A Geometric Approach for Personal Authentication based on Finger Back Knuckle Surface using Tangents and Secants

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ABSTRACT
Biometric based Personal authentication is still active research problem due to various issues such as providing high accuracy, computationally less complex feature extraction method and fusion strategy of multiple feature information. In this work we propose a personal authentication system using one such hand based biometric trait, Finger Back Knuckle Surface (FBKS). The texture pattern produced by the finger back knuckle intact surface is highly unique and makes the surface a distinctive biometric identifier. In comparison with existing approaches, which do not extract any angular data as feature information, this method extracts angular information using geometric analysis based on Tangents and Secants. This system acquires knuckle images using automated low resolution contact less method. In this, image pattern of both primary knuckle and core knuckle is completely considered as a Intra knuckle parameters of Finger back knuckle intact surface. The feature information of FBKS various fingers such as Left Index Finger, Left Middle Finger, Right Index Finger and Right middle Finger are extracted and fused using matching score level fusion. The experiments were conducted using newly created database for FBKS consists of samples collected from 100 volunteers. The experimental results from the proposed approach are promising and confirm the usefulness of such an approach for personal authentication.

General Terms
Personal Authentication, Finger Back Knuckle Surface, Geometric approach, Feature extraction

Keywords
Edge detection, Tangents and Secants, angular information, Matching score level fusion, correlation coefficient.

1. INTRODUCTION
Identifying a person based on hand traits is a significant research area of biometrics with applications in access control and various other security problems. Recognition using hand based biometric system is done by analyzing the overall structure of the hand with characteristics such as shape, length, width, ridges and creases [1]. The primary goal of such kind of recognition system is maximize the performance of the system.

The biometric authentication system have two stages First stage is an 'enlistment' stage – In which biometrics traits such as palm prints or finger prints are sample mobilized. The measurement of biometric trait is done and the information of the biometric characteristic measurements is enrolled in the database [2]. The second stage is 'liberate' stage - In which Mobilization of a new input biometric characteristic is done and then authentication process is done.

Hand based Biometric system can be called as frequently used personal authentication system with certain benefits among all other biometric traits[3]. Benefits of hand based biometrics can be given as follows (i) High User acceptability (ii) less prone to encroach (iii) Verification accuracy can be given by exploiting less number of features. (iv)Computational complexity for feature extraction can also be reduced. (V) Failure to enroll rate can be reduced [4]. Various modalities of hand based biometrics are Finger prints, Palm prints, Finger Knuckle prints, Palm side of the finger Knuckle etc.,

In this paper one of the hand based biometric trait Finger Knuckle Print is chosen. Texture pattern obtained from finger knuckle print is unique and birth feature of all human hands [5]. Finger Knuckle Print is accepted as a distinctive biometric identifier. There are many works in the literature for feature extraction based line and texture patterns of Finger knuckle print.

In the proposed work of [6] authors deploy a personal authentication system using Two dimensional finger back surface features. Further processing of two dimensional finger back surface features is done by means of extraction of line orientation features [7]. There is also some of the work which discusses knuckle print texture analyses based on location and line features [8]. In [9] also analyzed knuckle surface patterns based on fusion strategies.

This paper focuses on extraction of angular information by means of geometric analysis using tangents and secants. This method identifies features such as hybrid curves from the normalized input image. From the convex curves, feature points such as knuckle edge and Knuckle mid points were identified. Geometrical structures like Tangents and secants were constructed using the feature points to mine distinct angular information.

This paper is organized as follows. The paper commences with the discussion of existing recognition methods for the finger knuckle prints as a biometric trait. And proceeds with the brief discussion about the proposed technique for feature extraction from the Finger back knuckle surface. In depth analysis about the calculation of matching score and fusing of matching scores using matching score level fusion. Illustration of classification technique, which processes the similarities between the reference and input image for biometric authentication, is provided. Explanations of experimental set up in the mode of verification and identification is discussed. The results discussions are presented in the subsequent section. This paper concludes with a illustration of performance of the proposed technique and with the idea for future work.

