BEST: International Journal of Management, Information Technology and Engineering (BEST: IJMITE)
Vol. 1, Issue 3, Dec 2013, 147-158

FORECASTING ARM AND FOOT FEATURES OF HUMAN BODY

MANIMALA. S & C. N. RAVI KUMAR

Department of CS & E, SJCE, Mysore, Karnataka, India

ABSTRACT

Arm is an important and most useful organ that is used extensively in both verbal and non-verbal communication. Predicting geometrical features of arm is a challenging task. In this paper an attempt is made to estimate all the geometric features of the arm and foot using middle finger width. Geometric features of both the arms and foot from 75 female and 78 male subjects were collected as a dataset. The proposed method can be used to predict various arm features like palm width and length, width of elbow, wrist, forearm, biceps, length of arm from middle finger tip to elbow, elbow to shoulder using taalamana system. The estimation accuracy of more than 90% is achieved for all the estimated features of the arm except for biceps width which is 85%.

KEYWORDS: Taalamana System, Iconography, Human Arm, Arm Features, Feature Estimation

INTRODUCTION

Reconstructive plastic surgery is often performed on burn and accident victims. It may involve the rebuilding of severely fractured bones, as well as skin grafting. Reconstructive surgery includes such procedures as the reattachment of an amputated finger or toe [34]. Number of road, rail and air accidents is increasing. Human ability to transplant organs and reconstruction of lost parts of the human body is also increasing. So also the computing facility is becoming more cost effective. In case of accidents, if only partial knowledge of the finger is available, then the proposed method can be used to obtain complete knowledge and reconstruct the damaged part to its original form. Taalamana system is the concept utilized by the proposed method.

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 arm 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.

The paper is organized into five sections. Introduction to taalamana system is discussed in first section. Literature evaluation is given in the second section. Arm dataset generation is presented in section 3. The proposed method of arm and foot feature extraction is discussed in section 4 and the estimation analysis is illustrated in section 5.

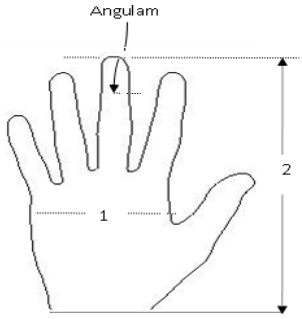


Figure 1: Extraction of Angulam

LITERATURE RECAPITULATION

Geometric measurements of the human hand have been used for various commercial applications like identity authentication systems. Anil K. Jain and others have worked extensively on hand geometry specifically for identification and verification systems [6, 7, 8]. Literature addressing the research issues related to hand geometry-based identity authentication is mostly in the form of patents [2, 3, 4]. Yaroslar and others have put forth that Hand geometry recognition systems may be used to 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 [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 shown that using 2D silhouettes of hands it is possible to construct 3D hand structure [13]. 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]. Sanjay Kumar and others have used geometric hand measurements in classifying hand gestures [20]. Geometric hand measurements are also used in hand gesture classification using a view-based approach for representation and Artificial Neural Network for classification [21].

Nataraja Moorthy and others are able to distinguish between athlete and non-athlete with the help of foot prints [35]. Anitha and others have tried to establish a normal range for the hand length as well as foot length when one parameter is known. This can be of tremendous use in medico-legal cases especially in the identification of severed body parts. The data can also be of help in plastic and re-constructive surgery [36]. A positive correlation between height and foot length was observed in both sexes by Shinde and Bokariya and found statistically significant. Regression equation for stature estimation was formulated using the foot lengths for both sexes [37]. Patel and others have estimated height from measurements of foot length in Gujarat region [42]. Chikhalkar and others have proposed a method to estimate the stature of a person from long bones, hand and foot dimensions [38]. Kumar and others have estimated stature by examining forearm and hand [39]. Krishnan and Sharma have estimated stature of north Indian population from hands and feet dimensions [40]. Athawale has performed a study of height of person from forearm bones. He considered one hundred Maharashtrian male adults of ages between twenty five and thirty years for his study [41].

Arm and Foot Dataset Generation

Anthropometry describes the dimensions of the human body. The name is derived from anthropos, meaning human, and metrikos, meaning of or pertaining to measuring [30]. Classical anthropometric data provides information on static dimensions of the human body in standard postures. Most measurements of the subject are taken in the most desirable position of standing [31]. The data collection is based on Traditional Anthropometric methods. The equipments used are Calipers, Scales and Tapes. Data is measured in centimeters with precision up to 2 decimal places. Figure 1 and 2 illustrates various arm features. 78 Male and 75 female subject data are collected.

