International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

A Hand Geometry Verification System relating Finger length, Position of the Finger base and Palm Center

Raunak Gopal, Asnath Victy Phamila Y, Geetha S

Abstract**: *Fingerprints and Iris scans have been the most popular form of biometrics for a long time. A more niche form of biometrics – based on geometric features has existed since the 1980's. The ideas were promising due to less intrusiveness and low storage requirements but had hardly seen use due to lower accuracy. In recent years however, geometric techniques are attracting attention as a result of better hardware and improved algorithms. In this paper, an algorithm to verify a person's identity based on the hand shape is presented. The paper gives an introduction to hand geometry then surveys existing work in the field. The main algorithm, which calculates the features to authorize and identify a person by deriving relations from attributes like finger length, coordinates of the finger base and palm center is explained in detail in the methodology section. The system is then tested on a locally collected dataset with 30 images from 7 different individuals. The results of the testing are provided in the experiment section, followed by a conclusion.***

Index Terms**: *Hand Geometry, Biometrics, Features, Fingertips, Accuracy***

I. INTRODUCTION

In 1858, Sir William Herschel, employed in the Civil Service of India, recorded a handprint on the back of a contract for each worker to distinguish employees from others when payday arrived. This was the first recorded systematic capture of hand and finger images that were uniformly taken for identification purposes. The field of biometrics has seen enormous progress since then, and growth has accelerated since the 1950's. The market of biometrics has been dominated by fingerprints for a long time – which has seen used as the default verification technique in several areas from small banks and offices to large government organizations.

Fingerprints saw a major boost again in 2013, when Apple introduced Touch Id for the iPhone5s, forcing competitors to follow suit and making it in essential part of every smartphone. More recently however, Apple launched Face Id, a system which identifies a person by using a 3d map of the user's face. The Face Id system, has proven to be faster and more reliable than it's touch counterpart, with the added bonus that the user doesn't even have to lay a finger on the phone to unlock it.

Geometry based biometric systems have been around since the 1970's, but never saw as much research or commercial success compared to fingerprints, iris or voice based systems. Even when implemented, they were paired with other verification techniques like an id card and were mainly used in cases that required lighter security. This was a shame as barring lower accuracy, these shape based systems required less intrusiveness and storage space, while having faster processing times. Yet all is not lost, as research in the field has kicked back up in the last decade as a result of improved hardware, resulting in algorithms that are light and fast while being highly reliable. The two most commonly used parts of the body in these algorithms are the hand and the face. Hand Geometry is a physiological biometric technique that identifies a person by extracting various geometric features (finger lengths, width, ratios, area, etc.) from the user's hand silhouette. A typical hand geometric biometric system makes use of a camera or scanner-based device to capture the hand image of a person and compares this against the information stored in a database to establish identity. Hand geometric systems are attractive because:

1) The hand image can be captured using inexpensive equipment such as conventional CCD cameras or higher end hand geometric scanners
2) The hand features can be extracted from low resolution images which have a small template size (~ 9 bytes)
3) Hand geometry systems are less intrusive as they do not link to criminal records
4) Additional biometric features such like fingerprints and palmprints can be easily integrated to an existing hand shape-based biometric system

Due to the above reasons, the hand geometry systems are easily accepted by the public and are used for verification in low to medium security applications like cash vault systems, time and attendance related applications, dual custody applications etc.

Manuscript published on 30 June 2019.
***** Correspondence Author (s)
Raunak Gopal*, Student, School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, India,
Asnath Victy Phamila Y, Associate Professor, School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, India
Geetha S, Professor, School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, India

II. RELATED WORKS

Hand Geometry as a biometric verification technique has gained immense popularity in the last decade. A lot of work has been published by various researchers in the field. In this section, we highlight some of the interesting works done in the field.

Peter Varcholet et.al. [1] has proposed a hand geometry verification system by extracting 21 features from a person's hand like finger length, heights, area etc. The images are captured by a scanner with the hand held in position with the use of pegs. Three experiments were performed with Euclidean distance, Gaussian Mixture Model(GMM) and Hamming distance. The best results were obtained in the GMM with an EER=4.62% and FAR=0.1812%.

Migeul Adan et. al. [2] on the other hand, proposed a biometric system based on natural hand layout – completely free of pegs. Images of both the left and right hands were captured using 2 CCD cameras. The features for a person were extracted from a polar representation of the contour of the hand followed by a normalized similarity measure for verification. The system has a 97.6% accuracy in identification with an EER of 1.3%.

Bahareh. Agile, et. al. [3] proposed a method insensitive to rotation which extracts features from four fingers. The images were captured by a desk scanner where the user can freely turn his hand which was not restricted by pegs. 24 features were extracted and Euclidian and Absolute distance were used as classifiers. The system had a 99.81% accuracy with an EER of 0.1734% while using the Absolute distance classifier.