2. Existing Work

A number of techniques for personal authentication based on hand based biometric traits such as palm print, finger prints have been proposed in the literature. Most of the Hand based biometric trait recognition methods primarily employ three types of feature extraction algorithm, such as, Line based, Texture based, Statistical based. [10] Line based feature extraction schemes are different edge detection methods are used to extract palm lines – Principles lines, wrinkles, ridges. The extracted edges directly or being represented other formats. In the Line based, palm lines are adopted as biometric feature would result in the possibility for more than one person having similar principal lines. [11]

Texture based extraction schemes, in which images are divided into blocks, where the variations exist in either blocks of images are extracted. In these concept techniques like Gabor filters, Ordinal filters, minutiae feature offer promising results. Some popular transform such as Discrete Wavelet transform Gabor Filters, Discrete Cosine Transforms, Discrete Fourier Transforms are used for extracting features from image data.

In [12] Online palm print identification system employs low-resolution palm print images to achieve effective personal identification. In this system a novel device for online palm print acquisition and an efficient algorithm for fast pal print recognition with 2D Gabor phase encoding scheme is proposed for palm print extraction or representation.

In this paper online system refers to a system which captures palm print images using a palm print capture sensor that is directly connected to a system for real time processing. In this paper, authors have identified three issues in developing online palm print identification.1.Palm print acquisition, 2. Palm print feature representation 3. Palm print identification.

In this [13] paper presented a new approach to achieve reliable personal authentication based on simultaneous extraction and combination of multiple biometric features extracted from 3-D and 2-D images of the human hand. The proposed approach in this paper acquires hand images in a contact-free manner to ensure high user friendliness simultaneously captured range and intensity images of the hand are processed for feature extraction and matching. The proposed method of 3-D hand-geometry features explicitly capture curvature variation on the cross-sectional finger segments. Simple and efficient metrics, capable of handling limited variations in the hand pose, are proposed for matching a pair of 3-D hands. In this authors were also introduced a new feature representation, namely, Surface Code, for 3-D palm print which achieves better performance. The experimental results on a database of 177 subjects demonstrate that the 3-D hand-geometry features have high discriminatory information for biometric verification. Besides hand-geometry information, other hand biometric features such as 2-D Palmprint, 3-D Palmprint, and 2-D finger texture can also be simultaneously extracted from the acquired images. Therefore, we investigated the potential of integrating these hand-based features into our unified framework and obtained the best performance when all of the features are combined.

In this [14] paper has presented a new approach for personal authentication using the finger back surface. The developed system automatically extracts the knuckle texture and simultaneously acquires finger geometry features to reliably authenticate the users. The proposed method of knuckle region segmentation, finger ring detection, and the extraction of finger geometry features has been quite effective in achieving higher performance.

The system is rigorously experimented on a specially acquired finger back image database from 105 users and achieved promising results. The appearance-based features are extracted from the segmented knuckles using subspace methods and a comparative study is reported. The palm print and fingerprint features can be simultaneously extracted from the palm-side hand images and combined to achieve performance improvement.

In [15] this paper, a new approach to authenticate individuals using triangulation of hand vein images and simultaneous extraction of knuckle shape information. The Proposed method of this paper is fully automated and employs palm dorsal hand vein images acquired from low cost, near infrared, contactless imaging. The knuckle tips are used as key points for the image normalization and extraction of region of interest.

In [16] investigates a new approach to quantify the quality of sensed data to generate a reliable estimate on the matching scores. The proposed method is based on the quality of the user templates. In this work, authors have proposed a bimodal biometric system with palm print and hand shape images from a single hand image. The biometric measurement for finger knuckle print is also presented in this work. The user quality is defined as from the associated biometric sample and quantified as a measure of confidence of user biometric sample with its own templates. In this approach a single quality measure for a user is estimated from its genuine training matching scores. This type of quality is the quality for the biometric of the user, rather than the quality of an image, and hence, it is termed as user quality. Feature Extraction for palm print images is done by extracting effective based on geometrical information or geometry plus interior content. The 17 features are characterized in every hand shape image - Perimeter, four finger lengths, eight finger width, palm width palm length, hand area and hand length are extracted. Matching process is done by means of Euclidean norm. DCT decomposition for the characterization of fixed size palm print images.

The matching scores are generated in stages - 1) Hierarchical matching score from the four topologies of triangulation in the binarized vein structures and 2) From the geometrical features consisting of knuckle point perimeter distances in the acquired images.

The weighted score level combination from these two matching scores are used to authenticate the individuals. The weighted score level combination from these two matching scores are used to authenticate the individuals. The experimental result of a system produces high performance with equal error rate of 1.14 %.

