Prediction of Middle Finger Features from its Width: A Novel Approach

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Abstract: This paper focus on the prediction of geometric features of middle finger from the known width of the 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 middle finger length, position of knuckles and also finger width at the second knuckle using taalamana system and shilpa shastra. The estimation accuracy of more than 91% is achieved for all the estimated features of the middle finger.

Keywords: golden mean, taalamana system, iconography, human hand, feature estimation.

I. INTRODUCTION

The human hand is a masterpiece of mechanical complexity. The anatomy of the hand is complex, intricate, and fascinating. Its integrity is absolutely essential for everyday functional living. Hands may be affected by many disorders, most commonly traumatic injury. Construction of the middle finger when only fractional part of the image is available is a challenging task. In this view middle finger features are estimated using taalamana system and golden mean.

A. 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.

B. 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.

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

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 proposed method for perfection in the plastic surgery.

The paper is organized into five sections. Introduction is given in first section. In the second section literature is reviewed.

Mathematical model is enumerated in section 3. In section 4 the proposed method is discussed and the simulation results are presented in section5.
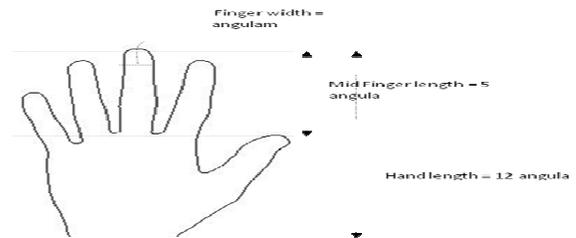

Figure 1: Computation of Middle finger length

II. LITERATURE SURVEY

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 Artifi cial Neural Network for classification [20].

III. MATHEMATICAL MODEL

Prediction of finger length, position of knuckles and finger width at the second knuckle are computed using taala mana system and golden ratio. The finger length is compu ted as five times the finger width (FW1). Finger joints or knuckles are predicted using golden ratio rule. The golden mean or ratio can be computed mathematically as shown in equation 2 and 3.

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

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

Positions of the knuckles from tip and bottom of the finger are computed using the equation 4 and the finger width at the second knuckle FW2 is computed as shown in equation 5.

$$L1 = L2 = phi * FL.......... .. \qquad 4)$$

$$FW2 = 2*FW1 - (phi*FW1)......... \qquad (5)$$

IV. PROPOSED APPROACH

200 silhouette of both the hands of 100 users are taken on sheets of paper and features are extracted Geometric features of both the hands from 100 different people of different age group collected. At first the silhouette of hand is taken on the paper and the positions of the knuckles are marked. 24 features are extracted as shown in figure 2. For each finger five features namely finger width 1 (FW1), finger width 2 (FW2), Finger Length (FL), Position of first knuckle from bottom(L1) and position of second knuckle from finger tip (L2) are extracted. Similarly for the four fingers these five features are collected and four features for the thumb totally to 24 feature set.

From first width of the middle finger (FW1), the values of FL, L1, L2 and FW2 are estimated. The actual and estimated values of a subset of samples are tabulated in table 1 and 2 in page 5.

V. 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 only middle finger length is computed using our approach.
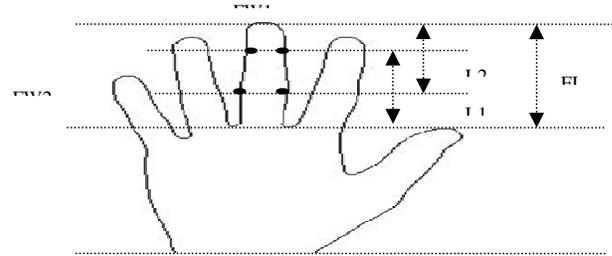

Figure 2: Feature Extraction

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

$$MSE = \frac{1}{n}\sum_{i=1}^{k}(f_i - y_i)^2......(6)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{k} abs(f_i - y_i)..............(7)$$

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 7, where f_i is the prediction and y_i the true value.

