ANTICIPATING TORSO AND FOOT FEATURES OF HUMAN BODY USING GOLDEN RATIO

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Abstract:

Human body is composed of structures like head, neck, torso, two arms and two legs. All the organs in human body are proportional in nature. In this paper, an attempt is made to anticipate the features of torso and leg of human body. Geometric features of the torso, leg and foot from 75 female and 78 male subjects were extracted. Height of a person is used to predict various features like throat to navel length, navel to knee top, knee length, beneath of knee to ankle, ankle to floor, navel to floor, hip to floor, body width near elbow, waist width, thigh width, knee width calf width, ankle width and shoulder width using divine proportion or Golden ratio. Most of the features are envisaged with an accuracy of more than 85% except for waist width which has an accuracy of 79%.

Keywords : Golden Ratio, torso and leg features, human structure, prediction

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Introduction

Human body is made up of head, neck, torso, two arms and two legs. Human torso is central part of the human body from which neck and limbs extend.

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 [1,2]. 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).

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

The golden mean or ratio can be computed mathematically as shown in equations (2) and (3).

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

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

Literature Review

Takahashi and others investigated human body posture estimation method based on back projection of human silhouette images extracted from multi-camera images [8,9]. To extract human silhouettes from color images accurately, a real-time background subtraction method that utilized the brightness and chromaticity in RGB color system for each pixel of the color image is proposed by Takahashi and his team [9].

Mousa Mojarrad and others have proposed an algorithm for Detection and recognition of the Human Body Composition and extraction of their measures (width and length of human body) in images. Finding people and extraction of their features in Images are particularly important problem of object recognition, because people can have high variability in the appearance.[10]

Li, Jing-Feng and others proposed a real-time system for 3D human upper body tracking and modeling. The system uses multiple cameras to recover the depth maps in real-time, then integrates both color and depth information to track the human body, head, and hands, and finally recovers the 3D upper body model parameters from the tracking results.[11] An attempt is made by Sasaki and others to describe an approach to estimate human hand posture using 3-dimensional range data. This approach employs an approximation of the human hand with a plane in the 3-dimensional space.[12]

Yamauchi and others presented a method for 3D human body modeling using range data. In this approach the entire human body is first decomposed into major body parts by a parts-based image segmentation method, and then a kinematics model is fitted to the segmented body parts in an optimized manner[13]

Werghi and others addressed the problem of recognizing a human body posture from a cloud of 3D points acquired by a human body scanner. Motivated by finding a representation that embodies a high discriminatory power between posture classes, a new type of feature is suggested, namely the wavelet transform coefficients (WTC) of the 3D data-point distribution projected on to the space of spherical harmonics.[14]

Marasamy and others have proposed a method that includes a development over classical LDA (i.e. LDA using wavelets transform approach) that enhances performance such as accuracy and time complexity.[15]

Pinto and others proposed a methodology based on 2D and 3D wavelet transforms, which are used to estimate multi-scale features from a real face acquired by a 3D scanner. The proposed methodology starts by considering a dataset composed by faces displaying seven different facial expressions [16]. Powar and others proposed an approach to use initial expression classification research using Hidden Markov Models (HMM) on 2D texture facial data.[17]

Dan Luo and others have presented an appearance-based multimodal gesture recognition framework, which combines the different groups of features such as facial expression features and hand motion features which are extracted from image frames captured by a single web camera.[18]

Spinello and others have presented a novel human detection method based on a Bayesian fusion approach using laser range data and camera images.[19] Wang and others proposed a method which consists of three major components: depth image acquisition, mean shift based preprocessing, and HMM-based gesture recognition.[20]

The human legs are conspicuous in erotic contexts, but few studies have experimentally tested preferences for longer legs. The authors examined the utility of the human leg-to-body ratio (LBR) as a specific aesthetic criterion among 71 British undergraduates. The results showed that a longer LBR was preferred as maximally attractive in women, whereas a shorter LBR was preferred in men. Evolutionary psychological and socio-cultural explanations for this aesthetic preference are discussed.[5] Leong and others have proposed a novel method of body feature extraction from a marker-less scanned body. The semantic definitions of body features found in ISO 8559 were interpreted into a series of mathematical definitions [7]. A total of 21 feature points and 35 feature lines on the human torso were identified. Each feature stands for an important landmark for garment making or the ergonomics industry. [6]

Dataset Generation

153 subjects (78 males and 75 females) between the ages of 22 and 25 years with no obvious deformities or previous history of trauma to the hands or feet were selected for the study. Anthropometry describes the dimensions of the human body. The name is derived from

anthropos, meaning "human", and metrikos, meaning "measuring" [21]. Classical anthropometric data provides information on static dimensions of the human body in standard postures. Most measurements of the subjects are taken in the most desirable position of standing [22]. 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.

