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Automatic Extraction of 3d Body Measurements from 2d Images of a Female Form

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Abstract: *The revolution of mass production and mass sizing in the 21st century has turned the perfect fit of a garment into a satisfactory one for an individual. A system for extracting body measurements for well-fitted garments at an affordable price is required. Even though 3D body scanning systems can give accurate results about the basic body dimensions, they have a limited use in the industry, especially in the small business setups. 2D images of a person can be used to determine their basic body dimensions. This paper proposes an inexpensive and automated system that will help the small business setups of garment manufacturers by giving a perfect fit to their customers. The experiments were performed on front and side 2D images of 40 young females (subjects) to extract thirteen of the basic body dimensions including the seven girth measurements [1]. All of them were first measured manually, and then 20 subjects were used for training to obtain the conversion formulas between the extracted and final obtained dimensions. The remaining 20 subjects were used for testing, i.e. for comparison between manual measurements and measurements from 2D imaging system.*

Keywords- *2D Images, Feature Points, MATLAB, Measurements*

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I. Introduction

This is the age of consumerism where consumers are aware and are becoming demanding, they require products which are made for their individual needs and style. These demands are also applicable on garments wherein consumers are requiring garments which are well fitting to their forms leading to growth in mass customization, custom fitted and custom designed garments.

The crucial part of meeting this demand of personalized fit is Body measurements. The fit of the garment depends upon the accuracy of these measurements [2]. Though there are traditional ways of measuring the body by use of measuring tapes and measuring by contact method which requires poking, jab, dig, nudge, move, push etc. i.e. basically touch the subject for measurement extraction but are not preferred by the consumers. Apart from that the tradition methods have other drawbacks [3]:

- They are time consuming.
- Many times, wrong positioning of instruments leads to wrong measurements taken.
- They have a low accuracy level

This problem can be solved by technology driven methods which use 3D Scanning but they use an expensive hardware and software which isn't affordable for many [3]. These days various Kinect driven technologies are also in use, which scan the full 3D human body and are provided at a much lower rate. But these also have a drawback: poor quality of reconstructed models due to low quality depth data by Kinects [4]. This creates a research gap to fill in.

In the above context, it was important to develop a reliable, accurate and affordable method of automatic body measurement extraction without touching the subject. This frames the objective for this research.

II. Literature Survey

There have been many attempts made in past to extract measurements through non-contact method and some of them are listed below.

Hung, Witana and Goonetilleke [5] proposed a system to extract anthropometric measurements from 2D images for males. They used front, side and back images and implemented the algorithm to extract the measurements using Visual Basic program.

Lin and Wang [6] and Jiang, Yao, Li, Fang, Zhang and Meng [7] created systems for automatically detecting body features from 2D images of a person. They also estimated 3D models from front and side 2D images of a person. [8]

Khan, Bhuiyan and Adhami [9] established methods of extracting body features from 2D images using the local frequency maps of the images.

Saito, Kouchi, Mochimaru and Aoki [10] extracted silhouette of the torso region from 2D images and optimized it using a target model to create a 3D model of the same.

Pradhan, Gao, Zhang, Gower, Heymsfield, Allison, and Affuso [11] gave an automatic method for constructing a 3D model of a body by making and collecting certain ellipse like slices of it, which used the length and width features, from the 2D back and side images of the body.

Gu, Liu and Xu [12] established girth prediction models of young female bodies using their orthogonal silhouettes.

Google Tango's 'Measure' [13] is a computer application which measures objects from their images. However, it does not give girths and is not very precise while measuring a human body.

These days various Kinect driven technologies are also in use, which scan the full 3D human body and are provided at a much lower rate. But these also have a drawback: poor quality of reconstructed models due to low quality depth data by Kinects [4]

As a conclusion, all these methods do not give the exact dimensions of the female body whether it is a width, a height or a girth measurement which establishes the gap in the research.

The objective of this paper is to propose an effectual, easy and robust technique of extracting 13 body dimensions [1] of a female body. The paper discusses a method of acquiring body dimensions from the 2D front and side images of a female through detection of silhouettes and, feature point extraction. The study was validated by comparison of the extracted measurements with the manual measurements to establish the accuracy of the proposed system. This method can prove to be an effective solution for small business operations in the garment industry or in any other area where these set of measurements are required.