Table 1 shows the actual values of FW1, FL and FW2. The finger length is predicted as five times of FW1. Finger width 2 is predicted using the equation 5. The actual and predicted values are tabulated. Absolute error and percentage of correctness for both FL and FW2 are also tabulated. Only 25 random samples are shown in the table. Similarly, in table 2 the actual and predicted positions of first knuckle (L1) and second knuckle (L2) are tabulated along with the absolute error. 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 middle finger. Mean absolute error and Root mean square error tabulated indicates that a maximum of 0.5 centimeters error is present in estimating position of the knuckles and approximately 0.3centimeters in estimating finger length.

Table I: Actual and predicted values of FL and FW2

Sl. No.	FW1	A-FL	P-FL	Abs Error	%Correct	A-FW2	P-FW2	Abs Error	%Correct
1	1.5	7.5	7.5	0	100.000	1.9	2.073	0.173	91.655
2	1.6	8	8	0	100.000	2	2.211	0.211	90.449
3	1.4	7	7	0	100.000	1.75	1.935	0.185	90.449
4	1.4	7	7	0	100.000	1.8	1.935	0.135	93.033
5	1.7	8	8.5	0.5	94.118	2	2.349	0.349	85.128
6	1.7	8.1	8.5	0.4	95.294	2	2.349	0.349	85.128
7	1.42	7.2	7.1	0.1	98.592	1.8	1.962	0.162	91.723
8	1.4	6.8	7	0.2	97.143	1.8	1.935	0.135	93.033
9	1.4	7.1	7	0.1	98.571	1.6	1.935	0.335	82.696
10	1.4	7	7	0	100.000	1.9	1.935	0.035	98.201
11	1.5	7.7	7.5	0.2	97.333	1.8	2.073	0.273	86.831
12	1.6	7.9	8	0.1	98.750	2	2.211	0.211	90.449
13	1.5	7.2	7.5	0.3	96.000	2	2.073	0.073	96.479
14	1.6	7.5	8	0.5	93.750	2	2.211	0.211	90.449
15	1.6	7.7	8	0.3	96.250	1.9	2.211	0.311	85.926
16	1.5	7.4	7.5	0.1	98.667	1.9	2.073	0.173	91.655
17	1.4	7.4	7	0.4	94.286	1.8	1.935	0.135	93.033
18	1.4	7.4	7	0.4	94.286	1.8	1.935	0.135	93.033
19	1.6	8.1	8	0.1	98.750	1.9	2.211	0.311	85.926
20	1.7	8.3	8.5	0.2	97.647	2.1	2.349	0.249	89.385
21	1.9	8.8	9.5	0.7	92.632	2.3	2.626	0.326	87.592
22	2.0	9.2	10	0.8	92.000	2.5	2.764	0.264	90.449
23	1.8	9	9	0	100.000	2.2	2.488	0.288	88.439
24	1.8	9.1	9	0.1	98.889	2.3	2.488	0.188	92.459
25	1.7	8.2	8.5	0.3	96.471	2	2.349	0.349	85.128

Table II: Actual and predicted values of L1 and L2

Sl. No.	FW1	A-L1	P-L1	Abs Error	%Correct	A-L2	P-L2	Abs Error	%Correct
1	1.5	4.9	4.635	0.265	94.283	4.9	4.635	0.265	94.283
2	1.6	5.6	4.944	0.656	86.731	5.1	4.944	0.156	96.845
3	1.4	4.6	4.326	0.274	93.666	4.5	4.326	0.174	95.978
4	1.4	5.1	4.326	0.774	82.108	4.8	4.326	0.474	89.043
5	1.7	6	5.253	0.747	85.780	5.5	5.253	0.247	95.298
6	1.7	5.5	5.253	0.247	95.298	5.2	5.253	0.053	98.991
7	1.42	5	4.388	0.612	86.048	4.2	4.388	0.188	95.720
8	1.4	4.4	4.326	0.074	98.289	4.4	4.326	0.074	98.289
9	1.4	4.8	4.326	0.474	89.043	4.5	4.326	0.174	95.978
10	1.4	4.8	4.326	0.474	89.043	4.8	4.326	0.474	89.043
11	1.5	5.4	4.635	0.765	83.495	4.8	4.635	0.165	96.440
12	1.6	5.2	4.944	0.256	94.822	5.4	4.944	0.456	90.777
13	1.5	4.8	4.635	0.165	96.440	4.8	4.635	0.165	96.440
14	1.6	5	4.944	0.056	98.867	5	4.944	0.056	98.867
15	1.6	5	4.944	0.056	98.867	5	4.944	0.056	98.867
16	1.5	4.9	4.635	0.265	94.283	4.7	4.635	0.065	98.598
17	1.4	5.4	4.326	1.074	75.173	5	4.326	0.674	84.420
18	1.4	5.2	4.326	0.874	79.797	4.7	4.326	0.374	91.355
19	1.6	5.3	4.944	0.356	92.799	5.3	4.944	0.356	92.799
20	1.7	5.5	5.253	0.247	95.298	5.4	5.253	0.147	97.202
21	1.9	5.4	5.871	0.471	91.978	6	5.871	0.129	97.803
22	2.0	6.2	6.180	0.020	99.676	5.8	6.180	0.380	93.851
23	1.8	6	5.562	0.438	92.125	5.7	5.562	0.138	97.519
24	1.8	6.2	5.562	0.638	88.529	5.6	5.562	0.038	99.317
25	1.7	5.8	5.253	0.547	89.587	5.1	5.253	0.153	97.087