Mathematical Model

The human body demonstrates the Divine Proportion. The Divine Proportion in the human body is illustrated as in figure 1[1,2]. Black line represents height of a person. The blue line is a golden section of the black line that defines the distance from the head to the finger tips in standing position.

blue=phi*Height;

The distance from the head to the navel and the elbows are defined by the yellow line which is a golden section of the blue line.

yellow=phi*blue;

The width of the shoulders and the length of the forearm are defined by the green line which is a golden section of the yellow line.

green=phi*yellow;

A golden section of the green line is magenta line that defines the distance from the head to the base of the skull and the width of the abdomen.

magenta=phi*green;

Additional golden sections are defined as darkblue, red, white, lightblue and lightgreen which are golden section of the previous golden section.

darkblue=phi*magenta;

red=phi*darkblue;

white=phi*red;

lightblue=phi*white;

lightgreen=phi*lightblue;

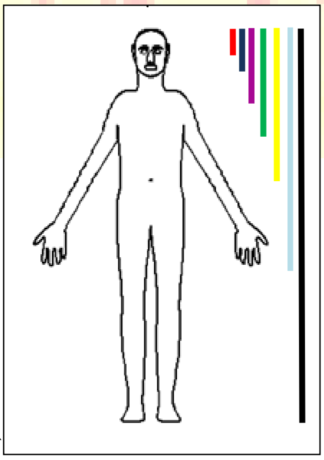


Figure 1: Divine Proportion of Human Body

With the help of above golden sections all the features of the Torso, leg and foot are estimated. Body width at elbow is extracted using equation 4. Length of the body from throat to navel is computed using equation 5. Waist width is extracted with the help of equation 6.

$$Body\ Width\ at\ Elbow = magenta \cdots (4)$$

$$Throat\ to\ Navel = green \cdots (5)$$

$$Waist\ Width\ = Phi * magenta \cdots (6)$$

Length of the human body from navel to knee top is calculated as shown in equation 7. Knee length is extracted with the help of equation 8.

$$Navel\ to\ Knee\ Top = green + red \cdots (7)$$

$$Knee\ Length = red \cdots (8)$$

Length of the human body from knee to ankle, knee to floor, navel to floor, hip to floor using equations 9 to 12 respectively. Shoulder width is forecasted using equation 13.

$$Knee\ to\ Ankle = green \cdots (9)$$

$$Knee\ to\ Floor = green + red \cdots (10)$$

$$Navel\ to\ Floor = phi * Height \cdots (11)$$

$$Hip\ to\ Floor = blue \cdots (12)$$

$$Shoulder\ width = green \cdots (13)$$

Foot Features

The measurement of the foot, like that of the hand, is of peculiar interest to artists, since it has also been used as a canon of stature. Foot height is estimated using equation 14. Left foot features like foot length, foot width and heel width are anticipated using equations 15 to 17 respectively. Similarly equations 18 to 20 are used to predict the features of right foot.

$$Foot\ Height = white \cdots (14)$$

$$Left\ Foot\ Length = magenta \cdots (15)$$

$$Left\ Foot\ Width = red \cdots (16)$$

$$Left\ Heel\ Width = white \cdots (17)$$

$$Right\ Foot\ Length = magenta \cdots (18)$$

$$Right\ Foot\ Width = red \cdots (19)$$

$$Right\ Heel\ Width = white \cdots (20)$$

Estimation Analysis

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 [3, 4]. The square root of MSE yields the root mean squared error or RMSE(21).

The mean absolute error is a quantity used to measure how close forecasts or predictions are to the actual values. The mean absolute error (MAE) is an average of the absolute errors computed as in (22), where f_i is the prediction and y_i the true value.

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

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

Using golden ratio all the length features are estimated with an average accuracy of more than 90%. Some of the width features like thigh width, calf width, ankle width are not possible to predict with good accuracy. Table 1 tabulates the statistical features like minimum, maximum, mean, standard deviation, root means square error, mean absolute error and prediction accuracy of the Torso and Foot features considering all the samples together.

