Applied Research Frontiers

Ariviyal Publishing

Research Article

DOI: 10.36686/Ariviyal.ARF.2022.01.02.009

Appl. Res. Front., 2022, 1(2), 10-14.

Hand Geometry Based Recognition System for User Authentication

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ISSN: 2583-3065

Crossref

Publication details
Received: 24th August 2021
Revised: 15th June 2022
Accepted: 15th June 2022
Published: 23rd June 2022

Abstract: This paper describes 3D Hand Geometry Based Recognition System that is widely applicable for user authentication. The strategy relies on optimum quality and a low-cost camera that captures the image. This paper presents a technique to get enhanced performance for hand geometry by acquiring 3D information from the given hand in a contact-free manner. The presented method utilizes a camera to capture optimum quality image of the hand in a contact-free fashion to maintain hygiene. A 3D Cartesian coordinates system is employed to capture a 3D image. The motive for employing a 3D image instead of 2D was to improve the performance of described model. Python plays a crucial role in this work with which this software -based paradigm has become achievable.

Keywords: Hand Geometry; Palm Geometry; Access Control; Finger Geometry; Hand Landmark Model

1. Introduction

In present world security issues are well tackled with the aid of Biometrics authentication. The benefit of biometric authentication lies in the fact that it appears to be pleasant to the user in contrast to the systems that require remembrance of various passwords or utilization of a card based systems. Further benefit also restricts the hacker from stealing the stored passwords or breaking down the entire system. The human physical characteristics are used in biometric authentication system, which clearly underlie the natural benefit of not being stolen or broken.

The unique characteristics of human being form the basis of biometric methods that prove their non-repudiation nature of authentication.[1] The physical or behavioral characteristics stored in database are matched in biometric authentication system to store, validate and authenticated data. The individual's identity can be exhibited based on the physical characteristics that mark the human hand features, which can be named as hand geometry based authentication system.[2] The forms of biometrics are:

Face Recognition: The human identity can be proven based on his facial expressions and geometry. The human emotions like sad, happy, stressed, awe etc. are very naturally exposed by face. The emotions also change the geometry of face which is captured by biometric authentication system. The facial parts like eye, nose, lips, cheeks, and forehead are the key indicators of underline human emotions and they ultimately form the basis of authentication.

Fingerprint Recognition: Ridges and valleys that form the basis of physical feature of human figure are used for authentication.[9] It is universally proven fact that it is very hard to find a match between the figure print features of two individuals.[3] This fact is widely used by many organizations for contact based authentication systems especially for marking the employee working hours. In India the government authentication system like UDI also uses figure print as a basis of authentication.[7, 8] This proves the natural importance of figure print based authentication even in largely populated country like India.[4]

Vein Recognition: The veins present in the eyeball, palm or figure have unique features that can be optically captured and employed for authentication of a person. The vein features are unique to every individual because of the changes of circulatory system from person to person. The changes in lifestyle of people lead to variations in exercise patterns of individuals and cause variations in venous patterns. The advancements in today's world especially in mobile technologies have lead to growth in vein based authentication system.

The work in this paper is partly motivated by finding its position in a greater range of applications and applications where the user's convenience is the emphasis. These applications include people identification in a vast corporation, attendance tracking in numerous institutions, government records and criminal records. Nonetheless, these strategies have grown quite popular and widely accepted. The image based nature of authentication forms the simplicity of the system. The extreme conditions of environment sometimes do not allow contact based authentication systems and in such applications the contactless systems like the one described prove to be advantages. The improvement in processing technologies has lead to the benefit of low storage space. The further advantage of improved speed of today's processors is useful in the processing of 3D captured images for authentication.

The word has experienced the benefits of commercialization of hand based geometry systems in last few decades.[5] One such example developed in 1970's is attributed to Identimation Corporation and was named as Identimat. This system was contemporary example of commercially proven system.[2] Even the critical and speedy applications like nuclear power installations and airports have taken the advantage of hand based geometry biometric systems for their authentication.

2. Literature Review

A contactless system using Laser technology is developed by Kanhangad et al.[1] The developed system is based on digital technology and processes images from hand for authentication. A variety of hand images are processed through the system for qualitative analysis and the results are presented.

The features of the palm are studied and experimental results are presented by Agbinya et al.[3] The work performed includes measurement of the palm, the length and width of the palm, and the length and width of each finger. The correlation between the lengths of the hands and their perimeters at the fingertips and the base of the fingers is presented.

Personal identification/authentication by utilizing hand geometry is proved experimentally by P. Agarwal et al.[10] The characteristic values such as finger length and palm breadth are estimated based on the knowledge of control points. It helped in grasping the extraction of 2D features and the matching of the same.

3. Experimentation

3.1. Software Tools used in Experimentation

The experimentation is performed using various software tools that include Python, Spyder, and DB- SQLite and Anaconda framework. These software tools form the core of the processing block of the system. The captured images are efficiently processed using these tools. These software tools proved to be efficient for authentication purpose.