III. Proposed System

The proposed algorithm for extracting the measurements from 2D front and side images is summarized in the flowchart (Fig. 1).

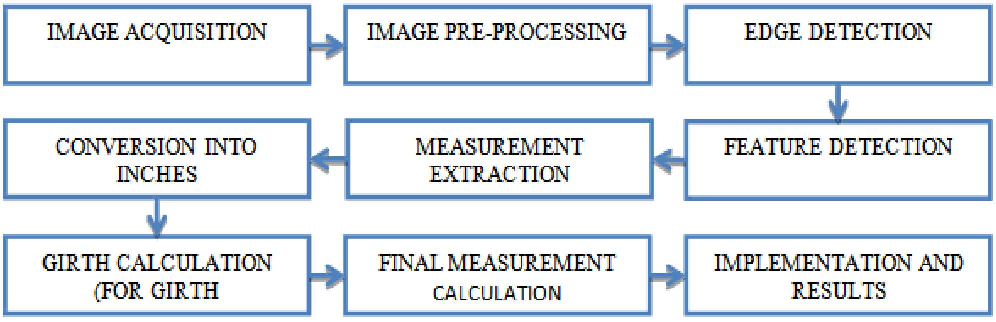

Figure 1 Proposed Algorithm Flow

3.1. Image Acquisition

For the ease and correct working of the feature extraction algorithm, two photographs of each female subject are taken with set standards. The subject was positioned in front of a white background wearing fitted clothes/ undergarments of contrasting colors from the background. (Fig. 2 & 3) For the front image, the subject stands keeping her limbs straight, and arms apart. The legs are separated by 15 inches. (Fig. 2)

Figure 2 Front Image

Figure 3 Side Image

The images were acquired using Canon 1200D and the setting was adjusted such that the image dimensions were 720 x 480 pixels. The camera was positioned 140 inches away from the subject and 36.5 inches above the floor (Fig. 4 & 5). Flash was used to reduce the background shadows in case of dim light.

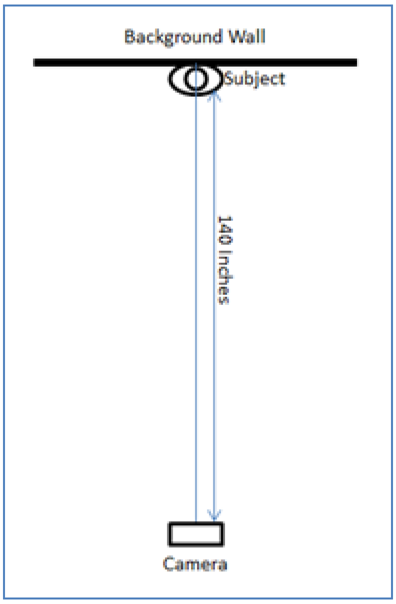

Figure 4 Position for Front Image

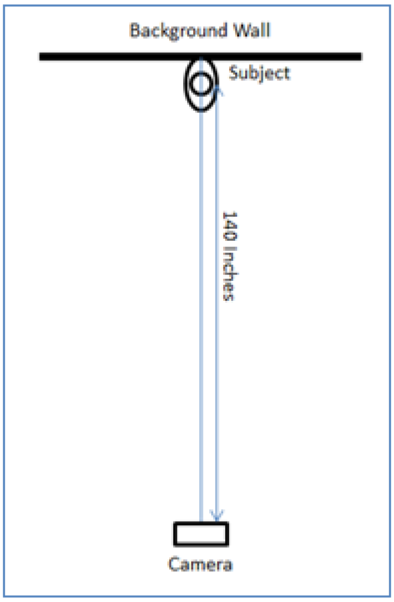

Figure 5 Position for Side Image

3.2. Image Pre-Processing

The images acquired were edited and processed using Adobe Photoshop CS3 for the ease of applying the algorithm. Every colored image was edited to obtain a black and white binary image. (Fig. 6 and 7) For this, the shape tool and the paint bucket tools were used. These tools become easier to use as the subject was wearing clothes of colors contrasting to the background. The body was colored black and the background was colored white. The arms were removed from the image using the same tool so that they do not create problems while extracting the upper body measurements.

Figure 6 Processed Front

Figure 7 Processed Side

3.3. Silhouette Extraction (Edge Detection)

Significant transitions or sudden changes of discontinuities in an image are called as edges. Most of the shape information of any image is enclosed in its edges.

