

## Human Body Measurement System in Clothing Using Image Processing

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**Abstract:** 3D body scanning systems in recent years have speeded up body size measurement and improved garment fitness. The high cost and the need for a bare body scan are the main problems associated with the existing systems so that they cannot be employed in many countries. This paper presents a new device that overcomes the problems. Three narrow ribbons on which two different shapes of circles and rectangles are printed with a luminous color are put around the chest, waist and hips of a body under a controlled tension. Two images are then taken from the front and back of the body with a digital camera. The data of the images are converted to three anthropometric sizes applying different image processing procedures. To evaluate the validity and accuracy of the system, 40 manikins are manually measured by 5 experts and five times by the system. Statistical analyses are performed by T-Test and the acceptable correlation of 95% has been achieved between the two results. It can be concluded that the anthropometric data of human body covered by luminance color ribbons can be inexpensively and quickly measured by the introduced system.

**Key words:** Human body Measurement • Measurement system • Image Processing

### INTRODUCTION

The first step in garment production is body measurement. There are different methods for body measurement. Among these methods, Muler is the most applicable in Iran. In general, this method involves measurement, pattern making and sewing [1, 2].

Nowadays, body measurement is done automatically. Automatic body measurement methods can be categorized in different groups, including light, laser, millimeter waves, modeling and image processing based systems [3, 4, 5, 7, 8, 10].

Moire shadow method is widely employed in 3-D white light-based body scanning devices. In this method different units are used including a lattice screen, a camera, a white light source and an operating system. The price of these devices is lower than laser devices [3, 4, 7, 8]. In this method, a predefined pattern is projected on the body. Three-dimensional sizes are extracted by processing the deformations of the reflected pattern.

In laser-based systems, the body is exposed to laser beams so that their reflections can be captured by more than one camera. The systems require a software to control the time and method of scanning. The systems can be quite expensive. The problem associated with this method is that unintentional movements of body create noises [2, 5, 6, 7, 8, 9].

In other systems, millimeter wave senders and receivers are used to capture the signals of the body and objects attached to it. The waves pass through thin objects such as clothes and hair. The electronic device takes a high quality three-dimensional photograph of the body which helps dressmakers produce clothes with right sizes quite fast. The three-dimensional image can be then turned into a two-dimensional one. In this case less data are to be processed [3, 4, 10].

All above-mentioned devices are quite expensive and except the millimeter wave method, bodies are measured by the systems without cloth. These two points are considered as the limitations for such devices.

Nowadays, image processing has many applications in garment industry and measurements. The purpose of applying image processing and modeling is to create three-dimensional models of a body. In this case, three-dimensional scanning is not carried out, since three-dimensional data can be elicited from two-dimensional images [3, 4, 11-23].

This paper presents a method based on image processing which can extract the main measurements of the body based on Muller method, with low cost and high speed. There are different methods for automatic body measurement, each of them has its own advantages and disadvantages. The present work introduces a semiautomatic method in which a self-made low cost printed fabric measuring tape is employed to overcome the problem of involuntary body movements.

## MATERIALS AND METHODS

**Materials:** Fabric made of 65% polyester and 35% cotton was used for preparing measuring tapes (three ribbons). The density of the warp and weft was 28 and 23 in centimeters, respectively. The strength was 289.17 N, elongation at break was 36.27 mm and the type of texture was taffeta L1/1.

A Nikon D300 color digital camera (2144×1424 pixels) was used to capture the front and back views of body. For image capturing MIRROR LENSES was employed. Also VISTAR VS 400A was employed for lighten printed colors. Images were captured in a dark room, under conditions described in Table 1. The pictures were taken from two sides, front and back views of the body.

The used materials for printing the fabric tapes are presented in Table 2. Also the printing paste containing materials are shown in Table 3. After printing, samples were dried and consolidation in 150°C for 10 minutes. The dimension of printed shapes and their distance from each other in strip are shown schematically in Figure 1.

**Body Measurement:** Stereo method is a method which can turn a picture into three-dimensional perspective based on the 2D capturing image. However, this method has some

Table 1: Conditions of Taking Pictures and Storage of Data

Color representation	sRGB
Bit depth	24
Vertical resolution	300 dpi
F-stop	f/5.6
Exposure bias	1 Sec
ISO Speed	ISO-640-Auto
Focal length	50 mm
White balance	Auto
Max aperture	4.5

Table 2: Type of used material

Materials	Type
Binder	Polymeric binder
Thickener	Acracons
Hygroscopic	Glycerin
Luminous paint	Luminous paint, grass green light, Ms x05

Table 3: Printing paste

Pigment color	50 gram
Binder	200 gram
Acracons (thickener)	600 gram
Glycerin	50 gram
Balance	X gram

limitations. In order to overcome the limitations of the method, three stripes were designed. Two different shapes, 3×4 cm rectangles and circles with a radius of 1 cm were printed with luminous colors on each stripe. Each of these stripes was laid on the chest, waist and hip using appropriate designed collector as shown schematically in Figure 2. Considering the stability of the distances between printed shapes and change of every other shape and their sizes, the missing points can be found and their lengths can be measured. The only variable distance is the point where two ends of the stripe meet each other which can be determined by using a scale.

