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A Novel Method of Envisaging Thumb Features from Middle Finger Width

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Abstract- The anatomy of the hand is complex, intricate, and fascinating. Hands may be affected by many disorders, most commonly traumatic injury. In treating hand problems, the mastery of anatomy is fundamental in order to provide the best quality of care. The focus in this paper is on predicting geometric features of thumb from the known width of the middle finger. Geometric features of both the hands from 100 people of different age group were extracted from the silhouettes. The proposed method can be used to predict length of the thumb, position of knuckle from the finger tip and also thumb width at the above and below knuckle using taalamana system and shilpa shastra. The estimation accuracy of more than 90% is achieved for TFL, TFW1 and TL features and around 85% accuracy is achieved for TFW2 feature of the thumb.

Index Terms— thumb features, golden ratio, taalamana system, iconography, human hand

1. Introduction

Human hand is the terminal part of the upper limb, used to manipulate the environment. It is a highly mobile organ, capable of fine discriminative function and manipulation, both of which require a copious blood supply [26]. Its integrity is absolutely essential for everyday functional living. Construction of the thumb when only middle finger width is known is a challenging task. In view of this thumb features are estimated using taalamana system and golden mean.

In case of accidents if only partial knowledge of the finger is available, then the proposed method can be used to obtain complete knowledge of the damaged part. In medical science when it is necessary to replace any part of the human body like fingers, it can be constructed using the features estimated by our proposed method for perfection in the plastic surgery.

1.1 Taalamana system

Iconography is the branch of art history which studies the identification, description, and the interpretation of the content of images. The word iconography literally means "image writing". The idea of constructing human hand is derived from Silpa Shastra. It has developed its own norms of measures and proportions. It is a complex system of iconography that defines rigid definitions [1,21,22]. The shilpa shastra normally employ divisions on a scale of one (eka tala) to ten (dasa tala). Each tala is subdivided into 12 angulas. It is called Taalamana paddathi or Taalamana system, the system of measurements by Tala, the palm of hand i.e. from the tip of the middle finger to the wrist as shown in figure 1.

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1.2 Golden ratio

Two quantities are in the golden ratio if the ratio of the sum of the quantities to the larger quantity is equal to the ratio of the larger quantity to the smaller one. The golden section is a line segment divided according to the golden ratio. If a and b are the lengths of the larger and smaller line segments respectively, then golden ratio is represented as shown in equation 1.

$$\frac{a+b}{a} = \frac{a}{b} = \Phi(Phi) \qquad (1)$$

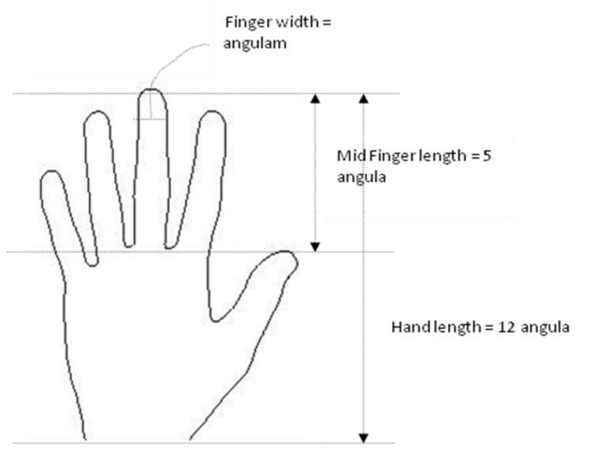

Figure 1: Computation of Middle finger length

The paper is organized into five sections. Introduction to taalamana system and golden ration are given in first section. Related work is discussed in the second section. Mathematical model is enumerated in section 3. In section 4 the proposed method is discussed and the simulation results are presented in section 5.

2. Literature Recapitulation

Geometric measurements of the human hand have been used for identity authentication in a number of commercial systems. Anil K.Jain and others have worked extensively on hand geometry specifically for identification and verification systems [6,7,8]. There is not much open literature addressing the research issues underlying hand geometry-based identity authentication; much of the literature is in the form of patents [2, 3, 4]. Hand geometry recognition systems may provide three kinds of services like verification, classification and identification [12]. A novel contact-free biometric identification system based on geometrical features of the human hand is developed by Aythami Morales and others [11]. A component-based hand verification system using palm-finger segmentation and fusion was developed by Gholamreza and others. The geometry of each component of the hand is represented using high order Zernike moments which is computed using an efficient methodology [15].

Windy and others have used geometric measurements to study the sexual orientation. The ratio of the length of the second digit (2D) to the length of the fourth digit (4D) is greater in women than in men. This ratio is stable from 2 years of age in humans [9,10]. Gender classification from hand images in computer vision is attempted by Gholamreza and others [16].