Table III: Statistical Analysis

	Min	Max	Mean	Std Deviation
FW1	1.3	2.0	1.5712	0.1246
FL	6.8000	9.6000	8.0374	0.5418
FW2	1.4000	2.5000	1.7582	0.2013
L1	4.4000	6.6000	5.5226	0.4200
L2	4.2000	6.8000	5.2632	0.4563

Table IV: RMSE and MAE

	MAE	RMSE	Estimation Accuracy
FL	0.3010	0.39881	96.03%
FW2	0.2013	0.18908	91.13%
L1	0.4199	0.42848	94.17%
L2	0.4563	0.51219	91.14%

In figure 3(a-d) around 40 – 50 subset of the samples are plot indicating the actual and predicted values of FL, FW2, L1 and L2 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.
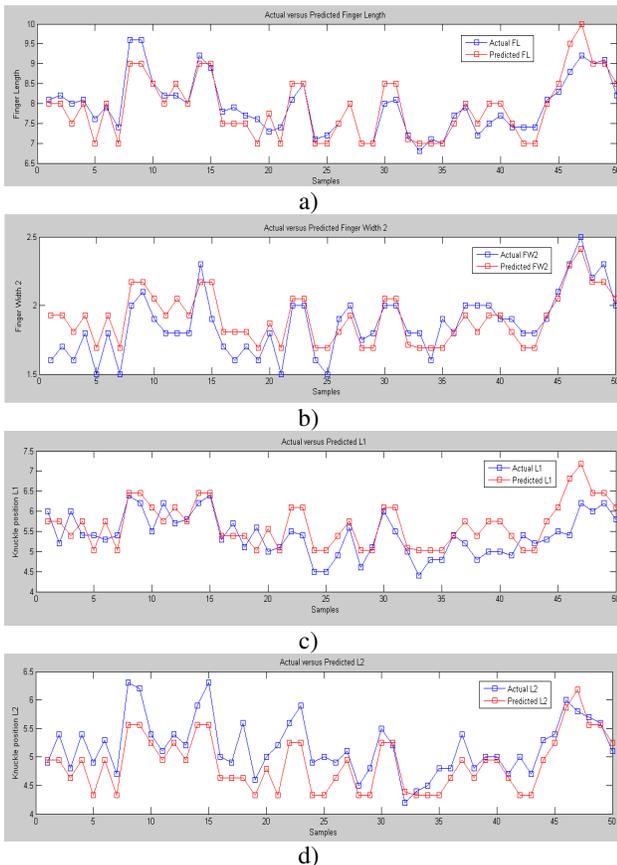

a)

b)

c)

d)

Figure 3(a-d): Plot of actual and predicted values of FL, FW2, L1 and L2

VI. CONCLUSION

To the best of our knowledge this is the first humble beginning in constructing human finger from its fractional part. In view of this Taalamana system and golden ratio are used to predict the feature values for FL, FW2, L1 and L2. The graph in figure 3 indicates close association of the actual and the estimated feature values. Estimation accuracy of 96%, 91%, 94% and 91% for FL, FW2, L1 and L2 features respectively is achieved.

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