Arm Feature Estimation

Middle finger width is called as an angulam. One tala is equal to twelve angula. One eighth of an angulam is called as yuva. Using Tala, Angula and Yuva all the features of the arm are estimated. Palm width is estimated with the help of equation 1 and as illustrated in figure1. Palm length is the distance between middle finger tip and wrist as shown in figure 1. Distance between middle finger tip and elbow as shown in figure 2. Label 5 in figure 2 indicates distance between wrist to elbow. Label 6 shows length of the arm from elbow to shoulder. Label 7 indicates the length of the arm from middle finger tip to shoulder.

$$\text{Palm Width} = 4 * \text{angula} + 6 * \text{yuva} \cdots \quad (1)$$

$$\text{Palm Length} = 12 * \text{angula} \cdots \quad (2)$$

$$\text{Wrist Width} = 3 * \text{angula} + 4 * \text{yuva} \quad (3)$$

$$\text{Mid Finger Tip To Elbow} = 28 * \text{angula} \cdots \quad (4)$$

$$\text{Wrist To Elbow} = 16 * \text{angula} \cdots \quad (5)$$

$$\text{Elbow To Shoulder} = 20 * \text{angula} \cdots \quad (6)$$

$$\text{Mid Finger Tip To Shoulder} = 48 * \text{angula} \cdots \quad (7)$$

Width features of the arm like wrist, forearm, el bow and biceps width are marked on the arm in figure 2. All these features are predicted using middle finger width using equations 8 to 13. Width features are estimated both from frontal and side view. Side width features can be used when three dimensional view of the arm is needed.

$$\text{Biseps Width Front} = 5 * \text{angula} \cdots \quad (8)$$

$$\text{Biseps Width Side} = 4 * \text{angula} + 3 * \text{yuva} \cdots \quad (9)$$

$$\text{Forearm Width Front} = 4 * \text{angula} \quad \cdots (10)$$

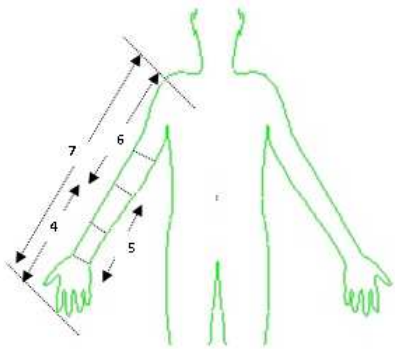


Figure 2: Arm Feature Extraction

$$\text{Forearm Width Side} = 3 * \text{angula} + 3 * \text{yuva} \cdots \quad (11)$$

$$\text{Elbow Width Front} = 5 * \text{angula} \cdots \quad (12)$$

$$\text{Elbow Width Side} = 3 * \text{angula} + 7 * \text{yuva} \quad \cdots (13)$$

Foot Feature Estimation

Measurement of foot features is of peculiar interest to all anthropologists. Foot length is measured as the distance from the top of the foot to the floor in standing position. 3 features of left foot and 3 features of right foot are envisaged using equations 14 to 20.

$$\text{Foot Height} = 3 * \text{angula} + 4 * \text{yuva} \cdots \quad (14)$$

$$\text{Left Foot Length} = 16 * \text{angula} + 4 * \text{yuva} \cdots \quad (15)$$

$$\text{Left Foot Width} = 6 * \text{angula} - 5 * \text{yuva} \quad \cdots (16)$$

$$\text{Left Heel Width} = 3 * \text{angula} + 4 * \text{yuva} \cdots \quad (17)$$

$$\text{Right Foot Length} = 16 * \text{angula} + 4 * \text{yuva} \cdots \quad (18)$$

$$\text{Right Foot Width} = 6 * \text{angula} - 5 * \text{yuva} \cdots \quad (19)$$

$$\text{Right Heel Width} = 3 * \text{angula} + 4 * \text{yuva} \cdots \quad (20)$$

ESTIMATION ANALYSIS

In order to quantify the difference between an estimated value and the true value of the quantity being estimated, the mean square error or MSE is used [32,33]. In statistics in order to know how close is the estimated feature to its actual feature MSE (Mean Square Error) is used. More frequently RMSE or root mean square error is used to show how close the estimate from actual value and computed as in equation 21.

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

$$MSE = \frac{1}{n}\sum_{i=1}^{k} (f_i - y_i)^2 \quad (21)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{k} abs(f_i - y_i) \quad (22)$$

Table 1: Statistical Analysis of Arm and Foot Features of ALL Samples

Features		Min	Max	Mean	Std Deviation	RMSE	MAE	Prediction Accuracy
Left ArmFeatures	Palm Width	6.3	8.5	7.356	0.42625	0.3526	0.27967	96.11
	Palm Length	15.3	19.2	17.301	0.8229	1.2314	1.032	94.414
	Wrist width	4.5	6	5.26	0.32962	0.29297	0.25867	95.142
	Mid Finger tip to elbow	34.2	43.9	40.229	1.8428	3.0317	2.494	94.237
	wrist to elbow	19	26.4	23.162	1.4063	1.9066	1.5447	93.733
	Elbow to Shoulder	24	32.2	28.596	1.8435	2.5148	2.0333	93.362
	Mid Finger tip to Shoulder	59.1	74.6	68.823	3.269	5.2392	4.308	94.179