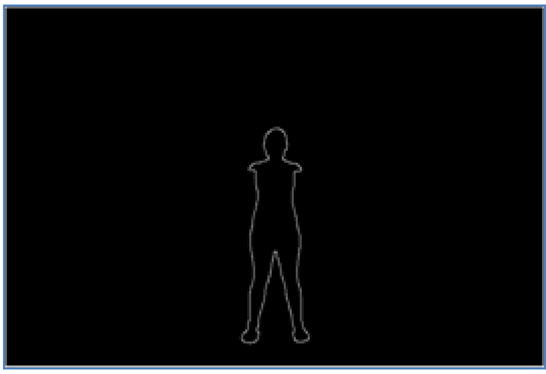

Figure 8 Front Silhouette

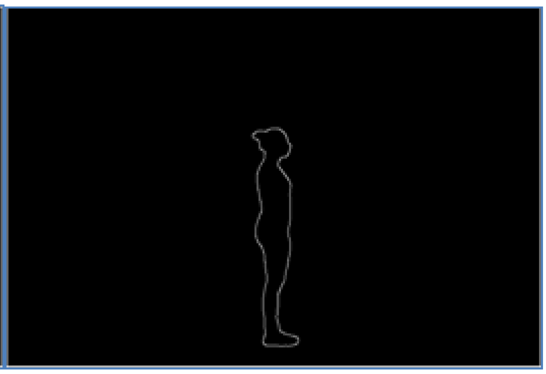

Figure 9 Side Silhouette

The Canny Edge detector has been used to identify the edges from the images. It takes as input a pre-processed image (Section 3.1.1), and produces as output an image showing the positions of tracked intensity discontinuities (Fig. 8 & 9). The Canny operator is less likely to be affected by noise, and more likely to detect true weak edges. [14]

3.4. Identification of Feature Points for Measurement Extraction

All the non-contact methods of body measurement include the mention of a feature point or an interest point and the extraction of these points. “An interest point/feature point is a point in an image which has a well-defined position and can be robustly detected.” [9]

The horizontal levels for each set of feature point were taken approximately for the training set. The feature points at these levels were identified and marked for the measurements. The steps involved to measure them were:

a) Calculate the height and median of the body.
b) Identify the approximate levels for each measurement relative to height and mark the estimated feature points.
c) Measure the Euclidean distance between the identified feature points and based on their maximum or minimum (depending on the measurement), mark the final feature points and discard the rest.

The height (marked as D) and median of the body is shown in Fig. 10. Fig. 11 shows the hip measurement. Three levels of the hip are identified as horizontal rows at 46%, 48% and 50% of the body height (by the average of the 20 subjects). And the feature points are identified at the corners of these rows. (Fig. 11) The Euclidean distances of these three rows is calculated and the points which have the maximum distance to the left and right of the median are considered as the hip feature points. This process is repeated by the side image of the same subject. [11]

