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Multi-touch Gestures Authentication Techniques: A Study

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Abstract: In current era the multitouch interfaces interactions with computing devices are changing fastly. The common problems related to users for user authentication are selecting weak textual passwords or forgetting password [1]. Hence we studied gesture based multitouch authentication system. Multitouch gestures based on the movement characteristics of the palmand fingertips being used to perform the gesture[1]. We studied a various techniques to verify multi-touch gesture templates. With score-based classifiers where only the first five samples of a good subject were considered as templates, author achieved4.46 % EER [1]. Further, with the combination of three commonly used gestures like pinch, zoom, and rotate, using more than one finger, 1.58% EER was achieved[1].Touch and multi-touch gestures are the most common way to interact with technology such as smart phones, tablets and other mobile devices[1].

Keywords: Finger-tracking, Android Operating system, Eclipse, Gesture, Normalization.

I. INTRODUCTION

Currently the smart phone users growing day by day. There are various applications that requires strong authentication. Single touch technology i.e. previously used technology also provides user authentication. In this system multitouch interface bring new capabilities to existing devices. In the smart phones, tablets, in living room, coffee table the multitouch technology is used. It is an effective user interaction features and the visual Experience provided by multi-touch interfaces, make them strong contenders for becoming the dominant human computer interface, possibly replacing the keyboard, mouse and stylus. Proof of identity of user is an input to multi-touch gesture authentication system. Correctness of the proof of identity is then evaluated by the system. After that, the answer, either accepts or rejects the user, is given based on the evaluation result. Enrollment stage and verification stage are two phases in verification system. In the enrolment stage the user's input is stored in the system. During verification stage, the user input is compared with the already stored biometric templates of the respective user while performing authentication [1]. There are various phases used in verification phases.

Multi-touch gesture based authentication consist the stages such as developing a gesture authentication technique, Matching touch sequences to specific fingers, Finger-tracking, Gesture Normalization, Feature Extraction, Distance evaluation, Thresholding[1].

II. GESTURE NORMALIZATION

Normalization is a transformation process that scales down data value within a feature. Large difference between the minimum and maximum value of a feature need to bring this variation to some acceptable range[1]. 0 and 1 are the specified range data values. Classification algorithms are used for this process along with min-max normalization. There are various techniques used in normalizations.

A. Intriguing technique

Retention of the correlation between actual dataset and accomplishing linear transformation on them are the key points in this technique. A feature value V is mapped to V' in min-maxnormalization, using the Equation (1).

$$V' = \frac{\text{V} - \text{min}}{\text{max} - \text{min}} \quad (1)$$

Significant information loss and concentration of values on certain parts of the normalized range occurs because of min-max normalization.

B. Block Scaling Normalization

Shifting the coordinates using centre mass is present techniques for normalization so that the centroid of the object will match. We need to perform rescale between new presented object and the stored objects so that match will occur. To enhance system performance cleaning up of data is necessary in the normalization phase.

III. FEATURE EXTRACTION

Feature extraction is responsible for generating the user template, by identifying and encoding distinguishing properties from a user's biometric data. Templates from two different users must be distinct and different and templates that are from the same user should be identical.

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In this research workthis process is very fundamental. Next phase is classification is nothing but it converts the biometric data into a feature vector to use as an input in the next phase[1]. To extract features that are discriminating with respect to the way users interact with a touch screen behavior this is purpose of extraction[2].

The collected raw data is main task of touch gesture application. In an android platform called Motion Event used todata collected in this research were from features that extracted using the application-programming interface, This API makes it possible to gather touch screen data for a touch event differs from other operating systems.

A human finger touch; finger pressure down, finger pressure up, finger size down, finger size up, duration, acceleration, distance, speed, touch major down, touch major down up, touch minor down, touch minor up and position this are thirteen features that extracted from.

The extracted features shown in Figure A. Figure shows touch features used in this research. With the TouchEvent () method in Android, a set of touch features can collected from the screen during the different types of touch event [3].