In this method, two pictures one from the front of body and another from the back of body were obtained and were used to determine body measurements (Figure 3).

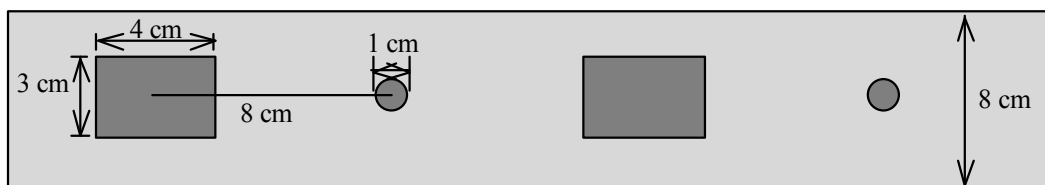


Fig. 1: Schematically specification of measuring tape (ribbon)

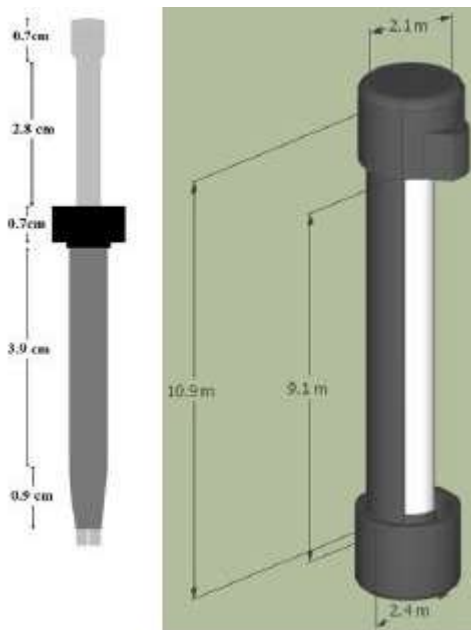


Fig. 2: Collector and its internal parts

Matlab software version 7.12.0.635 is used to process the picture. The two captured images-one from the front (Figure 3a) and the other from the back (Figure 3b) are shown in Figure 3. The former is processed first and the latter is processed after it. Considering the fact that the background color is black and the foreground is green, only green color were used for image processing.

At first the captured images by digital camera in RGB format (images in Figure 3) is converted to grayscale images, afterward grayscale image into binary image. The binary image is used to calculate the body measurement with image processing software developed in MATLAB. Also, noise in images is removed using standard techniques and an adaptive median filter algorithm.

By the binarization of the captured images, only the area of the shapes is extracted. There are only three stripes in the front picture; chest, waist and hips, on each of them some circles and rectangles are located whose centers are 8 cm in length. The front picture did not need much processing. Moreover, the types and number of shapes in each picture were determined. As shown in the Figure 3a, the shapes located on the chest line are almost of the same height. The same is true about the shapes located on the waist and hip lines.

As shown in the Figure 4, there are two mutations based on which total number can be divided into three groups. Then in each group the biggest area is determined so that the shapes can be classified based on that.