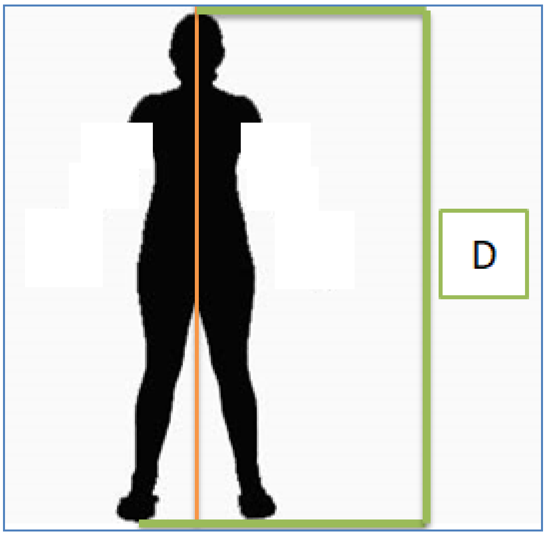

Figure 10 Height & Median

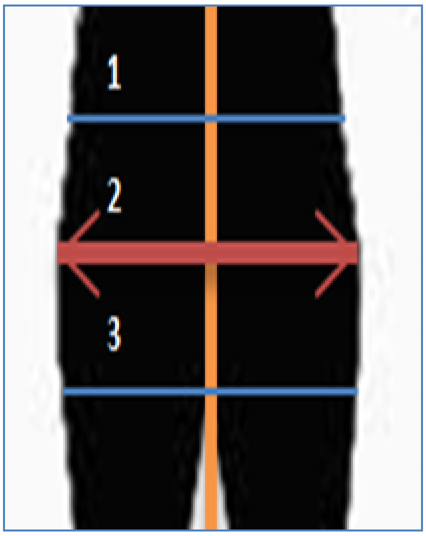

Figure 11 Hip Levels

The feature points for all the horizontal measurements except the Front Thigh measurement were identified in the same way taking different levels for different measurements. Feature points with minimum distances to the left and right of the median were taken in the case of Neck, Under-Bust and Lower-Hip from the three rows instead of the maximum ones.

Feature points for the Thigh width from the front images were extracted in a different way due to the distance between the legs. Firstly, the thigh intersection point was extracted on the median. Then, a transition point of the white to black of the image was taken towards the right of the median. That was the first thigh feature point and the second transition point on the same row was taken as the second thigh feature point.

The feature points for all the vertical measurements were taken on the side images by the existing horizontal features. Figure 12 shows the trunk length which is the distance between the neck feature point and the lower-hip feature point from the side image. The distances between the extracted feature points were noted for all the 13 measurements for all the 40 subjects.

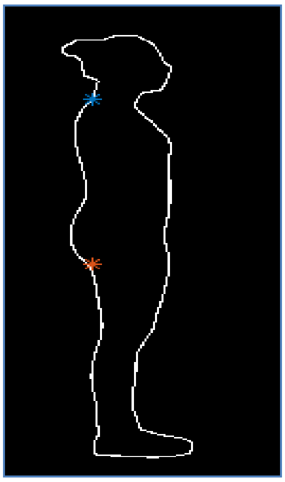

Figure 1 Trunk Length Measurement

3.5. Scaling of measurements extracted in pixels

The measurements extracted from the above method were initially in pixels. The actual measurements in inches were obtained using (1) and (2).

$$\boldsymbol{Horizontal\ Measurement\ (Inches)} = [Distance\ between\ Camera\ \&\ Subject\ (Inches) \times Sensor\ Width\ of\ Camera\ (mm) \times Extracted\ Dimension\ (Pixels)] \div [Focal\ Length\ of\ Camera\ (mm) \times Width\ of\ Image\ (Pixels)]$$

(1)

$$\boldsymbol{Vertical\ Measurement\ (Inches)} = [Distance\ between\ Camera\ \&\ Subject\ (Inches) \times Sensor\ Height\ of\ Camera\ (mm) \times Extracted\ Dimension\ (Pixels)] \div [Focal\ Length\ of\ Camera\ (mm) \times Height\ of\ Image\ (Pixels)]$$

(2)

3.6. Girth Calculation

Out of the 13 measurements; Neck, Bust, Under-Bust, Waist, Hip, Lower-Hip and Thigh are girth measurements. Till now we had the width and depth of all these measurements (From Equation (1) and (2)). We used the formula of perimeter of an ellipse taking the width to be the major axis and the depth to be the minor axis for the same (3).

$$\boldsymbol{Girth} = \pi (A + B) \times \left\{1 + 3 \times (A - B)^2 \div \left[(A + B)^2 \left(10 + \sqrt{4 - 3 \times (A - B)^2 \div (A + B)^2}\right)\right]\right\}$$

(3)

(Where A = ½(Width from front image) and B = ½(Depth from side image))

3.7. Final Measurement Calculation

After converting the extracted measurements to inches, there was still some amount of disparity left in the manual and converted measurements. To reduce this disparity, a conversion factor was experimentally derived for each measurement using the 20 training subjects. The details follow in the implementation and results section.

IV. Implementation and Results

In this study, total 40 female subjects were used (Age: 15 to 47). The front and side images of these subjects were acquired using Canon 1200D as discussed in Section 3.1. 20 subjects were used as training subjects and the remaining 20 were used for testing. Manual measurements of all the subjects were taken by a measuring tape (inches) and were recorded.

Implementation for feature extraction and all 13 measurements was done in MATLAB R2016a. For the feature extraction algorithm, certain levels of the body were required at which the horizontal measurements were to be taken. For this, the levels were manually measured from the 20 training subjects and the average of the same was taken; which was to be inserted in the algorithm for the extracted measurement to be at the correct level.