Table 1 shows the different way of extracting the features form human touch. There are consider distance, time, acceleration, position, speed etc factors when the user touches the screen to user release his finger from screen. According to their feature there are various types of features methods are used show in Table 1.

Tables 2 and 3 summarize the most interesting verification systems presented online and offline. In Tables 2 and 3 systems has EER, FAR, FRR factors shown in results of a systems. In multitouch gesture verification produce two types of errors false rejection rate (FRR) and false acceptance rate (FAR) by helping of this factor performance of system is measure. The error factors FAR and FRR are vice versa depending upon systems. The equal error rate calculated by the overall error of systems [3].

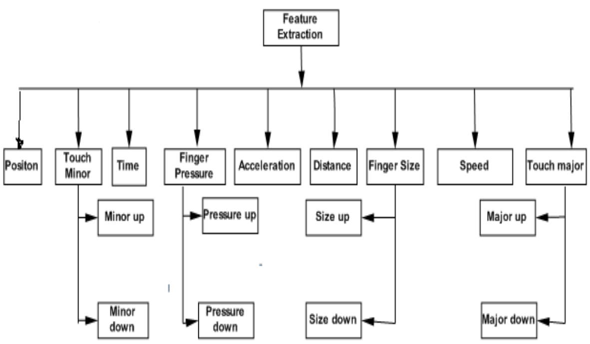

Figure 1.Feature extraction and feature component [3]

TABLE 1: FEATURES TABLE [3]

No	Features	Methods
1	Finger Pressure Down , Finger Pressure Up	To extract finger pressure value we used android library getPressure () method measured by kilopascals.
2	Finger Size Down, Finger Size Up	To extract finger size value we used android library getSize () method measured by pixels.
3	Time (ms)	The event press time along with the event release time were extracted from the two methods getDownTime () and getEventTime () respectively.
4	Acceleration	The formula (Speed /Time) was used to calculate acceleration.
5	Distance	$\sqrt{(x2 - x1)^2 + (y2 - y1)^2}$
6	Speed	The formula (Distance/Time) was used compute speed.
7	Touch Major Down , Touch Major Up	To extract the length of the Touch Major axis the android library method getTouchMajor (intpointerIndex) was used.
8	Touch Minor Down , Touch Minor Up	To extract the length of the Touch Minor axis the android library method getTouchMinor (intpointerIndex) was used.
9	Position	Position is reading the coordinates value of x-axis and y-axis of touch point location through GetX (), GetY ().

TABLE 2: PERFORMANCES: ONLINE SYSTEMS [3]

Main Features	Approach	Results
X-Y correlation, projection- based, Moment-based	NN	FRR:3%
Projection based, Contour based.	NN	FRR:1%, FAR:3%
Geometric-based, Projection-based, slant-based, grid-based	NN(RBF)	FRR:3%, FAR:9.81%
Contour-based	NN(MLP) (ME by cascaded Multiple experts	FRR:2.04%, FAR:0.01%
Wavelet transform	DTW	FRR:5.60%, FAR:10.98

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		%
Geometric-based, Projection-based, slant-based, Fourier Transform	Euclidean Distance, NN	FRR:2%, FAR:0.5%
Grid-based	HMM	FRR:0.75%, FAR:0.18%
Global(Wavelet-based), statically and geometrical	NN	FRR:6.2, FAR:5.5%
Projection-based	DTW	FRR:22.%, FAR:23.5%
Peripheral-based	Mahalanobis distance	EER:11.4%
Geometric-based	1.Euclidean Distance 2.SVM 3.HMM	1.FRR:5.61, FAR:4.96% 2.FRR:3.23 %, FAR:2.65% 3.FRR:2.2% , FAR:3.3%
Geometric-based, grid-based	NN	FRR:11.1%, FAR:11.8%
Geometric-based, Direction-based	NN	FRR:6.3%, FAR:8.2%
Graph metric-based	HMM	FRR:0.75%, FAR:0.22%
Grid-based	Fuzzy logic modeling	FRR:0%, FAR:3.5%
Position	Displacement Function	EER:24.9%
Gird-based	NN	FRR:7.27, FAR:11%