	Biceps width (front)	4.8	9.5	6.8013	0.97641	1.2562	1.088	85.774
	Biceps width (side)	5.1	11.5	7.324	1.3129	1.4412	1.014	84.707
	Fore arm width (front)	4.5	8.5	6.0253	0.6611	0.68147	0.532	91.316
	Fore arm width (side)	4.1	8	5.312	0.728	0.74015	0.54167	89.457
	Elbow width (front)	6	11.2	7.8813	0.80197	0.82503	0.59333	92.21
	Elbow width (side)	4.8	7.6	6.136	0.53692	0.5997	0.46067	92.109
Right Arm Features	Palm Width	6.7	8.5	7.4	0.38695	0.36751	0.28	96.346
	Palm Length	15.5	19.2	17.289	0.86048	1.2575	1.0387	94.373
	Wrist width	4.5	6	5.264	0.34313	0.30039	0.26133	95.085
	Mid Finger tip to elbow	35.3	44	40.655	1.7461	2.6964	2.2227	94.859
	Wrist to elbow	19.9	26.8	23.661	1.2846	1.5785	1.2747	94.798
	Elbow to Shoulder	23.8	32	28.632	1.8315	2.5319	1.9867	93.531
	Mid Finger tip to Shoulder	61	76	69.391	3.0284	4.7354	3.756	94.943
	Biceps width (front)	4.9	9.3	6.8187	0.81285	1.1172	0.98933	87.024
	Biceps width (side)	4.8	10.5	7.288	1.0268	1.1858	0.8645	86.933
	Fore arm width (front)	4.2	8.3	6.0427	0.66904	0.64146	0.496	91.848
	Fore arm width (side)	4	8	5.3853	0.77402	0.78523	0.57533	88.71
	Elbow width (front)	6	11.5	7.8907	0.8328	0.89308	0.66133	91.278
	Elbow width (side)	5	7.5	6.1733	0.56934	0.63279	0.51917	91.159
Foot Features	Height of foot	4.6	10	6.9059	1.5705	1.6659	1.3088	77.961
	Left Foot Length	19.9	28	24.554	1.721	2.7397	2.1317	92.339
	Left Foot width	7	11	9.0556	0.95732	0.71278	0.52101	94.134
	Left Heel width	4.7	7.4	5.7144	0.63341	0.53025	0.3915	93.32
	Right Foot Length	19.9	28	24.572	1.7507	3.4249	2.8463	89.992
	Right Foot width	7	11	9.0565	0.95497	0.69536	0.50801	94.263
	Right Heel width	4.1	7.4	5.7118	0.66143	0.72769	0.59902	90.464

Table 1 demonstrates the statistical features like Minimum value, Maximum value, Mean, Standard Deviation, RMSE, MAE and Prediction Accuracy of all 13 features of the Left and right arm and 7 features of the foot that are estimated using only middle finger width.

All the features have estimation accuracy of more than 90% except biceps width and foot height. Table 2 tabulates statistical analysis of the estimated features of left and right arm of only 78 male samples. Similarly in table 3 tabulates the statistical analysis of envisaged features of both the arms of only 75 female samples.

Table 2: Statistical Analysis of Arm and Foot Features of Only MALE Samples

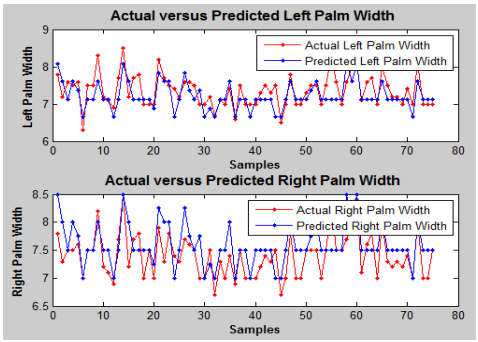
Features		Min	Max	Mean	Std Deviation	RMSE	MAE	Prediction Accuracy
Left Arm Features	Palm Width	8	9.75	8.7519	0.44652	0.86412	0.63205	92.25
	Palm Length	17	20	18.828	0.77286	2.9301	2.4801	88.679
	Wrist width	5.6	7.3	6.1821	0.42457	0.63498	0.48205	92.239
	Mid Finger tip to elbow	41.2	50.2	46.005	2.0916	5.273	4.1513	91.882
	wrist to elbow	24	32	27.187	1.9066	3.0167	2.3532	91.715
	Elbow to Shoulder	26	37.1	31.186	2.7526	5.5764	4.6551	87.133
	Mid Finger tip to Shoulder	68.5	84.9	76.645	4.1928	11.012	9.1795	89.476
	Biceps width (front)	6.2	10.3	8.5103	1.0854	1.259	1.0372	88.365
	Biceps width (side)	7.6	12.6	9.266	1.3261	2.1005	1.6071	78.718
	Fore arm width (front)	5.7	9.1	7.4929	1.0626	1.2289	1.0968	84.331
	Fore arm width (side)	6	8.5	7.2135	0.62214	1.4393	1.2651	78.343
	Elbow width (front)	6.5	10.2	8.334	0.96344	1.1617	0.925	89.635
	Elbow width (side)	6.4	10.1	7.7109	0.9257	1.4204	1.0564	84.07
Right Arm Features	Palm Width	8	9.75	8.7506	0.43816	0.82047	0.60962	93.103
	Palm Length	17	20.1	18.774	0.78739	2.9388	2.4955	88.61
	Wrist width	5.6	7.3	6.1853	0.4242	0.63273	0.48141	92.246