From the study conducted with the existing works in the Literature for Recognition methods of Finger Knuckle Print, the analysis shows some of the limitations. In some of the texture analysis methods the accuracy of the system is mainly depends upon the knuckle segmentation methodology. The more accuracy can be obtained with the more accurate segmentation, which gives rise to two different tradeoffs – User acceptability and Computational Complexity. According to the existing works with the low quality images the accuracy can be obtained by more number of portioned blocks which in turn increases computational complexity. It has been identified that there is a need of the multimodal biometrics approach which exploits the subset of features by means of geometrical analysis.

3. Implementation Model

The figure 1 shows the block diagram of Implementation model of Personal authentication System using FBKS. This model of personal authentication system has two stages, the first stage is enrollment stage – In which, the captured FBKS image can be called as Reference image are mobilized. The feature extraction from the FBKS reference image and feature information representation is done by means Geometric analysis based on Tangents and Secants Method. The information obtained is registered in the database to form the template for Personal authentication system. The second stage is 'authentication' stage – in which mobilization of a new input FBKS image is done to extract the biometric characteristics information and then compared with the registered template in the database.

4. Preprocessing and ROI extraction of FBKS

The preprocessing of the captured FBKS image is done to extract two different knuckle patterns. Figure 2 illustrates the two different knuckle pattern namely Primary knuckle and Core Knuckle of the FBKS. The segmentation of the captured FBKS image is done by incorporating the coordinate system. This is achieved by defining the x- axis and y-axis of the captured image. The base line of the finger is taken as x-axis. The y-axis for two different knuckle patterns in the finger is defined by means of convex curves determined from the edge record of the canny edge detection algorithm [13]. The curvature convexities of the obtained convex curves were determined for both Primary and Core Knuckle Pattern. The Y axis of the primary and Core Knuckle are resolute by means of the curvature complexity which is nearly equal to zero at the center point. By this method, ROI is extracted from the FBKS which of 100x80 pixel size for Primary knuckle region and 220x110 pixel size for Core knuckle region. The extracted ROI image consists of area contiguous to the joints of the FBKS, which consists of points, lines and cuvees for feature information extraction.

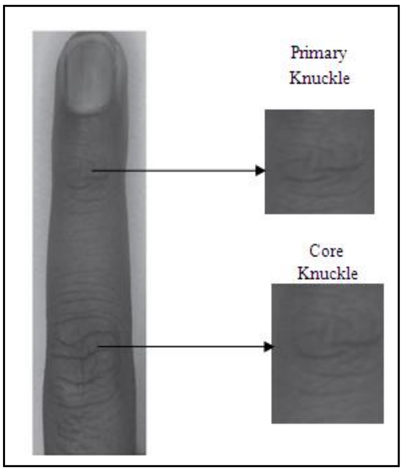

Figure 1: Illustration of Primary and Core Knuckle ROI pattern of FBKS

5. Geometric Analysis based on Tangents and Secants Method.

The features extracted by Tangents and Secants method are significant and also must not diverge for given reference or input FBKS image in the course of time. This method incorporates the features of both the Core Knuckle and Primary Knuckle. This method initially identifies FBKS feature points such as Knuckle edge points and Knuckle Mid points from both the primary and core knuckle surfaces.

5.1 Knuckle Edge Identification

Knuckle edge points were identified by means of Canny Edge detector algorithm [13][17], which identifies the curved feature from both primary knuckle and core knuckle surfaces of FBKS. These curves can be called as Hybrid convex curves, since it curves both leftwards and rightwards of the knuckle region as shown in the figure 3.

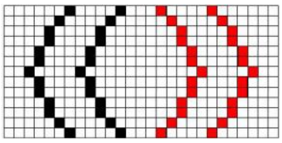

Figure 2: Illustration of Convex Curves obtained from FBKS.

From the identified convex curves, knuckle edge points were calculated. It is done by establishing sequence of points that the line passes through. Edge in the obtained is identified by the concept that the edges are the areas with the contrast in intensity. The intensity level in the edge varies from one pixel to the next pixel. Based on this criterion, the canny algorithm is the gradient based algorithm which highlights the maximum derivative region by restraining the pixel that is not maximum. Edge thresholding is used in this algorithm to identify the edge pixel which is above the high threshold. The edge points identified by means of convex curves can be named as Primary Knuckle Edge Right (PKER) and Primary Knuckle Edge Left (PKEL). For the core Knuckle edge points are named as Core Knuckle Edge Right (CKER) and Core Knuckle Edge Left (CKEL).