TABLE 3: PERFORMANCES: ONLINE SYSTEMS [3]

Main Features	**Approach**	**Results**
Position, Velocity, Acceleration	DTW	EER:0.4%
Shaped-based features	DTW	FRR:3.2%, FAR:0.55%
Velocity, Pressure	DTW	EER:4%
Velocity, Curvature based	String matching	FAR:3.3%, FAR:2.7%
X-Y correlation	HMM	EER:2.5%
Geometric-based	Mahalanobis distance, Euclidean Distance, DTW	FRR: 5.8%, FAR: 0%

System's performance can be measured by using factors such as EER, FAR, FRR.

Equal error rate (EER) is an algorithm in biometric security system which is used to determine the threshold values for false rejection **rate** andfalse acceptance **rate**. If the **rates** are **equal**, then common value is called as the **equal error rate**[4].

The **false acceptance rate**, or FAR, in biometric security system the rate at which the system wrongly **accept** an access attempt by an illegitimate user. A system's FAR is defined as the rate of the number of **false** acceptances divided by the number of identification attempts [4].

The **false rejection rate** the biometric security system will wrongly **reject** an access attempt by legitimate user. A system's FRR typically is defined as the rate of the number of **false** rejections divided by the number of identification attempts[4].

$$\mathbf{FAR}=\frac{\text{Wrongly accepted individuals}}{\text{Total number of wrong matching}}$$

$$\mathbf{FRR}=\frac{\text{Wrongly rejected individuals}}{\text{Total number of correct matching}}$$

IV. DISTANCE EVALUATION

On multitouch devices the number of touch point occurred and points differs from one multi-touch gesture to another if they were performed by the same user. The distance between two multi-touch gestures is calculated using dynamic time warping (DTW) algorithm [1]. To measure similarity between two time series that may have different lengths and time deformations by using DTW are a well-known matching algorithm. Given two time series, the DTW algorithm does a rule-wise linear mapping of the time axes to align the two sequences while minimizing overall warping cost. The formula is as follows [2]
Let $\pi = <p_1, p_2, ..., p_n>$ and $\sigma = <q_1, q_2, ..., q_n>$
Is the sequence of feature points derived from two gestures π and σ. Let $M = \{(p_i q_i)\}$ be an order-preserving complete correspondence between π and σ, and cost (p, q) a matching cost between p and q. The distance between π and σ is defined as

$$\text{Distance}(\pi,\sigma) = \frac{\min \sum_{\forall(p,q)\in M} \text{cost}(p,q)}{\min(m,n)} \quad [2]$$

There is following ways are used to calculate the distance between touch points.

A. Manhattan distance
The **Manhattan distance** is calculated by adding difference of two points.

$$\text{CostManhattan}(p, q) = \sum_{i=1}^{l} |p_i - q_i| \quad [1]\ [2]\ [6]$$

The **formula** for this **distance** between a point P= (p_1, p_2 etc.) and a point q=(q_1, q_2, etc.) isthe number of variables are denoted by n, and the values of the i^{th} variable for p and q are denoted by p_i and q_i.

B. Euclidean distance
In Cartesian coordinates, the length of the line that connects point's **p** and **q** is **Euclidean distance** between these points.

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Suppose there are two points **p** = (p_1, $p_{2...}$ p_n) and **q** = (q_1, q_2... q_n) in Euclidean formula, then the distance (d) is calculated between p to **q**, or **q** to **p** is bythe formula

$$\text{Cost Euclidean (p, q)}=\sqrt{\sum_{i=1}^{l}(p_i - q_i)^2} \quad [1]\ [2]\ [6]$$

Euclidean vector defines the position of a point in a Euclidean formula**.** So, here p and **q** are considered. As Euclidean vectors, they start from the origin.