The correlation factor for each measurement to convert values to inches was experimentally derived and is listed here in TABLE 1. The final measurements were obtained by dividing the converted measurements by their respective calculated conversion factor.

TABLE 1 Conversion Factor for Each Measurement

S.NO.	MEASUREMENT	CONVERSION FACTOR
1	Neck	1.25
2	Shoulder	1.16
3	Bust	1.10
4	Under-Bust	1.14
5	Waist	1.15
6	Hip	1.16
7	Lower-Hip	1.09
8	Thigh	1.24
9	Body Height	1.10
10	Trunk Length	1.06
11	Body Rise	1.24
12	Waist Height	1.19
13	Knee Height	1.24

The results for each final extracted measurement were evaluated against their respective manual measurements for the 20 test subjects. This was done using the Linear Regression Analysis. Correlation value signifies the strength of relationship between the compared measurements. The regression value is a statistical value which shows the closeness of the data to the fitted regression line. The correlation and regression for each measurement was calculated (TABLE 2) and the line fit plots of each are represented by Graphs shown in Fig. 13-25. The p-value or the calculated probability checks the null hypothesis which states that there is no effect of the system. Higher the correlation and regression values, better the results. The p-value should be ≤ 0.05 to reject the null hypothesis.

Table 2 Final Result Table

S.NO.	MEASUREMENT	CORRELATION VALUE	REGRESSION VALUE	p-Value
1	Neck	0.42	0.18	0.06
2	Shoulder	0.55	0.30	0.01
3	Bust	0.93	0.86	< 0.01
4	Under-Bust	0.92	0.86	< 0.01
5	Waist	0.91	0.83	< 0.01
6	Hip	0.96	0.92	< 0.01
7	Lower-Hip	0.95	0.90	< 0.01
8	Thigh	0.75	0.57	< 0.01
9	Body Height	0.90	0.80	< 0.01
10	Trunk Length	0.73	0.53	< 0.01
11	Body Rise	0.13	0.02	0.58
12	Waist Height	0.74	0.55	< 0.01
13	Knee Height	0.43	0.19	0.06