Jing Ming Guo et. al. [4] has designed a hygienic contact free hand geometry system, which captures images using a commercial webcam along with infrared devices. The infrared devices allow hand images to be captured in a dark environment. 13 points were extracted from the input hand image to derive 34 features. The system obtained a FAR rate of 1.85%, while using the libSVM framework for recognition.

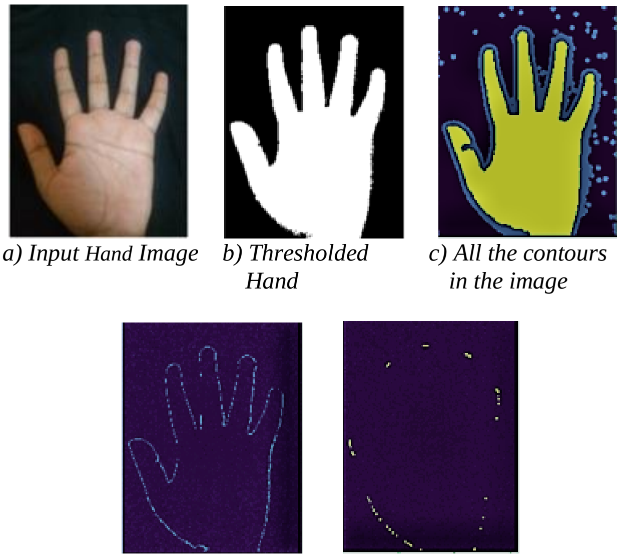
Miguel A. Ferrer et. Al. [5] proposed a biometric identification system which combined hand geometry with fingerprints and palmprints. The hand geometry part made use of 15 hand geometric features and used SVM as a verifier, while the fingerprint and palmprint used 2D Gabor phase encoding techniques and used Hamming distance as a verifier. A similar system was proposed by Nesrine Charfi [6] et. al. which used the palm shape with palmprints.

III. PROPOSED METHODOLOGY

The methodology section is divided into 2 parts - the first which explains the basic pre-processing required and how hand geometry characteristics such as finger length and coordinates of the base of the fingers and palm center are extracted with respect to a single hand. The second part of the section explains the main algorithm which uses said characteristics to derive the features used for discrimination.

The system is coded in Python 3.6 with OpenCV being used as the main image processing library. The images of the hands used in the example were captured by the rear camera of a Samsung Galaxy A9 smartphone against a black background.

A. *Image Preprocessing*



a) Input Hand Image *b) Thresholded Hand* *c) All the contours in the image*

d) Contour with the most points *e) Convex Hull of the hand*

Figure 1. Image Preprocessing steps

The image of the hand is read in and is converted from RGB to greyscale. The greyscale image is then passed through a threshold filter in which every pixel with grey value<limit is changed to black, and every pixel with grey value>=limit is changed to white. The thresholded image is then eroded and dilated to get rid of any outliers. The contour with the maximum number of points is extracted to get the outline of the hand. We then find the convex hull of the resultant outline.

B. *Feature Extraction – Finger Length, Coordinates of the Base of the fingers and Palm Center*

a) Image with the fingertips in yellow and fingerbases in red *b) Image with all fingers except the thumb cut off* *c) Image with the palm extracted*

Figure 2. Feature Extraction Steps

We extract the topmost non-zero point of the convex hull which gives us the co-ordinates of the middlefinger's tip(middletip). Next we erode the area around middletip by setting all pixel values in a rectangle (length = 0.05 * image-height , breadth = 0.05 * image-width) around middletip as zero. We then extract the topmost non-zero point again to give us the co-ordinates of the thumbfinger's tip(thumbtip).

Thumbtip is then eroded and the topmost point is extracted again to give us the co-ordinates of the indexfinger's tip(indextip).