3.2. Image Acquisition

The image needs to be initially captured for examining the photograph of the captured images of hand. This forms image acquisition part of the system.[6] The initial step in a hand geometry biometrics system is image acquisition. Image acquisition involves collecting digital images from digital cameras. The image of the palm forms the input to the system.

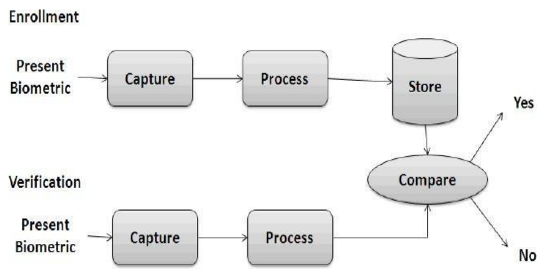

Fig. 1. Block Diagram of the Proposed System

3.3. 3D Hand Geometry

The representation of coordinate system for hand geometry and related terminology is explained in this section. The natural way of defining a location with the aid of coordinate systems is based on some reference point present in that image. The features retrieved from the 2D images obtained are not sufficient to suit the aim. The properties gathered from the 2D image are applied to generate a 3D image. To depict a 3D image, a 3D Cartesian coordinate system is employed. The x-, y- and z- axis are three mutually perpendicular axes in 3D Cartesian coordinate system. The representation of a point in 3D coordinate system is based on the values of the (x, y, and z) coordinates of that point. Python contains built-in libraries NumPy and Open-CV for coordinates. The Coordinate match is found between the images processed by NumPy and Open-CV.

3.4. Implementation in MediaPipe

The MediaPipe is found to be widely useful on various platforms for variety of applications. The calculator based techniques used in MediaPipe keep on gradually evolving for the purpose of processing of operations like model inference, data conversions, and media processing. The various processing operations like rendering, cropping and computations based on neural networks are upgraded in MediaPipe to take benefit of accelerated GPU processing.

The software tools namely, Python, Open-CV, and Media Pipe, are used for completion of real-time hand tracking and landmark estimation in this model. The Open-CV is used to read video from a camera and Media Pipe to accomplish hand tracking and landmark estimation.

The cv2 module is aided in acquiring frames from the camera. This further is useful for estimating landmarks using capability of the media pipe processing.

The presented model makes use of a machine learning technique that mixes different models.

3.4.1. Palm Detector Model

The palm detection model basically works on whole image and returns a bounding box structure of typical orientation.

3.4.2. Hand Landmark Model

The further processing stage involves applications of regression methods that return the locations of key points of 21 3D hand-knuckle coordinates. These coordinates are detected in the extracted hand regions. This technique is direct coordinate prediction.

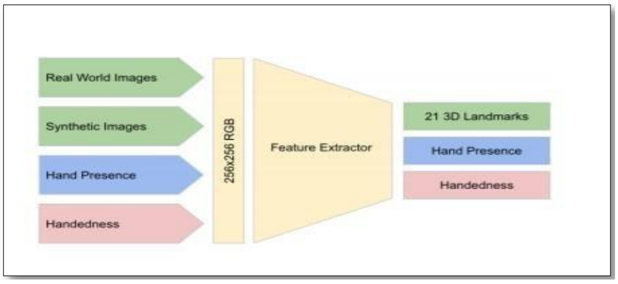

Fig. 2. Logical Workflow of the Proposed System

3.5. Proposed System

Fig. 1 shows block diagram of the proposed system that is used for human authentication based on hand geometry. The various blocks of the system include capture, process, store and compare.

The capture block employs low cost high quality digital camera that captures the geometry of the hand to be processed for authentication. The process block extracts the required features from the acquired image of hand. The store block represents the database of features that are used for authentication. The features of input image and those stored in database are compared for the purpose of authentication.

This is entirely a contact free approach for authentication and hence enjoys the natural benefits like hygiene and user friendly. This authentication approach makes use of unit normal vector and figure surface curvature for biometric measurement of 3D hand geometry. This system proves to be efficient and simple for the purpose of authentication. The reliability of the system lies in the fact that the 3D and 2D image features are matched for authentication purpose. The system can be broadly divided into two parts namely, enrolment and verification.

3.5.1. Enrolment Phase

This procedure entails adding a new user to the database. During the enrolment, 1000 images of a single user of the same hand are recorded in succession. These images are then used for feature extraction and kept in the database.

3.5.2. Verification Phase

This method entails matching a given hand with the database which has saved the data of the person while previously enrolling in the system.

3.6. Architectural Layout

Fig. 2 shows the logical workflow of the proposed system. The various blocks of the architecture include real world images, synthetic images, hand presence, handedness, feature extractor, 21 3D landmarks, hand presence, handedness. The various input images to the feature extractor are categorized into real world images, synthetic images, hand presence, handedness. The uniformity of input images of various categories is maintained by converting them into 256 X 256 RGB matrixes. This ensures reduction in computational complexity at feature extraction level. The feature extractor extracts 21 3D landmarks from the input matrix.