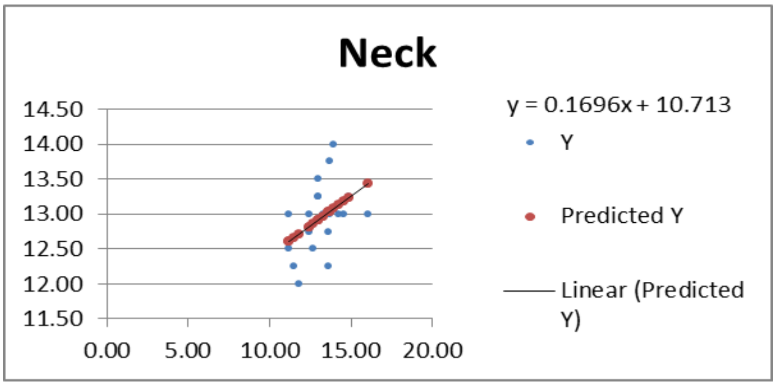

Figure 2 Line Fit Plot: Neck

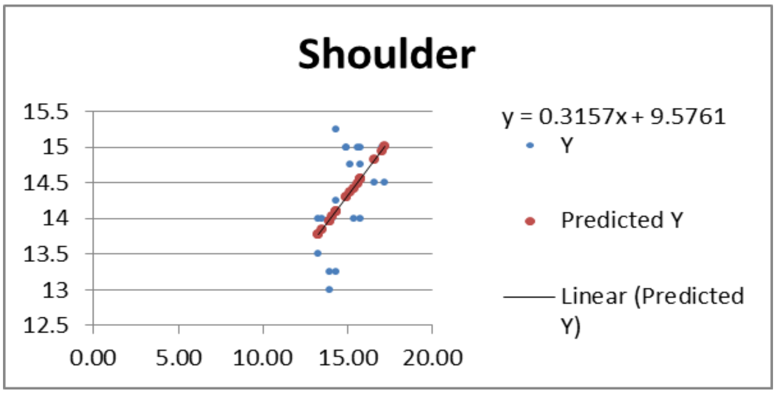

Figure 3 Line Fit Plot: Shoulder

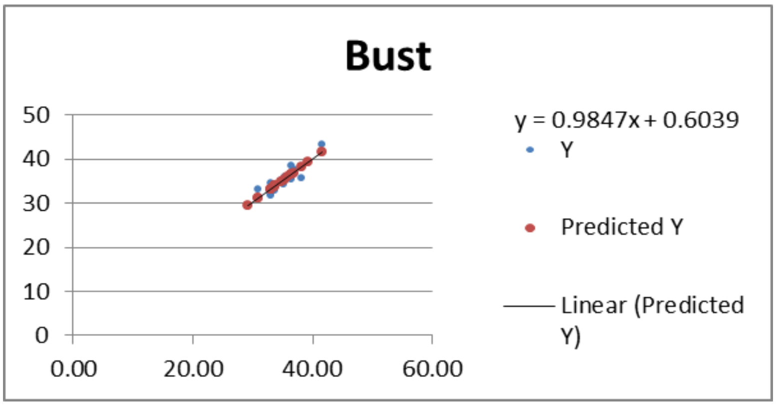

Figure 4 Line Fit Plot: Bust

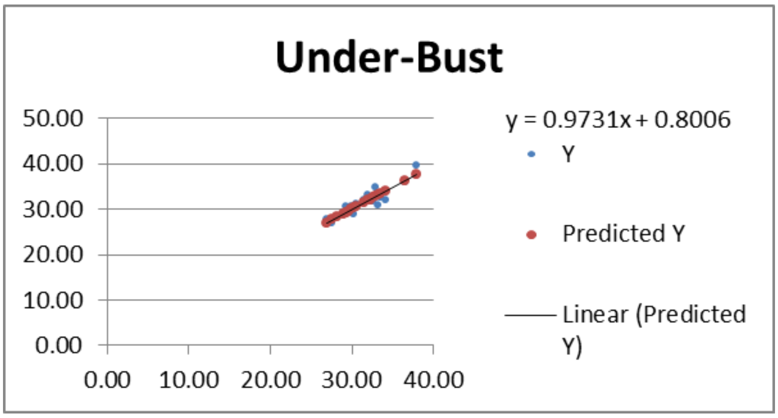

Figure 5 Line Fit Plot: Under-Bust

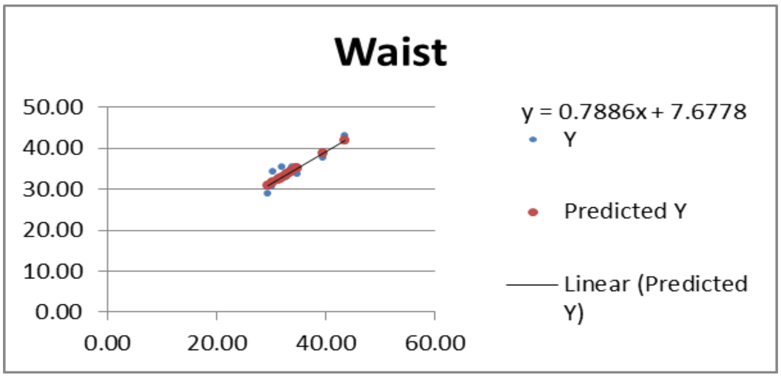

Figure 6 Line Fit Plot: Waist

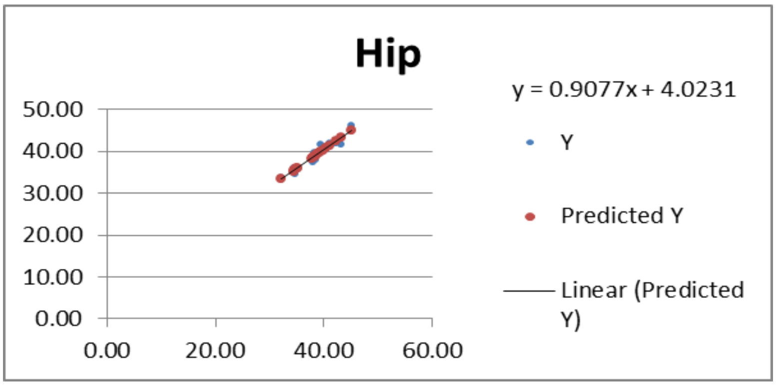

Figure 7 Line Fit Plot: Hip

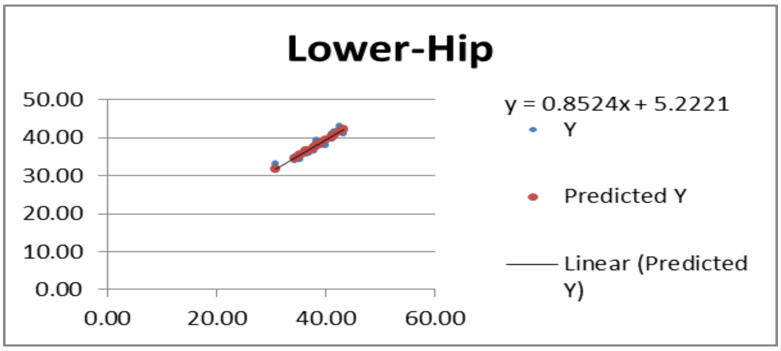

Figure 8 Line Fit Plot: Lower- Hip

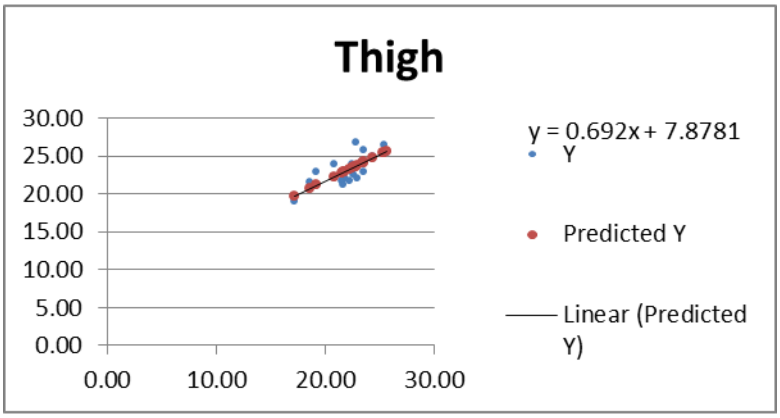

Figure 9 Line Fit Plot: Thigh

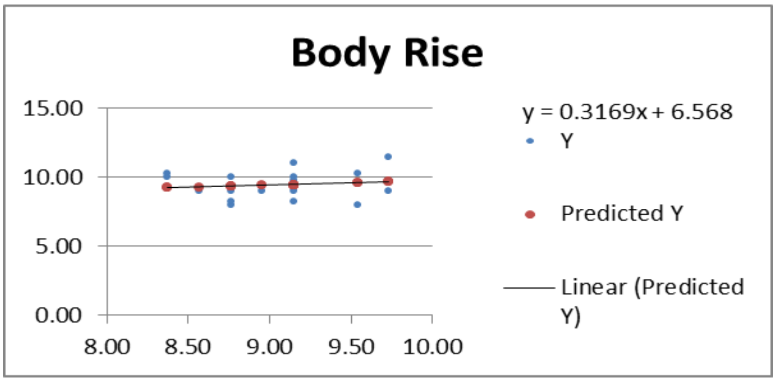

Figure 10 Line Fit Plot: Body Rise

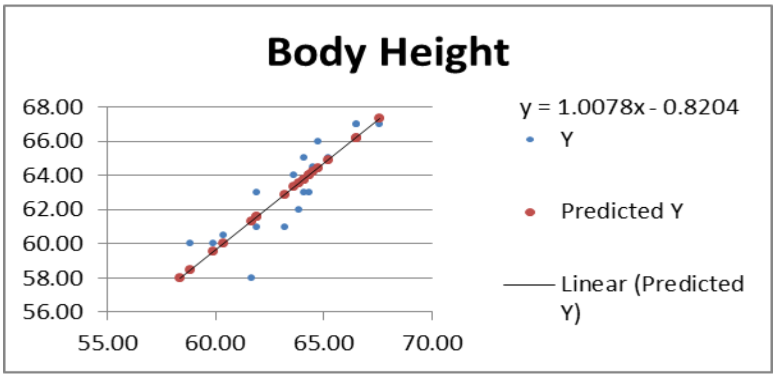

Figure 11 Line Fit Plot: Body Height

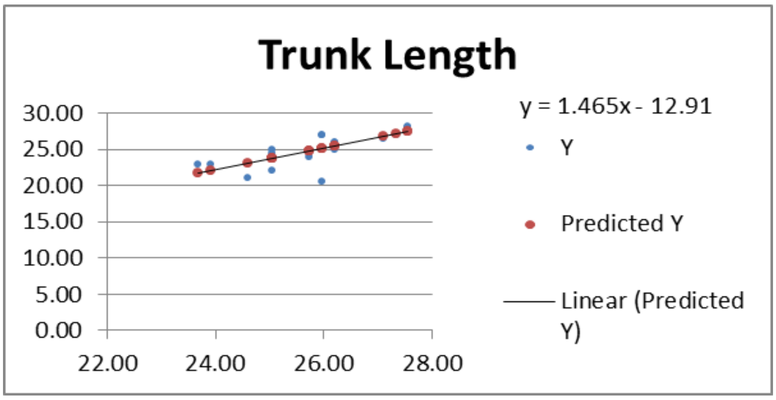