C. Cosine distance

$$\text{CostCosine (p, q)}=1-\frac{p.q}{||p||\ ||q||}[1][2]\ [6]$$

Euclidean dot product formula is used to derive the cosine of two non zerovectors.

$$a.b=||a||\ ||b||\cos\Theta$$

Dot productandmagnitudeare used to representtwo vectors that are nothing but A, B and cos (θ)[2].The result is defined in the form of −1 means opposite to similarity and 1 means same, where 0 shows in-between valuesintermediate similarity or dissimilarity. While performing text matching, the A and B are attribute vectors called frequency vectors of the documents. The cosine similarity is defined during comparison method by normalizing document length.

D. Jaccard Index distance

The Jaccardindex is termed as the Jaccard similarity coefficient. Originally it is developedby Paul Jaccard.
It is used for statisticand comparing the similarity and diversity between sample sets. It is termed as the intersection size divided by the union size between the sample sets.

$$J(X,Y)=1-\frac{|X\cap Y|}{|X|+|Y|-|X\cap Y|}[1]$$

Where X and Y are two samples sets.0 to 1 is the range that used to define cosine similarity of two documents in case of information retrieval; hence negative frequencies are not acceptable. The value of the angle should not more than 90. Centred cosine similarity it means the attribute vectors are normalized by subtracting the vector that is the measureand is same to the Pearson Correlation Coefficient. Lastly, a dissimilarity score is computed from all pairwise distances between an input test gesture and the enrolled samples corresponding to an identity as follows,

$$\text{Score}(\pi, \sigma)=\sum_{i=1}^{N}\left(\frac{\text{distance }(\pi,\sigma i)}{\sum_{j=1}^{N}\text{distance }(\sigma j,\sigma i)}\right)[2]$$

Wherei= 1. . . N, σ= {σi}, π=test gesture,
Andσ=enrolled gesture
If score (π, σ)is less than a predefined threshold then system accepts a test gestureπ otherwise it rejects. FAR or False Acceptance Rate means the system wrongly accepts an impersonation gesture or a biometric. FRR or False Rejection Rate is the rate at which the system wrongly rejects a gesture.Equal error rate (EER) is an algorithm in biometric security system which is used to determine the threshold values for false rejection rate and false acceptance rate. If the rates are equal, then common value is called as the equal error rate [4].

TABLE 4. FEATURES SET [2] [6]

Annotation	**Palm Movement**	**Fingertip movement**	**Dynamic Fingertip**
‘CCW’ ‘CW’ ‘Pinch’ ‘Drag’ ‘DDC’	Static Static Static Dynamic (↓) Dynamic (↘)	Circular (CCW) Circular (CCW) Close Parallel Close	All All All All All
‘DUO’ ‘FDB’ ‘FBSB’ ‘FASB’ ‘FPCCW’	Dynamic (↖) Static Static Static Static	Open Parallel(↓) Parallel (shape) Parallel (shape) Circular (CCW)	All Fixed thumb and pinky Fixed thumb and pinky Fixed thumb and pinky Fixed pinky
‘FPC’ ‘FPO’ ‘FPP’ ‘FTCCW’ ‘FTCW’	Static Static Static Static Static	Close Open Parallel(↓) Circular (CCW) Circular(CW)	Fixed pinky Fixed pinky Fixed pinky Fixed thumb Fixed thumb
‘FTC’ ‘FTO’ ‘FTP’ ‘Flick’ ‘Opened’	Static Static Static Dynamic (↘) Static	Close Open Parallel(↓) Parallel Open	Fixed thumb Fixed thumb Fixed thumb All(Quick) All
‘swipe’ ‘User-defined’	Dynamic (⟶) Dynamic	Parallel Parallel	All All

Verification performance of the proposed multi-touch gesture verification system is given by these rates, namely EER, FAR and FRR. Table 4 shows different feature notations. Here for circular movement, CW stands for Clock Wise and CCW stands for Counter Clock Wise.