Issac Cohen and others have worked on 3D hand construction from silhouettes of 2D hands [13]. Digital and metacarpal formulae are morphological variables which may also have functional significance in the understanding of how certain hand forms may be ill-fitted for certain tasks [14].

T.F.Cootes and others have worked on active shape models [17,18] which laid foundations for statistical shape analysis using Procrustes analysis, tangent space projection and Principal Component Analysis[19]. Geometric hand measurements are also used in hand gesture classification using a view-based approach for representation and Artificial Neural Network for classification [20].

3. Mathematical Model

Prediction of finger length, position of knuckles and finger width at the first and second knuckle of the thumb are computed using taalamana system and golden ratio. The golden mean or ratio can be computed mathematically as shown in equation 2 and 3.

The middle finger length (MFL) is computed as five times the middle finger width (MFW1). Thumb length (TFL) is computed using equation 4. Thumb width (TFW1 and TFW2) are computed with the help of equation 5 and 6.

$$\frac{\sqrt{5}+1}{2} = \Phi(Phi) = 1.6180339 \qquad (2)$$

$$\frac{\sqrt{5}-1}{2} = \Phi(phi) = 0.6180339 \qquad (3)$$

Position of the knuckle from finger tip (TL) is computed using the equation 7.

$$TFL = (phi * MFL) + \left(\frac{MFW1}{3.0}\right) \qquad (4)$$

$$TFW1 = MW1 \qquad (5)$$

$$TFW2 = MFW1 + \left(\frac{MFW1}{16.0}\right) \qquad (6)$$

$$TL = \left(\frac{TFL}{2.0}\right) + \left(\frac{MFW1}{9.0}\right) \qquad (7)$$

4. Proposed Method

Silhouettes of both the hands of 100 users are taken. 24 features are extracted as discussed below. For middle finger five features namely Middle Finger Width 1 (MFW1), Middle Finger Width 2 (MFW2), Middle Finger Length (MFL), Position of first knuckle from bottom(ML1) and position of second knuckle from finger tip (ML2) are extracted. Similarly for fore or index finger, ring finger and little finger these five features are collected and four features for the thumb totally to 24 feature set. Figure 2 illustrates feature extraction of thumb. From first width of the middle finger (MFW1), the values of TFL, TFW1, TFW2 and TL of thumb are estimated. The actual and estimated values of a subset of samples are tabulated in table 1 and 2.

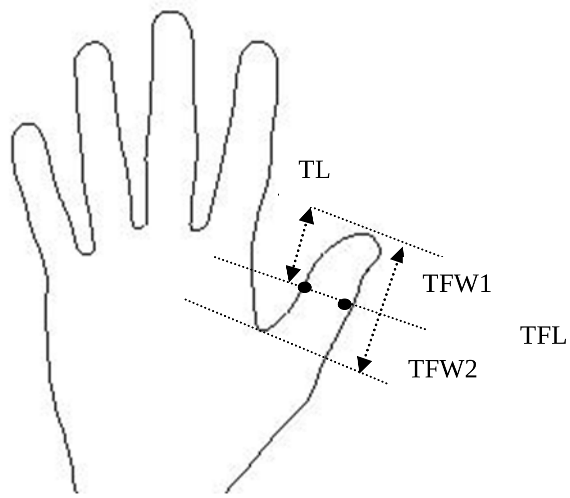

Figure 2: Feature Extraction of Thumb

5. Simulation Results

Geometrical features of both the hands are collected from 100 different people of different age group. Features collected for each of the finger are Finger Width (FW1, FW2), Finger Length (FL), Distance of first knuckle from bottom of the finger (L1) and distance of the second knuckle from the tip of the finger (L2). Total of 24 features are collected. In the current study thumb features are estimated using only middle finger width.

In statistics, the mean square error or MSE of an estimator is one of ways to quantify the difference between

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an estimator and the true value of the quantity being estimated. MSE is a risk function, corresponding to the expected value of the squared error loss or quadratic loss. MSE measures the average of the square of the "error." The error is the amount by which the estimator differs from the quantity to be estimated. The difference occurs because of randomness or because the estimator doesn't account for information that could produce a more accurate estimate. The square root of MSE yields the root mean squared error or RMSE.