Table 1 : Statistical analysis of all the samples

Features of Human Body		Min	Max	Mean	STD	RMSE	MAE	Prediction Accuracy
Torso Features	**Body width at elbow**	20	42.5	26.327	3.6159	3.9265	2.9432	87.767
	Throat to Navel	29	44.3	37.285	3.7929	3.3525	2.8607	92.604
	waist width	25	39	29.694	2.5269	9.8712	9.352	76.259
	Navel to Top of knee	32.5	57.8	49.051	4.1454	2.8686	2.0802	95.633
	Knee length	5	10	6.9647	1.0727	2.655	2.2829	75.795
	Lower of knee to ankle	29.5	42	35.929	3.5012	3.7859	3.2772	91.49
	Knee to floor	41	55.3	47.288	3.7775	2.4115	1.9035	96.06
	Navel to Floor	80.5	117	98.982	7.1974	5.4271	3.6739	96.42
	Hip to Floor	66.3	102.5	89.147	7.3889	15.947	13.015	87.541
	Shoulder Width	29.5	44.7	37.124	3.1373	4.1481	3.2816	91.73
	Height of foot	4.6	10	6.9059	1.5705	1.7816	1.4265	75.676
	Left Foot Length	19.9	28	24.554	1.721	0.96801	0.76311	96.816
	Left Foot width	7	11	9.0556	0.95732	0.65165	0.52196	94.247

Foot Features	Left Heel width	4.7	7.4	5.7144	0.63341	0.43932	0.34774	93.962
	Right Foot Length	19.9	28	24.572	1.7507	0.97446	0.77142	96.779
	Right Foot width	7	11	9.0565	0.95497	0.65219	0.51752	94.287
	Right Heel width	4.1	7.4	5.7118	0.66143	0.47016	0.3688	93.567

Table 2 tabulates statistical features and analytical features of only female samples. All 17 features of torso, leg and foot are estimated with an accuracy of more than 90%.

Table 2 : Statistical analysis of only Female samples

Features of Human Body		Min	Max	Mean	STD	RMSE	MAE	Prediction Accuracy
Torso Features	Body width at elbow	20	31	25.229	2.9099	3.7257	2.9423	87.087
	Throat to Navel	29	43.5	34.752	2.8851	3.482	2.9192	92.123
	waist width	25.5	39	30.113	2.6639	7.6021	7.1091	80.942
	Navel to Top of knee	32.5	54	46.784	3.777	3.2374	2.4679	94.582
	Knee length	6	10	7.8107	0.66973	1.179	1.0386	88.219
	Lower of knee to ankle	29.5	41.5	33.688	2.5836	4.0528	3.698	90.013
	Knee to floor	41	50	44.78	1.8671	2.1431	1.6361	96.464
	Navel to Floor	86	102.5	95.1	3.7432	2.9514	2.4772	97.455
	Hip to Floor	83	100	92.064	3.848	5.6195	5.2399	94.614
	Shoulder Width	31.5	44.7	37.905	2.8259	2.5115	1.9302	94.833
Foot Features	Height of foot	4.6	7	5.4707	0.57652	0.57903	0.48256	91.078
	Left Foot Length	19.9	25	23.201	1.1271	0.90866	0.69688	96.943
	Left Foot width	7	9.5	8.22	0.48015	0.75361	0.64064	92.734
	Left Heel width	4.7	6	5.2387	0.27257	0.338	0.28529	94.772
	Right Foot Length	19.9	25	23.2	1.1189	0.89909	0.69555	96.949
	Right Foot width	7	9.5	8.22	0.48015	0.75361	0.64064	92.734
	Right Heel width	4.1	6.6	5.2293	0.36047	0.40307	0.31924	94.11

Statistical analysis of all 17 features of torso, leg and foot of only male samples of human structure is tabulated in table 3. Some of the features have prediction accuracy of less than 90%. All the length features are anticipated with greater accuracy when compared to width features.