TABLE 5.EER FOR DTW DISTANCE FUNCTION OF 20 FEATURESSET WITH THREE DIFFERENT COST FUNCTIONS [2]

Gesture	**Manhattan**	**Euclidean**	**Cosines**
‘CCW’	5.50	4.95	8.14
‘CW’	7.21	7.26	9.45
‘Pinch’	8.34	9.02	9.15
‘Drag’	9.50	9.56	8.69

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'DDC'	4.46	4.43	8.14
'DUO'	6.80	6.53	8.70
'FDB'	11.53	11.62	13.13
'FBSB'	6.85	7.89	6.61
'FASB'	9.96	9.84	11.27
'FPCCW'	10.60	10.60	10.63
'FPC'	8.83	8.87	11.46
'FPO'	13.32	14.45	12.42
'FPP'	11.01	10.80	13.85
'FTCCW'	4.48	4.54	5.33
'FTCW'	6.22	6.42	7.98
'FTC'	5.88	5.94	8.88
'FTO'	9.52	9.39	9.98
'FTP'	4.66	4.91	7.36
'Flick'	10.75	10.98	12.85
'Opened'	6.80	8.02	9.90
'swipe'	8.25	9.00	10.14
'User-defined'	2.98	2.85	5.86
Average EER	**7.88**	**8.09**	**9.54**

The results from the algorithm described using three cost functions are reported in Table 2. Visualization of clockwise rotation gesture samples (CW). Specifically, using a single instance of multi-touch gestures, the system achieves verification performance at 7.88% EER on an average. Author seen that Manhattan distance have slightly better performance than Euclidean and the cosine distance. So, Manhattan distance was used as the cost function[2].

V. THRESHOLDING

As stated earlier threshold value is selected based on the minimum error criterion and dissimilarities between all the signatures of all the system are computed [1].The simplest approach to segment an image is using thresholding[7].
If f (x, y) >T then f (x, y) □ □ 0 elsef (x, y) □ □ 255

A. Automatic thresholding
To make segmentation more robust, In Automatic thresholding the threshold should be automatically selected by the system. To choose the threshold automatically knowledge about the objects, the application, and the environment should be used[7].

B. Choosing the threshold using the image histogram
In the histogram regions which have uniform intensity starts to increase to strong peaks. In this casemultilevel thresholding is also possible[7].

C. Hysteresis thresholding
Various background pixels which have the same gray level value with object pixels means that histogram of an image have not clear valley.

Pixels below the low threshold are classified as background and above the high threshold asobject.

If pixels are adjacent to other object pixels and they are between low and high thresholds then it classified as object[7].

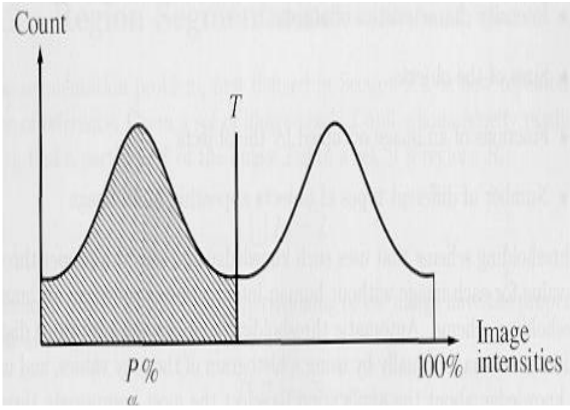

Figure 2. Histogram of thresholding[8]

VI. CONCLUSION

In this paper we have studied Gesture Normalization techniques such as intriguing technique and block scaling. Also we have studied different feature extraction techniques, which can be compared based on FAR, FRR and ERR and in that techniques projection based technique have best performance as shown in table no 2.

Also we have studied Distance evaluation techniques such as Manhattan Distance, Euclidean Distance, Cosine Distance and Jaccard Distance out of which Manhattan Distance and Euclidean Distance gives best performance as per the results shown in table no 5.
In this paper also we have studied Thresholding techniques such as Automatic thresholding, choosing the threshold using image histogram and Hysteresis thresholding.

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