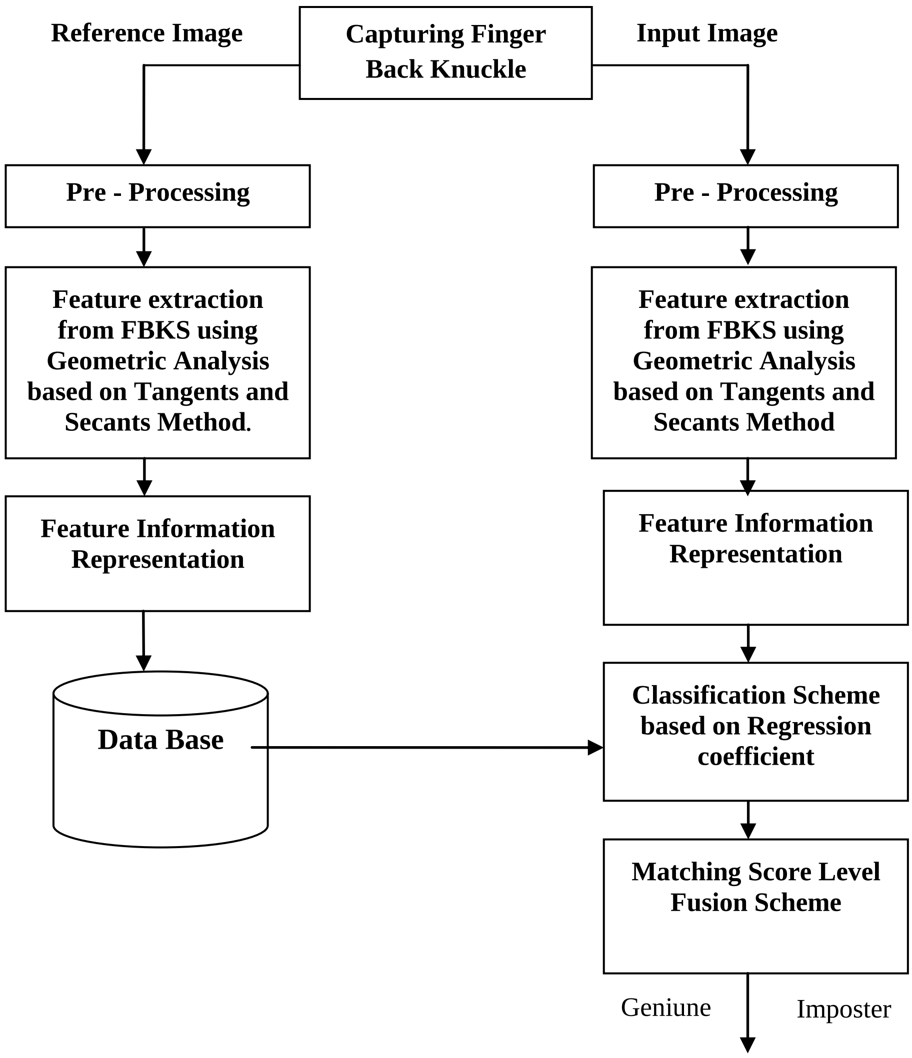

Fig 3: Block Diagram of Implementation Model for Personal Authentication System using FBKS

5.2 Knuckle Mid Point Identification

Knuckle Mid identification is done by the determination of X-axis and Y-axis of the knuckle image as shown in the figure 2 (d). The axis identification is also done based on the canny edge detection algorithm. The X-axis can be captured from the acquired image itself. By considering the bottom boundary is a straight line, local coordinate system is determined. The hybrid curves identified from the canny edge algorithm curves both the sides. There are some area around the middle surface of the FBKS contains some of the lines whose curvature convexity is nearly equal to zero. One such line is identified around the center of the curved surface of the knuckle and it is used to set the Y-axis. The midpoint of the Y axis line is taken as Primary Knuckle Mid Point (PKMP). Similarly, Y' is y-axis of the core knuckle, the knuckle mid point is identified as the mid point of the Y' axis and it is named as Core Knuckle Mid Point (CKMP).