Now that we have the indextip, middletip and thumbtip, we aim to find the co-ordinates of the base of the fingers and the finger length. Take the y-coodinates of the middletip(y1) and ringtip(y2). For every x(row) starting from 0, we check the pixel values of the between y1 and y2 for that x. We find the first row that has no non-zero values between the y-coordinates of middletip and ringtipThis gives us the x-coordinate where the base of the fingers meets the palm (We shall hereby refer to this value as rowmin). To find the y-coordinates of the base of the fingers, we begin by assigning x=rowmin-(0.01*image-height). For the fixed x, we start with y=0 and increment y till we encounter a pixel at (x,y) with a non-zero grey value. This y-coordinate of the pixel is then stored in y-left. Then the y value is incremented again till the first pixel at (x,y) with grey-value of 0 is encountered. The y-coordinate of this pixel is stored in y-right. The y coordinate of the base of the index finger (which will now be referred to as indexbase) is (y-left+y-right)/2 while the x-coordinate is rowmin. The above four steps is repeated twice starting from y-right to find middlebase and ringbase. The length of the indexfinger(which will be called indexlength) can be calculated from the eucledian distance between indextip and indexbase. The middlelength and ringlength can be calculated similarly. To find the coordinates if the center of the palm, we set the pixel values in every row from x=0 till x=rowmin as 0. This gives us the image of the hand with the indexfinger, middlefinger, ringfinger and pinkiefinger cut off. To remove the thumb, we first find the x-coordinate of the occurrence of the first non-zero grey value for every column i.e. along the y-axis. We then select the pixel in the column with the maximum x-coordinate value. Every column left of the selected pixel is made to have grey-value as 0 to cut off the thumb. This will give an image of only the palm from which we can find the center coordinate of the palm (which we will refer by x-mid,y-mid).

C. *The Main Distance Computation Algorithm*

Figure 3. Image with the 3 circles C1, C2 and C3

Now that we have indexlength, middlelength, ringlength, indexbase, middlebase, ringbase and the palm-center, we can apply the algorithm to extract the final features used to identify a person. The first step involves drawing a circle with it's center at indexbase, and it's radius as indexlength (we shall hereby refer to this circle as C1). We similarly draw 2 more circles with the center at middlebase and radius as middlelength (which we shall call C2) and another circle with center as ringbase and radius at ringlength (which we shall call C3). The advantage of using circles is that each finger can only rotate in an arc of the given circle, which will ensure the same circle is obtained for the finger everytime irrespective of the finger's position.

Figure 4. Image with the point of intersection of the circles in red and the palm center in yellow

Now that we have the 3 circle's C1, C2 and C3, we will find the point of intersection between C1 and C2(which will be referred to as P1 and P2), C2 and C3(which will be referred to as P3 and P4) and C1 and C3(which will be referred to as P5 and P6).

Figure 5. Image with the line joining P1 and P2

The next step involves drawing a line connecting P1 with P2,P3,P4,P5 and P6. Similarly we draw a line connecting P2 with P3,P4,P5,P6(P1 is omitted since that line is already drawn). We repeat the process for the remaining points, so that there is a line connecting every pair of the 6 points. This gives us 6C2=15 lines.

Figure 6. Image with the perpendicular distance from the palm center to the line joining P1 and P2

Finally, we have to find the perpendicular distance of the palm center from each line, which will result in 15 values. These 15 distance values are the final features for the given hand.

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IV. EXPERIMENT

For the experiment, a small locally collected dataset of 30 hand images from 7 subjects was used. The first 25 images are collected from 5 people (5 images each), while the last 5 images are collected from 2 people. The subjects age group ranged from 10-85 years and both male and female samples were taken. The images of the subjects left hand were taken on a Samsung Galaxy A9(2018) with a resolution of 3000 x 4000 against a black background. Only the first 5 persons are going to be registered in the database, while the last 2 persons will be unauthorized. For registration of a person, the distance vectors for the first 2 of his hand images is computed (The remaining 2 hand images for that person will be used in testing). The average-distance-vector is then calculated by taking the mean column-wise using the above obtained 2 vectors. We calculate and store this average-distance-vector for each of the first 5 people (The last 2 people are omitted from the process as they are unauthorized).

Table 1. Average-distance-vector for the first five people

Person	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
1	991	1562	68	1502	381	780	170	912	98	244	1524	336	155	150	384
2	829	1740	185	1665	260	751	12	816	82	243	1686	316	220	18	304
3	687	1558	382	1449	70	459	194	586	92	687	1423	20	533	101	38
4	858	1688	238	1630	263	624	183	764	123	437	1650	177	339	154	235
5	913	1717	211	1646	278	796	23	888	61	309	1666	332	266	22	327

For testing, we use all 30 images. Given an input hand image, the distance-vector of the hand is calculated. This distance-vector is then compared with each of the 5 stored average-distance-vectors by using the Manhattan distance metric, which results in 5 values. The minimum of these 5 values is then selected (which will refer to as MINVAL). We check if MINVAL > Threshold. If yes, the system concludes that the person is unauthorized. Else, the system checks which person's average-distance-vector produced the minimum Manhattan distance value MINVAL and identifies the input hand image as belonging to that person. The Threshold is selected based on the Average-distance-values of the registered individuals and is calculated as

Threshold = 0.125 * (Sum of all values in Table 1). This results in a Threshold value of 1137.