	Mid Finger tip to elbow	41.2	50.2	46.035	2.0828	5.2558	4.1468	91.887
	Wrist to elbow	24	31.5	27.235	1.8758	3.023	2.3417	91.773
	Elbow to Shoulder	26	37.2	31.112	2.8735	5.7099	4.7673	86.811
	Mid Finger tip to Shoulder	68.5	84.9	76.728	4.2555	10.885	9.1038	89.552
	Biceps width (front)	6.2	10.2	8.5532	1.109	1.2653	1.0353	88.396
	Biceps width (side)	7.6	12.6	9.2878	1.3171	2.1073	1.6212	78.536
	Fore arm width (front)	5.7	9.1	7.4904	1.0493	1.2184	1.0814	84.548
	Fore arm width (side)	6	8.5	7.2288	0.59905	1.4442	1.2856	78.011
	Elbow width (front)	6.4	10.3	8.2276	1.0213	1.295	1.034	88.448
	Elbow width (side)	6.4	10.2	7.8026	0.95727	1.4628	1.101	83.458
Foot Features	Height of foot	6.4	10	8.2859	0.78343	2.2581	2.0936	65.669
	Left Foot Length	23.4	28	25.854	1.0632	3.451	2.842	90.362
	Left Foot width	8.8	11	9.8591	0.50345	0.90296	0.69971	92.44
	Left Heel width	5.4	7.4	6.1718	0.53686	0.67378	0.52244	91.459
	Right Foot Length	22.6	28	25.891	1.1187	4.208	3.6026	88.12
	Right Foot width	8.8	11	9.8609	0.49159	0.87591	0.6742	92.695
	Right Heel width	5.4	7.4	6.1756	0.54229	0.84096	0.69904	89.568

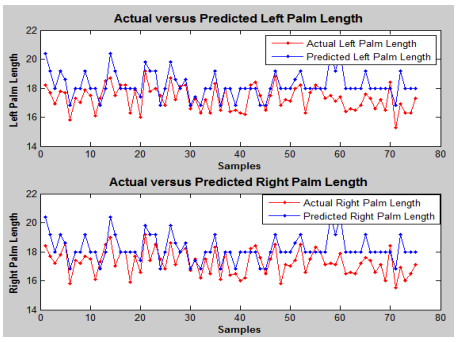
Table 3: Statistical Analysis of Arm and Foot Features of Only FEMALE Samples

Features		Min	Max	Mean	Std Deviation	RMSE	MAE	Prediction Accuracy
Left Arm Features	Palm Width	6.3	8.5	7.356	0.42625	0.3526	0.27967	96.11
	Palm Length	15.3	19.2	17.301	0.8229	1.2314	1.032	94.414
	Wrist width	4.5	6	5.26	0.32962	0.29297	0.25867	95.142
	Mid Finger tip to elbow	34.2	43.9	40.229	1.8428	3.0317	2.494	94.237
	wrist to elbow	19	26.4	23.162	1.4063	1.9066	1.5447	93.733
	Elbow to Shoulder	24	32.2	28.596	1.8435	2.5148	2.0333	93.362
	Mid Finger tip to Shoulder	59.1	74.6	68.823	3.269	5.2392	4.308	94.179
	Biceps width (front)	4.8	9.5	6.8013	0.97641	1.2562	1.088	85.774
	Biceps width (side)	5.1	11.5	7.324	1.3129	1.4412	1.014	84.707
	Fore arm width (front)	4.5	8.5	6.0253	0.6611	0.68147	0.532	91.316
	Fore arm width (side)	4.1	8	5.312	0.728	0.74015	0.54167	89.457
	Elbow width (front)	6	11.2	7.8813	0.80197	0.82503	0.59333	92.21
	Elbow width (side)	4.8	7.6	6.136	0.53692	0.5997	0.46067	92.109
Right Arm Features	Palm Width	6.7	8.5	7.4	0.38695	0.36751	0.28	96.346
	Palm Length	15.5	19.2	17.289	0.86048	1.2575	1.0387	94.373
	Wrist width	4.5	6	5.264	0.34313	0.30039	0.26133	95.085
	Mid Finger tip to elbow	35.3	44	40.655	1.7461	2.6964	2.2227	94.859
	Wrist to elbow	19.9	26.8	23.661	1.2846	1.5785	1.2747	94.798
	Elbow to Shoulder	23.8	32	28.632	1.8315	2.5319	1.9867	93.531
	Mid Finger tip to Shoulder	61	76	69.391	3.0284	4.7354	3.756	94.943
	Biceps width (front)	4.9	9.3	6.8187	0.81285	1.1172	0.98933	87.024
	Biceps width (side)	4.8	10.5	7.288	1.0268	1.1858	0.8645	86.933
	Fore arm width (front)	4.2	8.3	6.0427	0.66904	0.64146	0.496	91.848
	Fore arm width (side)	4	8	5.3853	0.77402	0.78523	0.57533	88.71
	Elbow width (front)	6	11.5	7.8907	0.8328	0.89308	0.66133	91.278
	elbow width (side)	5	7.5	6.1733	0.56934	0.63279	0.51917	91.159
Foot Features	Height of foot	4.6	7	5.4707	0.57652	0.59869	0.49267	90.744
	Left Foot Length	19.9	25	23.201	1.1271	1.7108	1.393	94.395
	Left Foot width	7	9.5	8.22	0.48015	0.43415	0.33517	95.895
	Left Heel width	4.7	6	5.2387	0.27257	0.31849	0.25533	95.257
	Right Foot Length	19.9	25	23.2	1.1189	2.348	2.0598	91.939
	Right Foot width	7	9.5	8.22	0.48015	0.43415	0.33517	95.895
	Right Heel width	4.1	6.6	5.2293	0.36047	0.58716	0.495	91.397