5.3 Tangents and Secants Method.

Tangents and Secants Method of proposed work enables to construct various geometrical structures on identified knuckle features. In this method, geometrical structures like circles, Tangents, Secants were constructed using Primary knuckle edge points, Core Knuckle Edge points, Primary Knuckle Mid Point and Core Knuckle Mid Point. From the identified Core Knuckle Mid Point (CKMP), a circle is constructed with the distance between CKMP and CKER as radius and it is named as circle 'R_c'. From the identified Primary Knuckle Mid Point (PKMP), which is away from the circle, the following structures were constructed, (1) Two tangents were constructed to the circle, (2) Two Secants were constructed to the circle, (3) A tangent and a secant is constructed to the circle. All the structures were constructed from the identified knuckle feature points are shown in the figure 4.

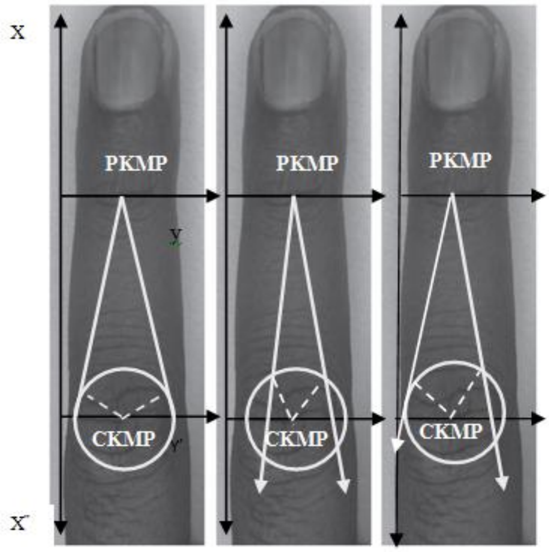

Figure 4: Illustration of Tangent and Secant Method using Core Knuckle Parameters

Similar structures were constructed using the feature points of Primary Knuckle. From the identified Primary Knuckle Mid Point (PKMP), a circle is constructed with the distance between PKMP and PKER as radius and it is named as R_p. From the identified Core Knuckle Mid Point (PKMP), which is away from the circle R_P, the following structures were constructed, (1) Two tangents were constructed to the circle, (2) Two Secants were constructed to the circle, (3) A tangent and a secant is constructed to the circle. All these structures were constructed from the identified knuckle feature points are shown in the figure 5.

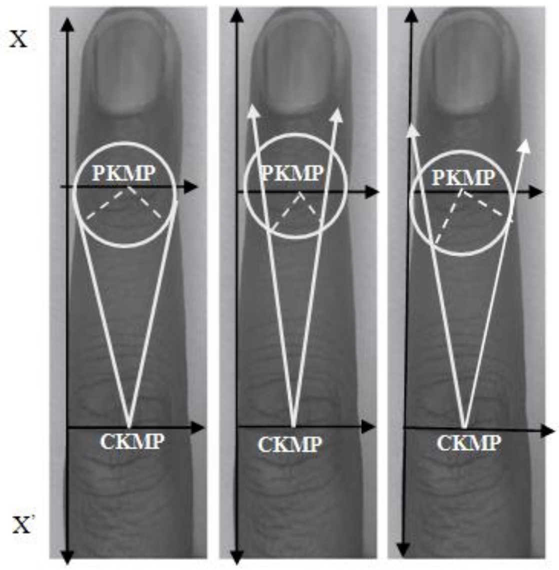

Figure 5: Illustration of Tangent and Secant Method using Primary Knuckle Parameters

Let Θ be the angle formed by each set of constructed geometrical structures such as (1) Tangent-Tangent (2) Secant – Secant (3) Tangent – Secant. The angle value of the Θ can be calculated by the equation given below.

$$\theta = \frac{far\ arc\ length - near\ arc\ length}{2} \tag{1}$$

The far arc can be defined as the arc formed by the each set of constructed geometrical structure which is away from the point from where these structures were constructed.