The mean absolute error is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. The mean absolute error (MAE) is an average of the absolute errors computed as in equation 9, where fi is the prediction and yi the true value.

$$MSE = \frac{1}{n}\sum_{i=1}^{k}(f_i - y_i)^2 \qquad (8)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{k} abs(f_i - y_i) \qquad (9)$$

Table 1 shows the actual and estimated values of TFL and TFW1 are shown. Absolute error and percentage of correctness for all the three features are also tabulated. Only 25 random samples are shown in the table. Similarly, in table 2 the actual and predicted values for TFW2 and position of knuckle (TL) of the thumb are tabulated along with the absolute error and percentage of correctness. In table 3, the statistical features of the samples namely min, max, mean and standard deviation are tabulated. Table 4 shows RMSE, MAE and estimation accuracy for all the four features predicted for the thumb using middle finger width. Mean absolute error and Root mean square error tabulated indicates that a maximum of 0.36 centimeters error is present in estimating position of the knuckles and approximately 0.5 centimeters in estimating thumb length. Thumb width shows an error of only 0.1 centimeters.

Table 1: Actual and predicted values of TFW1 and TFW2

MFW1	A-TFW1	P-TFW1	AE	%Correct	A-TFW2	P-TFW2	AE	%Correct
1.50	1.50	1.50	0.00	100.00	1.50	1.56	0.06	96.00
1.50	1.50	1.50	0.00	100.00	1.30	1.56	0.26	83.20
1.60	1.60	1.60	0.00	100.00	1.60	1.67	0.07	96.00
1.60	1.80	1.60	0.20	87.50	1.90	1.67	0.23	86.00
1.50	1.30	1.50	0.20	86.67	1.30	1.56	0.26	83.20
1.40	1.20	1.40	0.20	85.71	1.20	1.46	0.26	82.29
1.60	1.50	1.60	0.10	93.75	1.40	1.67	0.27	84.00
1.60	1.60	1.60	0.00	100.00	1.90	1.67	0.23	86.00
1.40	1.40	1.40	0.00	100.00	1.60	1.46	0.14	90.29
1.40	1.20	1.40	0.20	85.71	1.30	1.46	0.16	89.14
1.40	1.30	1.40	0.10	92.86	1.20	1.46	0.26	82.29
1.50	1.60	1.50	0.10	93.33	1.40	1.56	0.16	89.60
1.40	1.60	1.40	0.20	85.71	1.30	1.46	0.16	89.14
1.40	1.50	1.40	0.10	92.86	1.30	1.46	0.16	89.14
1.60	1.30	1.60	0.30	81.25	1.40	1.67	0.27	84.00
1.60	1.60	1.60	0.00	100.00	1.70	1.67	0.03	98.00
1.40	1.40	1.40	0.00	100.00	1.50	1.46	0.04	97.14
1.40	1.50	1.40	0.10	92.86	1.30	1.46	0.16	89.14
1.40	1.30	1.40	0.10	92.86	1.20	1.46	0.26	82.29
1.40	1.70	1.40	0.30	78.57	1.30	1.46	0.16	89.14
1.60	1.40	1.60	0.20	87.50	1.50	1.67	0.17	90.00
1.60	1.60	1.60	0.00	100.00	1.40	1.67	0.27	84.00
1.60	1.30	1.60	0.30	81.25	1.20	1.67	0.47	72.00
1.50	1.60	1.50	0.10	93.33	1.40	1.56	0.16	89.60
1.60	1.30	1.60	0.30	81.25	1.50	1.67	0.17	90.00

Table 2: Actual and predicted values of TFL and TL

MFW1	A-TFL	P-TFL	AE	%Correct	A-TL	P-TL	AE	%Correct
1.50	5.70	5.39	0.32	94.15	3.30	2.86	0.44	84.58
1.50	5.40	5.39	0.02	99.72	3.00	2.86	0.14	95.07
1.60	6.60	5.74	0.86	85.10	3.50	3.05	0.45	85.24
1.60	6.00	5.74	0.26	95.54	3.60	3.05	0.55	81.96
1.50	5.50	5.39	0.12	97.86	2.70	2.86	0.16	94.43
1.40	5.30	5.03	0.27	94.55	2.30	2.67	0.37	86.19
1.60	6.50	5.74	0.76	86.84	3.50	3.05	0.45	85.24
1.60	6.50	5.74	0.76	86.84	3.00	3.05	0.05	98.37
1.40	5.00	5.03	0.03	99.48	2.60	2.67	0.07	97.43
1.40	4.90	5.03	0.13	97.49	2.90	2.67	0.23	91.33
1.40	6.10	5.03	1.07	78.63	3.10	2.67	0.43	83.83
1.50	5.50	5.39	0.12	97.86	2.60	2.86	0.26	90.94
1.50	6.10	5.39	0.72	86.72	3.50	2.86	0.64	77.59
1.40	5.50	5.03	0.47	90.57	2.30	2.67	0.37	86.19
1.40	5.40	5.03	0.37	92.56	2.90	2.67	0.23	91.33
1.60	5.80	5.74	0.06	99.03	2.20	3.05	0.85	72.14
1.60	6.20	5.74	0.46	92.06	3.40	3.05	0.35	88.52
1.40	5.20	5.03	0.17	96.54	2.40	2.67	0.27	89.94
1.40	5.50	5.03	0.47	90.57	2.80	2.67	0.13	95.07
1.40	5.00	5.03	0.03	99.48	2.20	2.67	0.47	82.44
1.40	4.90	5.03	0.13	97.49	2.50	2.67	0.17	93.68
1.60	5.60	5.74	0.14	97.49	2.50	3.05	0.55	81.97
1.60	5.60	5.74	0.14	97.49	3.00	3.05	0.05	98.37
1.60	5.50	5.74	0.24	95.75	2.50	3.05	0.55	81.97
1.60	5.60	5.74	0.14	97.49	2.60	3.05	0.45	85.25