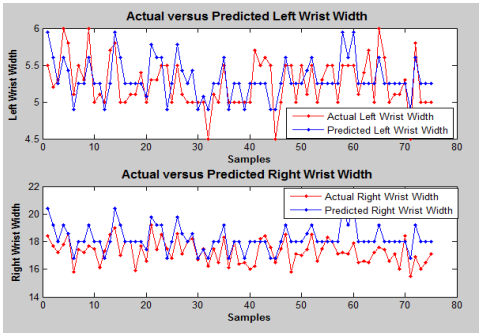
In figure 3, a random subset of eighty samples are selected to plot indicating the actual and predicted values of all the 13 features of both left and right arms. Blue line in the plot shows the actual or true values and red line indicates the predicted values. In figure 3a left and right arm palm width feature is shown. The features of the hand palm length, wrist width, middle finger tip to elbow length, wrist to elbow length, elbow to shoulder length, biceps width from front and side, forearm width from front and side, elbow width from front and side are represented in figure b-m respectively.



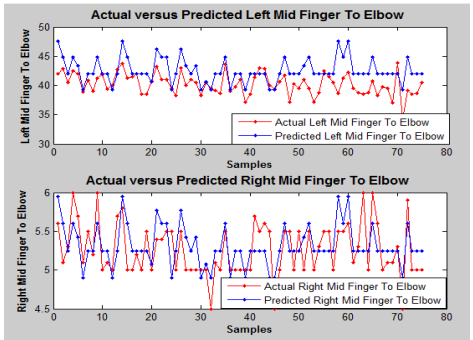
a)



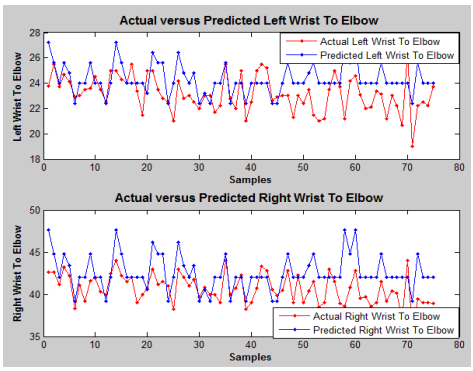
b)



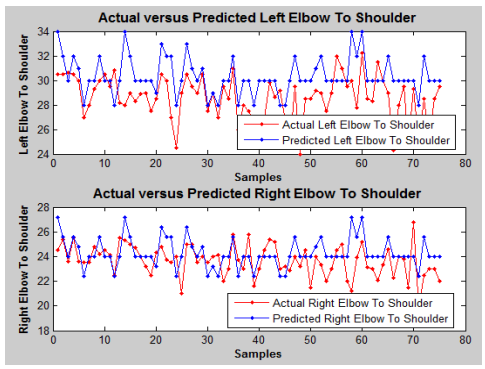
c)



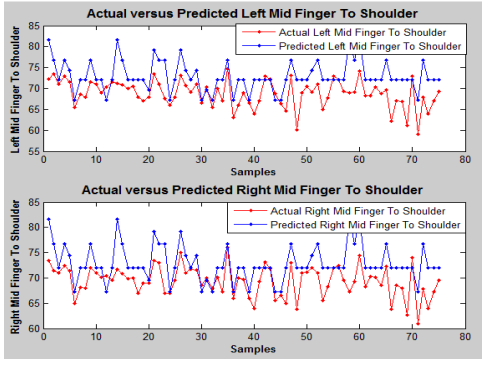
d)