The near arc can be defined as the arc formed by each set of constructed geometrical structure which is nearer for the point from which these structures were constructed. The far arc and near arc lengths can be computed by calculating the angle formed by the sector which is equivalent to the arc length. The far and near arc angle can be calculated as below.

$$\measuredangle NearArc(angle) = \frac{a^2 + b^2 - c^2}{2bc} \tag{2}$$

$$\measuredangle Far\ Arc(angle) = 360 - \measuredangle NearArc(angle) \tag{3}$$

$$Near\ Arc(length) = \frac{NearArc(angle)}{180} * \pi * r \tag{4}$$

$$Far\ Arc(length) = \frac{Far\ Arc(angle)}{180} * \pi * r \tag{5}$$

5.4 Feature Information Representation.

Angular information extracted by means of Tangents and Secants method by considering both the Primary and Core knuckle parameters are represented in the form of vectors. The obtained angular information can be named as Core Angle Tangent-Tangent (CATT), Core Angle Secant-Secant (CASS), Core Angle Tangent-Secant (CATS), Primary Angle Tangent-Tangent, Primary Angle Secant-Secant and Primary Angle Tangent-Secant. These information were stored in two different vectors known as $VRef_{core}$ and $Vref_{Primary.}$ Similarly for input image the vectors obtained is $VInp_{core}$ and $VInp_{Primary}$

6. Classification Scheme

Classification Scheme is defined and developed based on regression coefficient analysis. The regression coefficient gives the differences between dependant values by varying the independent values. The geometrical information obtained from the FBKS based on Tangents and Secants Method is stored in two different reference vectors namely as $VRef_{core}$ and $Vref_{Primary.}$

The regression analysis between the values from the two different vectors $VRef_{core}$ and $VInp_{core}$, $Vref_{Primary}$ and $VInp_{Primary}$, can be defined by the regression coefficient by analyzing the dependency upon x value on y value. The x value is taken from the reference vector and the value is obtained from the input vectors.

Regression coefficient dependency x on y can be determined by means of equation (4)

$$RC = \frac{\sum((x-\bar{x})*(y-\bar{y}))}{\sum(y-\bar{y})^2}$$

The coefficient RC is obtained is analyzed to find the percentage of variance between the compared vectors.

7. Fusion Scheme

Matching Score level fusion [18] scheme is adopted to consolidate the matching scores produced by Knuckle surface of the single finger. In the Matching score level, different rules can be used to combine scores obtained by biometric systems. All these approaches provide significant performance improvement. In this paper, weighted rule has been used. In the weighted rule, for example if S1, S2, S3 and S4 represent normalized score obtained from Finger back knuckle surface of Left Index Finger, Right Index finger, Left middle finger and Right middle finger respectively. The final score SF is computed using (5)

$$S_F = w_1S_1 + w_2S_2 + w_3S_3 + w_4S_4 \quad (5)$$

where w_0, w_1, w_2 and w_3 are weights associated with the units define in the

$$w_i = \frac{EER_i}{\sum_{k=1}^{t} EER_k} \quad (6)$$

EER_k is Equal Error Rate obtained by considering single feature extraction method.

8. Experimental analysis and Results Discussions

To evaluate the performance of Personal authentication system based on Intra Knuckle Parameters is done by creating a new database of 120 samples of Finger Back Knuckle Surface. This FBKS database consists of images with size 120×300, captured from 60 male and 60 female volunteers in two different sessions. In this multiple feature information are exploited and the results are given in the form of comparison and combination using the same database. The experiments were conducted and the performance of the method is experimentally certified by computing Genuine Acceptance Rate, False Rejection Rate and comparing this with the existing Finger Knuckle geometric Method, Palm and Knuckle print method and Hand vein geometric method.

Experiment 1:

The goal of the experiment is to evaluate the performance of Tangents and Secants Method by exacting features from Single Finger, fusion of Two Fingers type, Fusion of Three Fingers type and all the four fingers in both verification and identification mode. The following table I illustrate the GAR values obtained from the different experimental analysis.

TABLE I. GAR % FOR DIFFERENT VALUES OF FAR % FOR VARIOUS FEATURES AND COMBINATIONS OF FUSION.

Sl.No	Features	GAR		
		FAR =0.5%	**FAR = 1%**	**FAR = 2%**
1	Left Index Finger (LI)	85	89	82
2	Left Middle Finger (LM)	79	80	83
3	Left Ring Finger (LR)	82.5	84	85
4	Left Little Finger (LL)	85	89	91
5	LI +LM	87	89	92
6	LI+LR	89	92	92
7	LI+LL	90	93.5	94.5
8	LM+LR	87	96.5	97
9	LM+LL	92.5	97	97
10	LR+LL	83	92	93
11	LI+LM+LR	94	96.5	97
12	LI+LM+LL	94.5	97.5	98.5
13	LM+LR+LL	95.5	98.5	98.5
14	LI+LR+LL	96	97	98
15	LI+LM+LR+LL	97.5	98.6	98.9

The following figure 6 shows the graphical representation of comparison of performance of the Tangents and Secants Method by analyzing the individual results of the four fingers in verification mode.