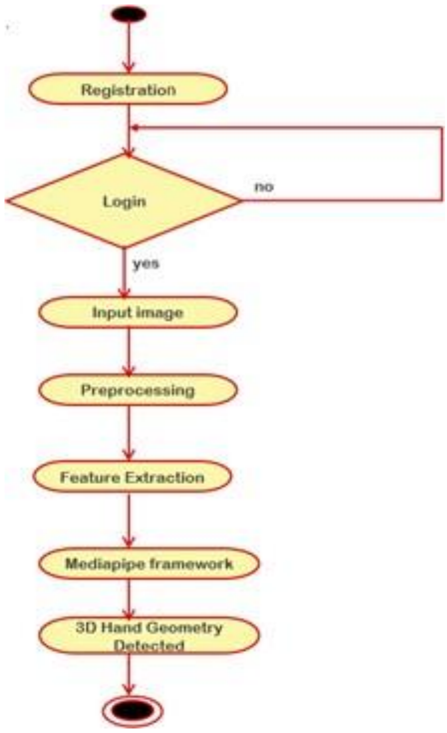

Fig. 3. Activity Diagram of the Proposed System

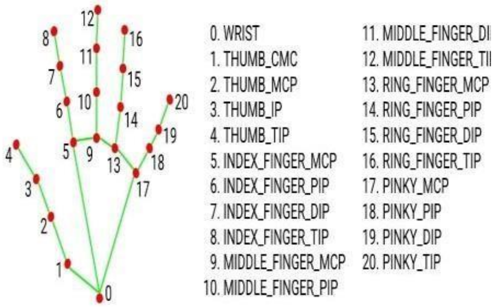

Fig. 4. Various Landmarks Extracted from a Palm

3.7. Diagram of Activities

Fig. 3 shows the activity diagram of the proposed system for the purpose of enrolment. The initial phase in the entire process of authentication involves registration of samples. When user wants to have authentication the system will perform a check on login credentials. This check involves matching of input image and those stored in database. After successful login the enrolment of user is performed. A similar activity diagram can be presented for the purpose of verification.

3.8. Performance Evaluation

Fig. 4 depicts the various landmarks that are extracted from a palm for the purpose of authentication. There are 21 landmarks that can be extracted from the proposed system. A palm is identified from the entire image the hand landmark model precisely extracts 21 3D hand-knuckle coordinates using regression technique. The model learns a consistent internal hand pose representation and is robust even to partially visible hands and self-occlusions. The manual annotation of 30K real world images is performed for obtaining

Fig. 5. Qualitative Results for the Enrolment Phase

Fig. 6. Qualitative Results for the Verification Phase

ground truth data. The proposed system also takes care of variety of hand poses and variations in hand geometry. The variations in the background are also taken care with the aid of a well-developed synthetic model of hand.

Each user places his or her right hand in front of the camera to take photos. No user was instructed to place their hands properly or to clean them. All users had to do was place their hand in front of the camera and inside the imaging region. Python includes built-in libraries that aid in the detection of key points. After recognizing the palm, our model performs key point localization of 21 3D hand knuckle coordinates. The media pipe library, which is accessible in Python, can be used to identify critical points.

4. Result and Discussion

4.1. Results

Fig. 5 shows the qualitative results for the enrolment phase. A subject is selected with the palm facing the camera as shown in Fig. 5. The 21 3D key landmark points are detected and stored in the database. This is the process for enrolment of the subject.

Fig. 6 shows the qualitative results for the verification phase of the proposed system. A subject is selected with the palm facing the camera as shown in Fig. 6. The 21 3D key landmark points are detected and a match is searched in the database. If match is found then the authentication is said to be successful. This is the process for verification of the subject.

4.2. Discussion

The proposed system finds its presence in huge enterprises that require personnel identification and attendance tracking systems which are used by a number of universities. Similarly the system can be utilized for the purpose of maintaining a database for government records by profiling individuals for security purposes. It can be used as an access control system to keep strangers out of specific areas.

5. Conclusions

In the present paper the data of hand geometry is combined from 2D as well as 3D perspective for simultaneous extraction in order to obtain reliability in personal verification. The presented system puts user at comfort because of contact free nature at the image capture level. In the present Covid-19 scenario, where personal cleanliness and hygiene are at the top priority even for common person, the system proves to be useful. The feature extraction as well as matching for authentication purpose is performed in the present system by simultaneous collection of range and 2D images of hand. The system also exhibits features like unit normal vector and figure surface curvature in order to measure 3D features of geometry of hand. The important and challenging task involving 3D hand images for the purpose of matching is simplified using the present system without any degradation in terms of efficiency. The reliability of the system in terms of authentication is improved by having match scores for 2D and 3D hand geometry images.

Acknowledgements

I would like to take this opportunity to thank my PhD supervisor, Dr. D. S. Chaudhari, for his continuous support and motivation to carry out this research work. I am also thankful to all my colleagues and friends from Sinhgad Academy of Engineering, Pune, for their inspiration and motivation.

Conflicts of Interest

The author declares no conflict of interest.

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