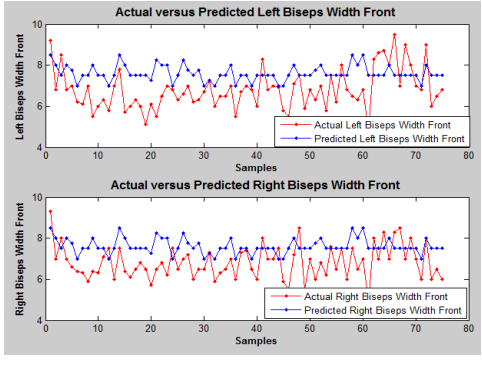
e)



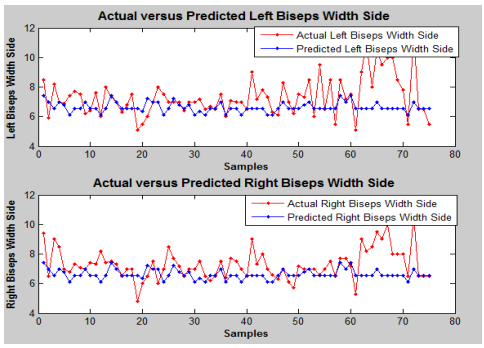
f)



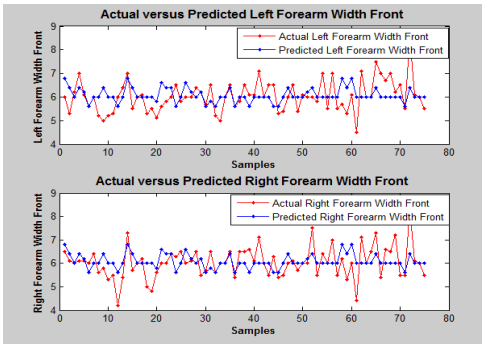
g)



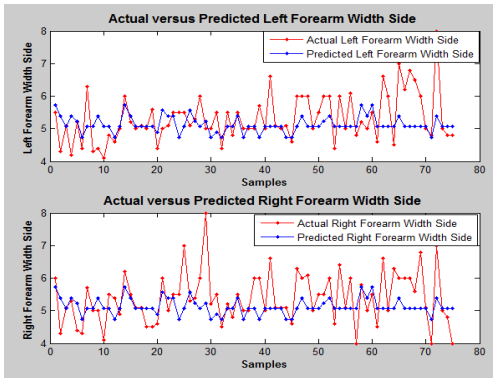
h)



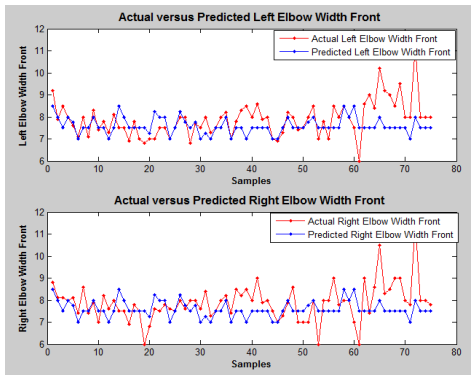
i)



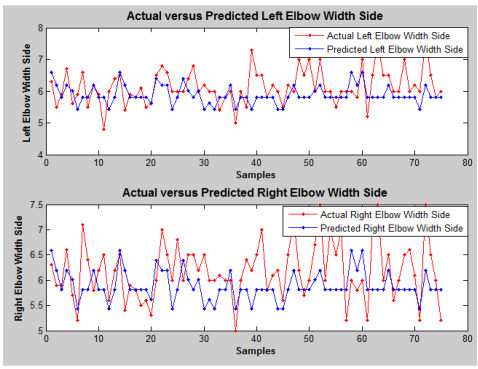
j)



k)



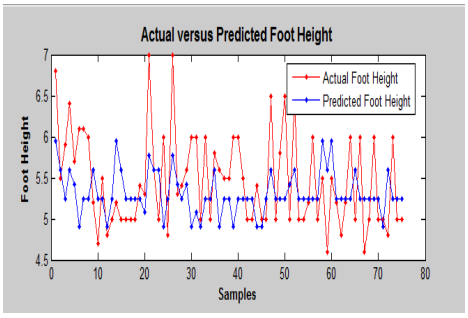
l)