Figure 12 Line Fit Plot: Trunk Length

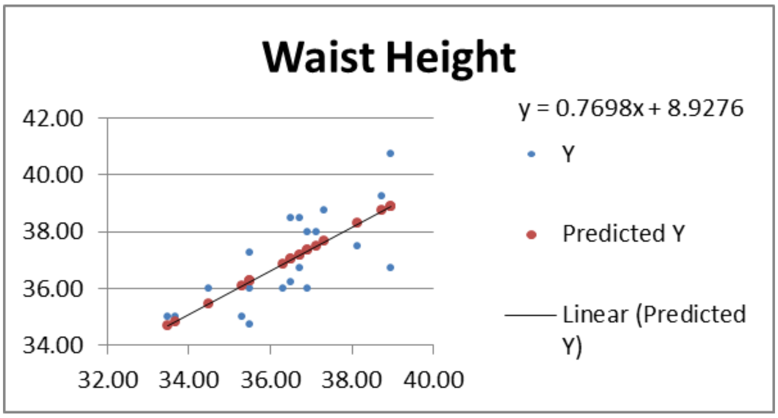

Figure 13 Line Fit Plot: Waist Height

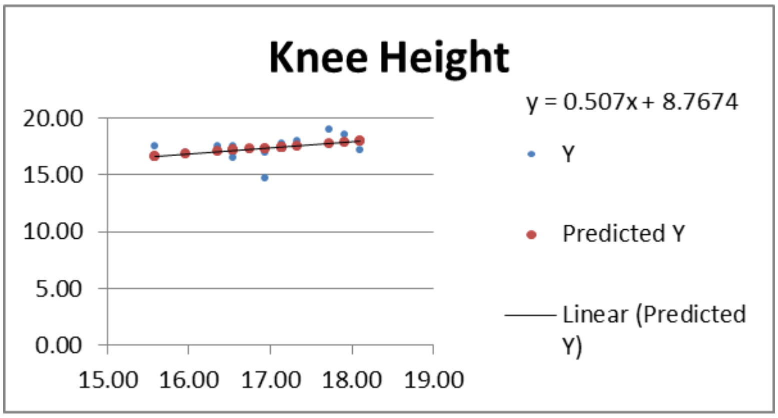

Figure 14 Line Fit Plot: Knee Height

The measurement Body Rise was discarded since its p-value was much greater than 0.05. Amongst all the considered measurements, Hip showed the highest correlation (R= 0.96) whereas Neck showed the lowest (R= 0.42). Body Rise showed major disparity because it is manually measured from the back of the subject (Waist to lower hip) and it is calculated from the front body in the above method. Neck showed this disparity because of the hair pixels merging with the neck pixels in the image. These defects would be tried to be reduced in the further study.

V. Conclusion

This research concentrated on establishing a model which uses 2D images of females, for the extraction of their basic body measurements. This study proposed an easy and inexpensive method which avoids the expensive 3D scanning techniques and the lengthy methods for manual measurement to create custom fit apparel.

On the basis of front and side images of a female subject in this setup, 13 of the basic body measurements were extracted in pixels. Then, these measurements were converted into inches by the distance formulas. Conversion factors were also derived for each measurement to reduce the disparities during measurements. It was experimentally found that girth measurements showed a higher correlation than the height measurements. Body Rise and Neck Measurements are further to be studied.

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