Table 3 : Statistical analysis of only Male samples

Features of Human Body		Min	Max	Mean	STD	RMSE	MAE	Prediction Accuracy
Torso Features	Body width at elbow	20.3	42.5	27.383	3.9203	4.1104	2.944	88.422
	Throat to Navel	34.5	44.3	39.72	2.8536	3.223	2.8044	93.066
	Waist width	25	33.2	29.291	2.3343	11.643	11.509	71.756
	Navel to Top of knee	47	57.8	51.231	3.2236	2.4626	1.7075	96.644
	Knee length	5	8.1	6.1513	0.68798	3.5342	3.4794	63.849
	Lower of knee to ankle	31	42	38.085	2.861	3.5102	2.8727	92.909
	Knee to floor	42.9	55.3	49.699	3.5778	2.6439	2.1607	95.671
	Navel to Floor	80.5	117	102.71	7.7461	7.0285	4.8246	95.424

	Hip to Floor	66.3	102.5	86.343	8.7915	21.644	20.492	80.739
	Shoulder Width	29.5	41.9	36.373	3.2541	5.2618	4.581	88.747
Foot Features	Height of foot	6.4	10	8.2859	0.78343	1.2988	1.1476	85.353
	Left Foot Length	23.4	28	25.854	1.0632	1.0218	0.8268	96.694
	Left Foot width	8.8	11	9.8591	0.50345	0.5356	0.40784	95.701
	Left Heel width	5.4	7.4	6.1718	0.53686	0.51839	0.4078	93.184
	Right Foot Length	22.6	28	25.891	1.1187	1.0418	0.84438	96.616
	Right Foot width	8.8	11	9.8609	0.49159	0.53689	0.39914	95.78
	Right Heel width	5.4	7.4	6.1756	0.54229	0.52667	0.41646	93.045

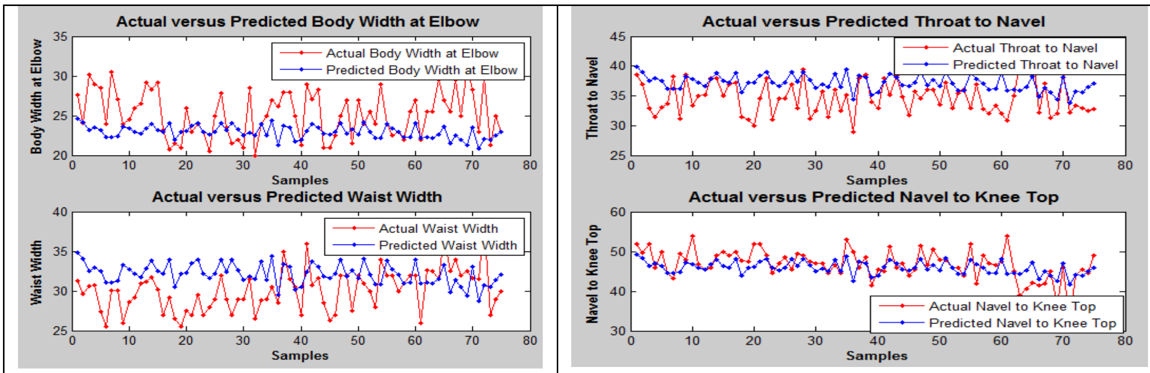
Actual and estimated features of around eighty randomly selected samples are represented in figure 3 and 4. Ten features of torso and leg are estimated using height of the person. Body width at elbow and waist width is shown in figure 3a. Length of the body from throat to navel and navel to knee top is represented in figure 3b. Plot of knee length and shoulder width is presented in figure 3c. Figure 3d shows the chart of length of the leg from knee to ankle and knee to floor. Length of the human body from navel to floor and hip to floor is shown is figure 3e.

Seven features of foot are estimated with the help of height of a person. In figure 4a actual and estimated height of the foot is illustrated. Figure 4(b-d) represents actual and estimated features foot length, foot width and heel width of both left and right foot. Overlap in the graph represents the close association of actual and estimated features.