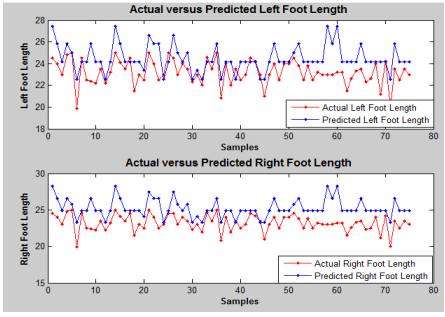
m

Figure 3 (a-m): Actual and Predicted Features of Left and Right Arm

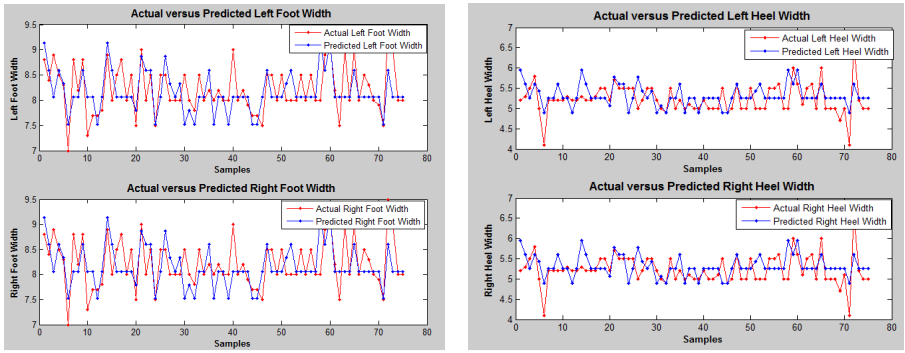
Foot features are forecasted using only middle finger width. Figure 4 a displays the plot of height of the foot. In figure 4b, predicted and actual foot length of both left and right foot are plot. Figure 4c demonstrates left and right foot width and similarly in figure4d heel width is plot. Blue line in the graph depicts the predicted or forecasted features while red line indicates actual value.



a)



b)



e) **f)**

Figure 4(a-d): Actual and Envisaged Foot Features

CONCLUSIONS

The challenging task of predicting arm and foot features is accomplished with the knowledge of Taalamana system. Using only known middle finger width geometrical features of both the arms and foot are estimated. The graph of hand features in figure 3 and foot features in figure 4 indicates close association of the actual and the estimated feature values. Proportions of the human structure would be stable after age of 10 years. Estimation of length features is more accurate when compared to width features. Estimation accuracy of more than 90% is achieved for most of the features.

REFERENCES

1. Gopinatha Rao, T. A, “Talamana, or, Iconometry”: Memoirs of the Archaeological Survey of India ; no. 3. Calcutta: Supt. Govt. Print, 1920
2. R. P. Miller, “Finger dimension comparison identification system”, US Patent No. 3576538, 1971.
3. R. H. Ernst, “Hand ID system", US Patent No.3576537, 1971.
4. H. Jacoby, A. J. Giordano, and W. H. Fioretti, “Personnel Identification Apparatus", US PatentNo. 3648240, 1972.
5. Raul Sanchez –Reillo, Carmen Sanchez-Avila, Ana Gonzalez-Macros, “Biometric identification through hand geometric measurements”, IEEE Transactions on pattern analysis and machine intelligence, Vol 22, No. 10, Oct 2000.
6. Anil K. Jain, Arun Ross, Sharath Pankanti, “A Prototype Hand Geometry-based Verification System”, 2nd International Conference on Audio- and Video-based Biometric Person Authentication (AVBPA), Washington D.C., pp.166-171, March 22-24, 1999.
7. A.K. Jain, A. Ross, and S. Pankanti. A prototype hand geometrybased verification system. In Proceedings of 2nd Int’l Conference on Audio- and Video-based Biometric Person Authentication, pages 166–171, March 1999.
8. Anil K. Jain and Nicolae Duta. Deformable matching of hand shapes for verification. In Proceedings of International Conference on Image Processing, October 1999.
9. Windy M. Brown, Melissa Hines, Briony A. Fane, S. Marc Breedlove, “ Masculinized Finger Length Patterns in Human Males and Females with Congenital Adrenal Hyperplasia”, Hormones and Behavior 42, 380–386 2002, Elsevier Science (USA)