In figure 3(a-e) around 40 – 50 subset of the samples are plot indicating the actual and predicted values of LFL,LFW1, LFW2, LL1 and LL2 respectively.

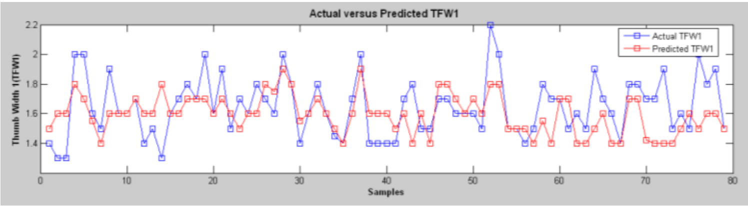
Red line in the plot shows the actual or true values and blue line indicates the predicted values. Overlapping in the graph shows the close relation of predicted values to the actual values.

Table 3 : Statistical Analysis

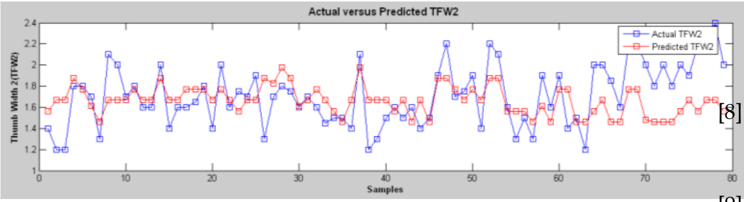
	Min	Max	Mean	Std Deviation
MFW1	1.3	2.0	1.57	0.12
TFL	4.2	7.0	5.67	0.49
TFW1	1.1	2.2	1.57	0.20
TFW2	1.1	2.4	1.57	0.31
TL	2.0	4.3	2.94	0.36

Table 4 : RMSE and MAE

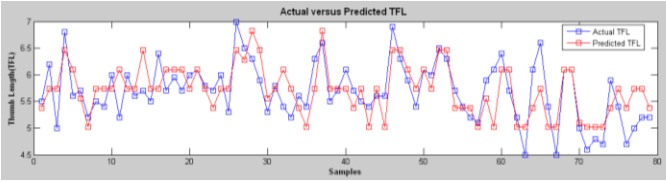
	MAE	RMSE	Estimation Accuracy
TFL	0.372	0.474	93.38
TFW1	0.139	0.183	91.09
TFW2	0.243	0.291	85.11
TL	0.30	0.391	90.03



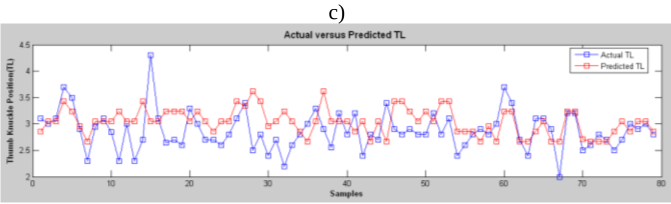
a)



b)



c)



d)

Figure 3(a-d) : Plot of actual and predicted values of TFW1, TFW2, TFL and TL

CONCLUSION

To the best of our knowledge this is the humble beginning in estimating the geometrical features of thumb from the width of the middle finger. To accomplish this challenging task, Taalamana system and golden ratio are used to predict the geometric features of the thumb TFL, TFW1, TFW2, and TL. The plot in figure 3 indicates close association of the actual and the estimated feature values. Estimation accuracy of 93%, 91%, 85% and 90% for TFL, TFW1, TFW2 and TL features respectively is achieved. All the four geometric features of the thumb are successfully estimated using only the width of the middle finger.

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