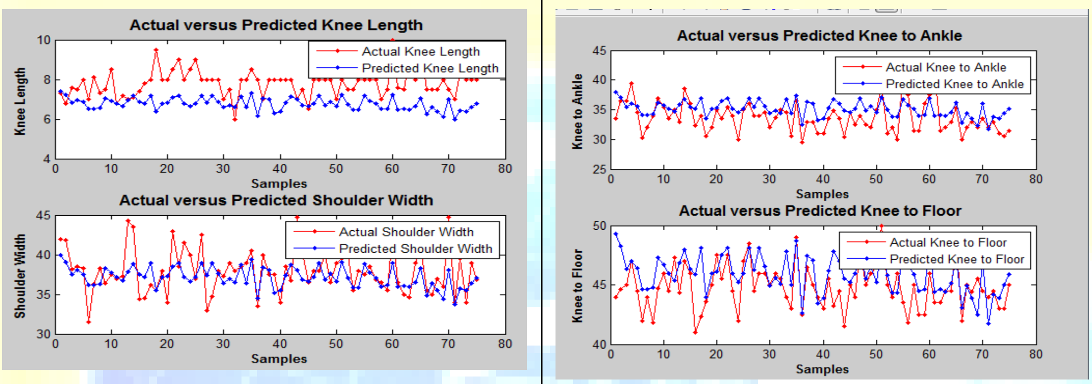
Conclusion

The task of estimating 10 features of the torso and leg is accomplished with the help of Golden ratio. All the features are estimated with an accuracy of more than 90%. Height of the foot and 3 features of left and 3 features of the right foot are predicted with the help of height of a person. Table 1, 2 and 3 tabulates the statistical analysis of all the features for both male and female samples, only female samples and only male samples respectively. Only height of the person is used to predict all the features of torso, leg and foot.

a)	b)



c) d)



e)

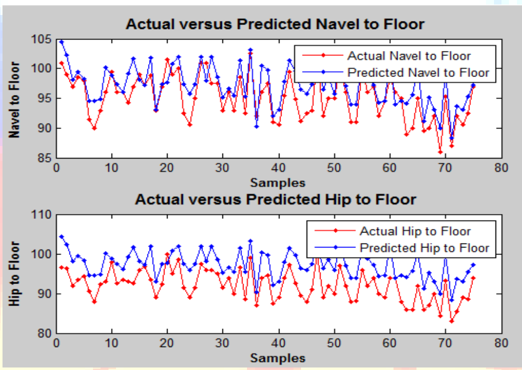
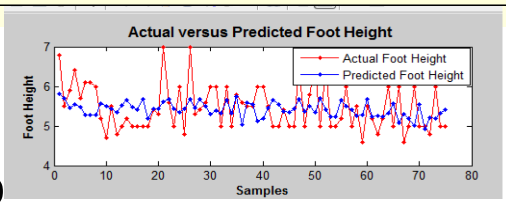
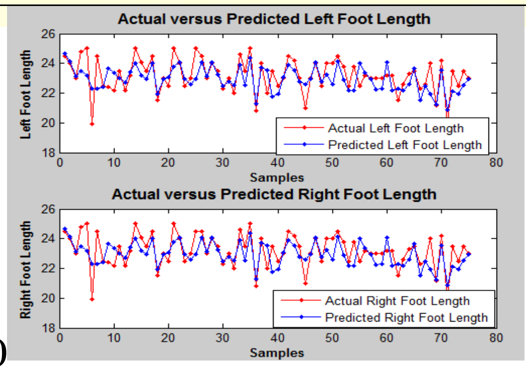


Figure 3(a-e) : Actual and envisaged features of Torso



a)



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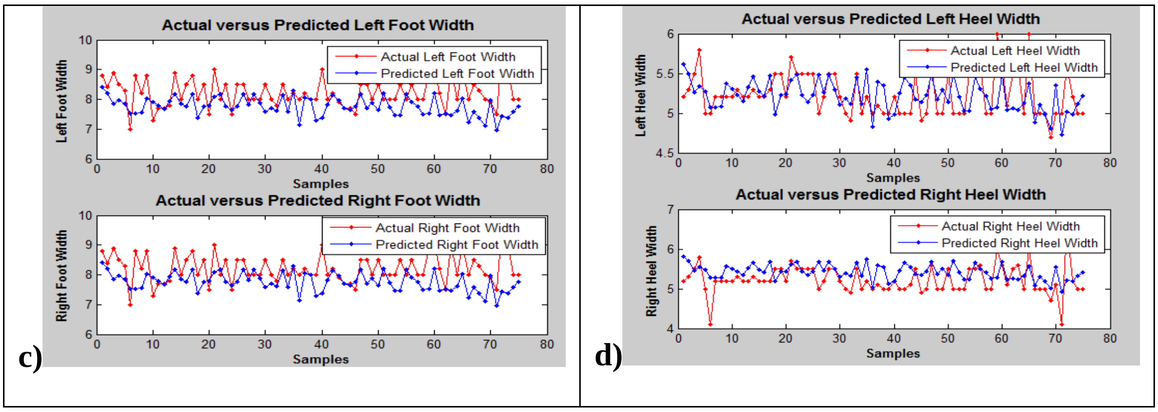

Figure 4(a-d) : Actual and Estimated Features of Foot

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