10. Windy M. Brown, B.A., Christopher J. Finn, B.A., Bradley M. Cooke, and S. Marc Breedlove,"Differences in Finger Length Ratios Between Self-Identified Butch and Femme Lesbians", Archives of Sexual Behavior, Vol. 31, No. 1, February 2002, pp. 123–127
11. Aythami Morales, Miguel A. Ferrer, Francisco Díaz, Jesús B. Alonso, Carlos M. Travieso, "Contact-free hand biometric system for real environments",16th European Signal Processing Conference, Lausanne, Switzerland, August 25-29, 2008.
12. Yaroslav Bulatov, Sachin Jambawalikar, Piyush Kumar, Saurabh Sethia, "Hand recognition using geometric classifiers" Biometric Authentication, Lecture Notes in Computer Science, 2004, Volume 3072/2004, 1-29
13. Isaac Cohen, Sung Uk Lee , "3D Hand and Fingers Reconstruction from Monocular View", 17th International Conference on Pattern Recognition, 2004
14. Stephen Lewis "Morphological aspects of male and female hands", Annals of Human Biology,1996 Nov-Dec;23(6):491-4.
15. Gholamreza Amayeh, George Bebis, Ali Erol, Mircea Nicolescu, "A Component-Based Approach to Hand Verification", IEEE Conference on Computer Vision and Pattern Recognition, 2007
16. Gholamreza Amayeh, George Bebis, Mircea Nicolescu, "Gender Classification from Hand Shape", IEEE Computer Society Conference on Computer Vision and Pattern recognition workshops, 2008
17. T. F. Cootes and Taylor, "Active shape models – smart snakes", British Machine Vision Conference, pages 266–275, 1992.
18. T. F. Cootes, G. J. Edwards, and C. J. Taylor, "Active appearance models", IEEE Transactions On Pattern Recognition and Machine Intelligence, 23(6):681–685, 2001.
19. Mikkel B. Stegmann and David Delgado Gomez, "A Brief Introduction to Statistical Shape Analysis", a data report at http://www.imm.dtu.dk/~mbs/
20. Sanjay Kumar, Dinesh K Kumar, Arun Sharma, and Neil McLachlan "Classification of Hand Movements Using Motion Templates and Geometrical Based Moments", IEEE, ICISIP 2004
21. Gift Siromoney; M. Bagavandas, S.Govindaraju (1980). "An iconometric study of Pallava sculptures". Kalakshetra Quarterly 3 (2): 7–15.
22. http://www.cmi.ac.in/gift/Iconometry/icon_pallavasculpture.htm
23. Kramrisch, Stella; Raymond Burnier (1976). The Hindu Temple. Motilal Banarsidass Publ.. pp. 309. ISBN 9788120802247.
24. Wangu, Madhu Bazaz. Images of Indian Goddesses: Myths, Meanings and Models. Abhinav Publications. pp. 72. ISBN 978817017416
25. Manimala.S and C N Ravi Kumar," Prediction of Middle Finger Features from its Width: A Novel Approach", International Journal of Advanced Research in Computer Science, ISSN :0976-5697,Vol 1, Issue 4, 2010, pp 42-46
26. http://encyclopedia.stateuniversity.com/pages/9384/hand.html

27. Manimala.S and C N Ravi Kumar, “A Novel Method of Estimating Index Finger Features from Middle Finger Width”, International Journal of Research and Reviews in Computer Science, ISSN: 2079-2557, Vol 2, No. 1, 2011, pp 121-126
28. Manimala.S and C N Ravi Kumar, “Anticipating Features of Ring Finger from MiddleFinger Width : A Novel Method”, International Journal of Computer Science & Emerging Technologies, ISSN : 2044-6004, Vol 2, Issue 1. February, 2011, pp 89-94
29. Manimala.S and C N Ravi Kumar, “Forecasting Little Finger Features from Middle Finger Width: A Novel Method”, International Journal of Advanced Research in Computer Science, 0976-5697,Vol 2 Issue 2
30. Roebuck, Jr., J.A. (1995). Anthropometric methods: Designing to fit the humanbody. Santa Monica, CA: Human Factors & Ergonomics Society.
31. Kroemer, K.H.E., Kroemer, H.J., & Kroemer-Elbert, K.E. (1986). Engineering physiology: Physiologic bases of human factors/ergonomics. Amsterdam: Elsevier
32. http://www.52nlp.com/mean-absolute-error-mae-and-mean-square-error-mse/
33. http://en.wikipedia.org/wiki/Mean_squared_error
34. http://www.surgeryencyclopedia.com/Pa-St/Plastic-Reconstructive-and-Cosmetic-Surgery.html
35. Nataraja Moorthy, Wan Nur Zawani, Wan Mohd Samsudin and Mohamad Saat Ismail, “ A study on footprints of Malaysian Athelets and non-athelets for application during Forensic comparision”, Malaysian Journal of Forensics Sciences, 2011, 2(1).
36. Anitha Oommen, Avinash Mainker and Tom Oommen, “A Study of the Correlation Between Hand Length And Foot Length In Humans”, J.Anat.Soc. India 54 (2) 1-9 (2005)
37. M. R. Shende,P. Bokariya “Role of Foot Length in Estimation of Stature of Central Indian Population”, Indian Journal of Forensic Medicine and Pathology, Volume 3, Number 4, Oct - Dec 2010
38. Chikhalkar BG, Mangaonkar AA, Nanandkar SD, Peddawad RG. Estimation of Stature from Measurements of Long Bones, Hand and Foot Dimensions. J Indian Acad Forensic Med. 2010; 32(4) 329-33.
39. Kumar S, Srivastava AK, Sahai MKB, “Estimation of stature by anthropometric examination of forearm and hand”, J Indian Acad Forensic Med. 2010; 32(1) 62-65.
40. Krishnan K, Sharma A, “ Estimation of stature from dimensions of hands and feet in a North Indian population”, Journal of Forensic and Legal Medicine.2007; 14(6):327-332.
41. Athawale MC. “Anthropological study of height from length of forearm bones. A study of one hundred Maharashtrian male adults of ages between twenty five and thirty years”, American Journal of Physical Anthropology.1963; 21:105-112.
42. Patel SM, Shah GV, Patel SV, “Estimation of height from measurements of foot length in Gujarat region”, J Anat Soc India. 2007; 56(1): 25-27.