses of hands of each subject. The dataset also aggregates

metadata and further stores them. The second form of the dataset consists of hand images but with the presents of user pegs in order to gain better control over the poses of the hand and its respective variation of image scales. Although, the adoption of pegs is not much comfortable for users its beneficial aspect is that it assists in limiting the texture of palm print to significant image variation. It should be noted that the first dataset offers additional information as well as skin color which is not facilitated by the second dataset. A simplified visualization of the first and second datasets is shown below.

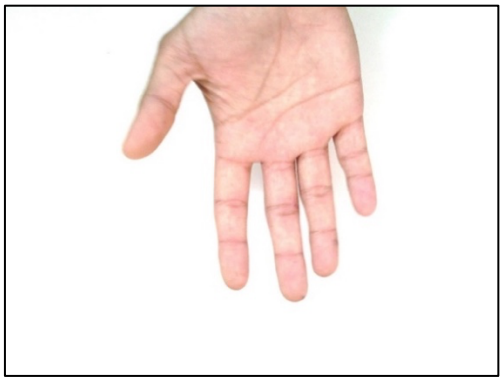

Fig. 6. Example of hand image from 11K hands dataset

Fig. 7. Example of hand image from IITD dataset

As can be observed above, both datasets have different illumination, color palate, and sensors. Both datasets are chosen to show that the system works robustly in any scenario. These two are chosen since the method of acquiring the images is entirely different in both of them. For an effective analysis of the study, the proposed scheme has been compared with existing approaches discussed in the work of [32] viz. i) Conventional Siamese Neural Network and ii) CNN based Latent Dirichlet Algorithm (LDA).

Figure 8 showcases comparative analysis between two pairs of existing systems (i.e. CNN based Latent Dirichlet Algorithm (LDA) and conventional Siamese Neural Network) with the proposed scheme of segmentation. Figure 9 highlights a comparison between the proposed system and another two pairs of the existing system (i.e. Support Vector Machine (SVM) and conventional Siamese Neural Network).

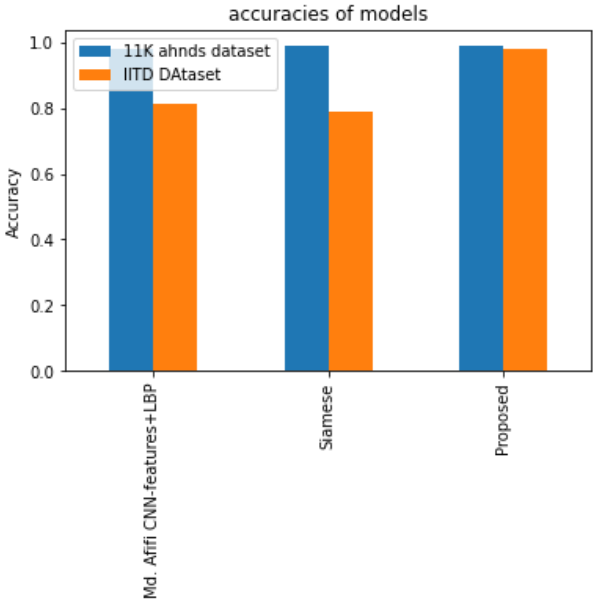

Fig. 8. Comparative analysis of accuracy (Part-I)

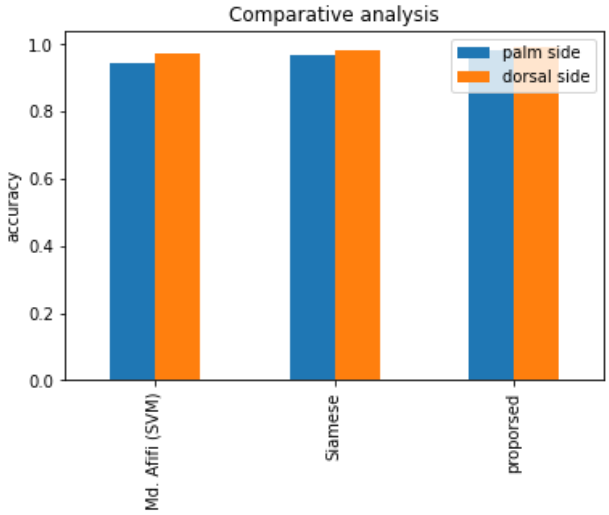

Fig. 9. Comparative analysis of accuracy (Part-II)

7 Conclusion

Segmentation is one of the essential processes in the identification of an object in image processing. This paper has contributed towards a unique segmentation process using a deep convolution neural network and Siamese Neural Network. The contribution of this paper is as follows: i) unlike any existing process of machine learning classification scheme towards identification, the proposed scheme is comparatively easier to implement in practical application, ii) Identification of hand from hand-based ROI image is quite a novel implementation discussed in this paper, iii) the accuracy of the proposed system is found to be consistently high when compared with existing machine learning schemes.

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