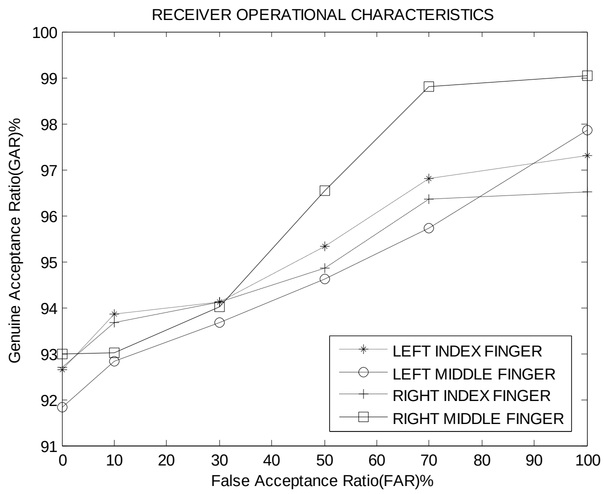

Figure 6: ROC obtained using Tangent and Secant Method on four different fingers in Verification Mode.

The following figure 7 shows the graphical representation of comparison of performance of the Tangents and Secants Method by analyzing the individual results of the four fingers in identification mode

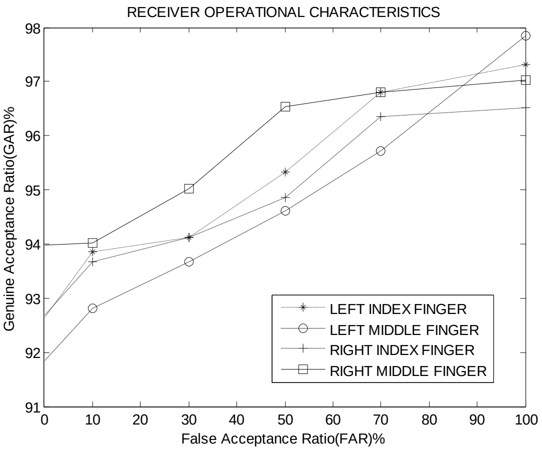

Figure 7: ROC obtained using Tangent and Secant Method on four different fingers in Identification mode

Experiment 2:

In this experiment, the comparison of proposed Tangents and secants method with existing methods in Verification mode is exercised and results were tabulated in Table II.

Finger Geometric Method: In this method, six geometrical feature information is obtained from the Finger Knuckle Print. Along with that Knuckle texture information identified by means of PCA, ICA and LDA algorithms. The result obtained for the fixed dimension of feature vector.

Palm print and Hand Shape Method: In this method, Palm print texture information is obtained by applying PCA algorithm to the entire image. The Hand shape information is obtained by various control points in the acquired hand image. In addition to that, Finger knuckle information is used to improve the performance.

Hand Vein Geometric Method: In this method, Delaunay triangulation is used to extract hand vein structure information and geometrical methods for extracting the Knuckle shape information. Using this method, this limits to selected set of feature vector. The following table I illustrates the comparison of AGAM with the existing work.

The comparison of proposed Tangents and secants method with existing methods in Identification Mode is illustrated in Table III.

Palm Print and Knuckle Print (PKP): In this method, PCF is used to find the correlation between input and reference images. The modalities are subjected to DFT to identify he phase difference. The result obtained for the fixed dimension of feature vector.

Finger Knuckle Print (FKP): In this method, the quantification of the gray scale information is done by means of AAD method. The combination of PCA and ICA were used to utilize the most prominent information the FKP.

TABLE II .COMPARISON OF RESULTS OF TANGENTS AND SECANTS METHOD WITH EXISTING METHOD IN VERIFICATION MODE.