Table 3. MINVAL calculated for the hands of the unregistered people

Hand No.	MINVAL	Belongs to Person	Identified as Person
1	382	1	1
2	382	1	1
3	472	1	1
4	668	1	1
5	758	1	1
6	187	2	2
7	187	2	2
8	607	2	2
9	535	2	2
10	537	2	2
11	508	3	3
12	508	3	3
13	766	3	3
14	760	3	3
15	901	3	3
16	165	4	4
17	165	4	4
18	328	4	4
19	191	4	4
20	304	4	4

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21	410	5	5
22	410	5	5
23	672	5	5
24	387	5	5
25	447	5	5

Table 2. MINVAL calculated for the hands of the registered people

Hand No.	MINVAL	Belongs to Person	Identified as Person
26	2116	6	Unauthorized
27	2289	6	Unauthorized
28	2187	6	Unauthorized
29	2308	7	Unauthorized
30	2151	7	Unauthorized

The maximum and average value of MINVAL in Table 2 is 901 and 465 while the minimum and average value of MINVAL in Table 3 is 2116 and 2210 respectively. This helps mark the large difference in MINVAL between authorized and unauthorized people, which results in accurate authorization. The threshold value of 1137 enables the system to accurately accept all 25 registered hands and reject the last 5 unregistered hands. With respect to the registered hands, the system has identification accuracy of 100% as seen from Table 2.

V. CONCLUSION

An extensive study of various hand geometry biometric techniques has been taken up. Using this knowledge, a new algorithm which relates hand geometry characteristics like Fingerlength, Coordinates of the Fingerbase and Palm Centre has been proposed. A system to extract the characteristics and use the algorithm has been developed and tested practically to verify the identity of individuals. For very large datasets, the thumb and pinkiefinger can be integrated in the system.

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AUTHORS PROFILE

Raunak Gopal is a student who has completed his 3rd Year B.Tech, Computer Science & Engineering, at Vellore Institute of Technology (VIT, Chennai Campus). He has an excellent academic record and a keen interest in practical exposure in the field of Artificial Intelligence, Deep Learning, Analytics and Big Data.
Raunak is currently doing his summer internship in a Global Technology Company which is leader in Hardware, Software and Cognitive computing. In 2019, Raunak was part of a winning team that worked on a Drone using a Pixhawk Controller for locating and identifying people in situations of emergency such as floods, earthquakes etc. This Project has been awarded "Best Project in Technical Answers for Real World Problems by VIT Chennai". In 2018, in his summer internship at Indian Institute of Technology, Madras, he had worked on a Machine Learning Project for development of a new algorithm for "Hypergraph Representation Learning using Deepwalk". In 2017, Raunak had worked on the development of a new algorithm for "Predictive Driver Behaviour" for "Instantaneous Driver Intent" at one of India's largest Commercial Vehicle Manufacturers as part of his summer internship. He has developed serveral other models using Machine Learning and AI for predictive analysis at College. Raunak is proficient in the use of the latest programming languages and wants to pursue a career in Machine Learning, Artificial Intelligence and Big Data to provide disruptive solutions to society. A voracious reader, Raunak also has interests in music, movies and history.

Dr.Asnath Victy Phamila Y, is Associate Professor, School of Computer Science and Engineering, Vellore Institute of Technology, Chennai, India. She holds M.E and Ph.D degree in Computer Science and Engineering from Anna University. Her research area includes image processing, wireless sensor networks, network security and cyber physical systems. She has around 13 years of academic and 3 years of industry experience. She has several research papers to her credit which have been published in reputed journals. She also serves as a reviewer in reputed journals. Her fields of skills and expertise include Signal, Image and Video Processing, Medical and Biomedical Image Processing, Image Compression, Data Compression, Image Coding and Image Fusion.

Dr.S.Geetha is a Professor in School of Computing Science and Engineering, VIT University, Chennai Campus, India. She has received the B.E., and M.E., degrees in Computer Science and Engineering from Madurai Kamaraj University, India in 2000 and Anna University of Chennai, India

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in 2004, Ph.D. Degree from Anna University in 2011, respectively. She has rich teaching and research experience. She has published more than 80 papers in reputed International Conferences and refereed Journals. Her research interests include steganography, steganalysis, multimedia security, intrusion detection systems, machine learning paradigms and information forensics.

She is a recipient of University Rank and Academic Topper Award in B.E. and M.E. in 2000 and 2004 respectively. She also holds the Certificate of Appreciation from IBM in 2009, 2010 for Great Mind Challenge, Mentor IBM Academic Initiative Program. She is also the proud recipient of ASDF Best Academic Researcher Award 2013, ASDF Best Professor Award 2014, Research Award-2016 and High Performer Award – 2016, from VIT University, ISCA Best Poster Award - 2018.

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