Reference	Data set	Feature Extracted	Results
Finger Knuckle Geometric Method	103 users of FKP	Finger Length , width, area, Perimeter.	EER 1.39%
Palm Print and Hand Geometric Method	100 users of hand image database	Palm Print texture, Knuckle Length, width,	EER-2.22%
Hand Vein Geometric Method (HVG)	100 users of hand back surface	distances, vein geometrical information	EER - 1.77%
FBKS - Tangents & Secants method	100 users of Finger Back surface	Distances, Magnitudes Angular Information	EER - 0.62%

TABLE III. COMPARISON OF RESULTS OF TANGENTS AND SECANTS METHOD WITH EXISTING METHOD IN IDENTIFICATION MODE

Reference	Data set	Feature Extracted	Results
Finger Knuckle & Palm PCF Method	PolyUFKP PolyUPP	Palm & Knuckle Texture	EER 1.589%
Palm Knuckle Print PCA& ICA	PolyUFKP,	Knuckle Texture coding information	EER- 2.72%
FBKS - Tangents & Secants method	100 users of Finger Back surface	Distances, Magnitudes Angular Information	EER - 0.95%

The following figure 8 shows the graphical representation of comparison of performance of the Tangent and Secant Method with the existing methods. The accuracy of the proposed Method is proved to be better than the existing methods in the literature

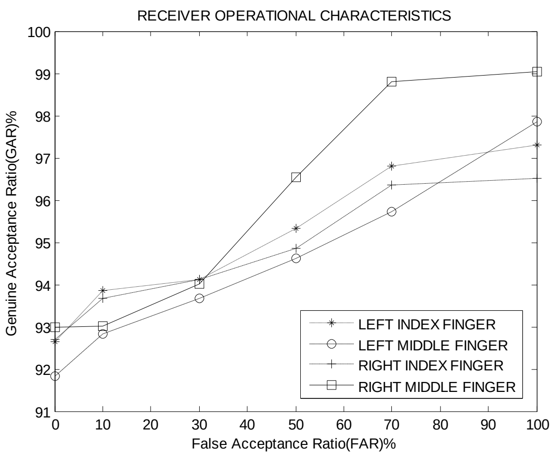

Figure 8: ROC obtained using Tangent and Secant Method compared with existing methods in Verification mode

The following figure 9 shows the graphical representation of comparison of performance of the Tangents and Secants Method with the existing methods. The accuracy of the Tangents and Secants Method is proved to be better than the existing methods in the literature.

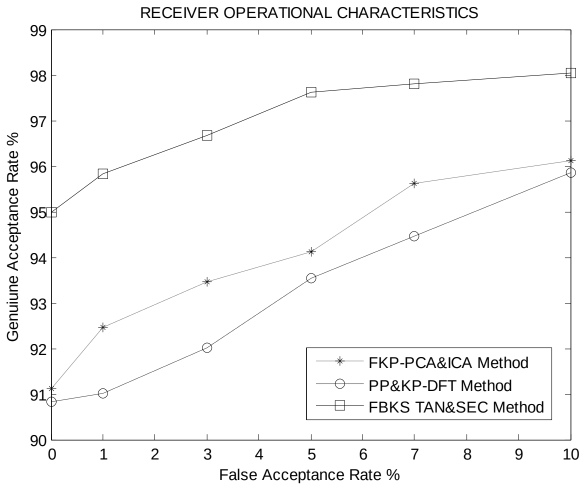

Figure 8: ROC obtained using Tangent and Secant Method compared with existing methods in Identification mode.

The discussions about the results of an experimental study were presented below.

(i) Tabulation of results for various feature combination suggest that there is significant improvement in performance using the Intra Knuckle Parametric Method.

(ii) From this experiment, It is also been proved that the Finger back knuckle surface as a biometric identifier achieves better performance similar to that of other biometric traits which has been under research for longer time such as finger prints.

(iii) In the conducted experiments, there is no single fusion combination best performing type. Different fusion combination performs better during the different experimental types.

(iv) When using the finger prints in the same experimental setup there was 1.67% difference in performance.

(v) Also using the finger print in the fusion experimental setup, there was 2.57% difference in the performance obtained.

9. Conclusion

The Geometrical analysis based Tangent and Secants method for personal authentication based on of FBKS surface is well examined in this paper. The feature information is obtained from both core knuckle and primary knuckle parameters. The constructing some of the geometrical structures like circles, tangents an secants from the identified feature points like knuckle edge points and mid points. Using this, Tangent and Secant Method derives the feature information in terms of angles. The obtained information is classified by means of regression coefficient. To achieve better performance matching score level fusion is applied on features extracted from four finger of the hand. Experimental results clearly demonstrate the competency of the Tangents and Secants method. Performance of the proposed system is also analyzed by means of computational complexity for feature extraction also found to be less.

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