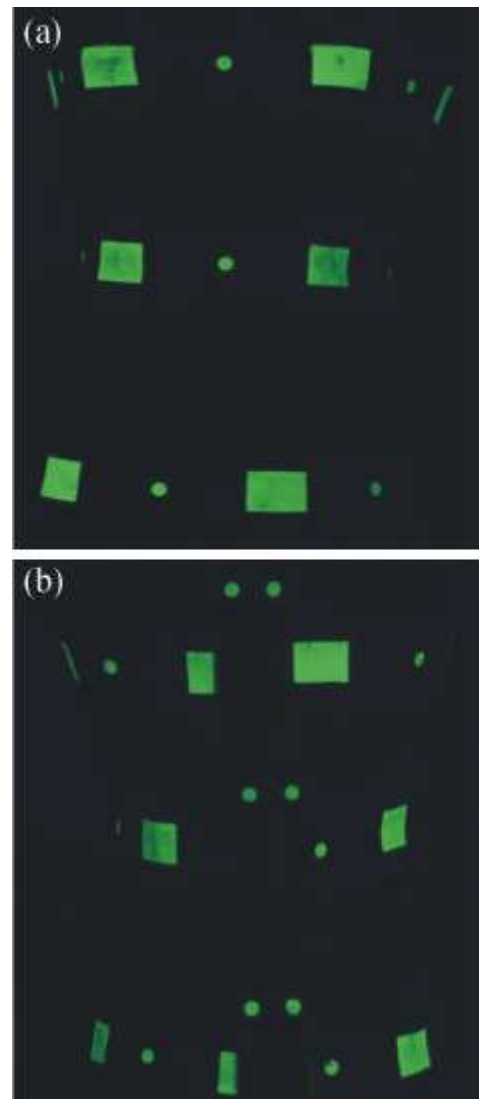


Fig. 3: The captured image from the body:  
(a) Front view, (b) back view

Since the biggest area belongs to a rectangle, number 1 is assigned to that. Then all the other shapes are numbered, therefore the type of shapes can be determined. The sample is provided in Table 4. In Table 4, for example, for chest, the first row is the index number of the shapes in Matlab, the second row refers to the vertical position of the shapes in Matlab coordinates, the third row refers to the area of the objects in pixel and the last row shows numbers 0 and 1 which is related to the circle shape and rectangle shape, respectively. In order to determine the strip length, the number of points in each group is subtracted from 1 and multiplied by 8 which is the distance between the points.

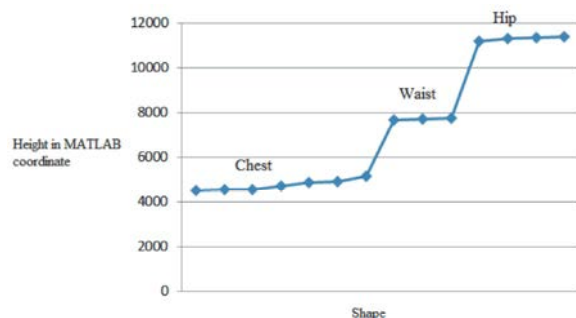


Fig. 4: Height increase to determine classification

Table 4: The extracted results from pictures

Front	$\times 10^3$						
Chest	0.0020	0.0030	0.0040	0.0070	0.0110	0.0130	0.0140
	0.4912	0.4705	0.4543	0.4494	0.4542	0.4866	0.5146
	0.2880	0.0440	5.0030	0.4000	5.4110	0.1370	0.4180
	0.0010	0	0.0010	0	0.0010	0	0.0010
Waist	0.0050	0.080	0.0100				
	0.7694	0.7718	0.7760				
	4.0250	0.3800	3.5300				
	0.0010	0	0.0010				
Hips	0.0010	0.0060	0.0090	0.0120			
	1.1192	1.1347	1.1389	1.1339			
	3.3000	0.3850	5.7160	0.2190			
	0.0010	0	0.0010	0			
Back	$\times 10^3$						
Chest	0.0010	0.0030	0.0070	0.0090	0.0120	0.0150	0.0200
	0.5179	0.5273	0.5365	0.4034	0.4021	0.5195	0.5142
	0.2510	0.3290	2.7470	0.4030	0.4120	5.7240	0.2310
	0.0010	0	0.0010	0	0	0.0010	0
Waist <sub>[D9]</sub>	0.0040	0.0060	0.0100	0.0130	0.0160	0.0180	
	0.7850	0.8098	0.7327	0.7297	0.8222	0.7872	
	0.0450	3.4000	0.3840	0.3970	0.3390	2.4460	
	0	0.0010	0	0	0	0.0010	
Hips	0.0020	0.0050	0.0080	0.0110	0.0140	0.0170	0.0190
	1.1311	1.1532	1.1815	1.0766	1.0736	1.1723	1.1488
	1.3120	0.3270	1.8000	0.4410	0.4650	0.3710	3.0600
	0.0010	0	0.0010	0	0	0	0.0010

All the above mentioned processes are also applied to the back picture. The difference is that it needs more processing. In the back picture, the chest, waist and hips are divided into two parts: right and left. Each part is separately processed and labeled. Thus, their shapes are determined. Two points on the collector are used as criterion. Since the distance between the points on the collector is fixed, the length of the variable distance can be determined. The data reflected to the back picture are also presented in the Table 4.

The other type of processing done on the back picture is for the purpose of determining the side points. In general, side points can have three conditions:

- The side point in the back picture can be the same as its counterpart in the front view. In this case no value is added.
- The side point in the back picture can be the different from its counterpart in the front view and no point is eliminated. In this case 8 units should be added to measured length.
- The side point in the back picture can be different from its counterpart in the front view and a point is eliminated. In this case 16 units should be added to measured length.

## RESULTS AND DISCUSSION

### Evaluation of Changes in Distance Between the Points:

To evaluate the changes of distance between the points due to applied tension to strips during the fastening, at first the sample is cut  $5 \times 13$  cm in the direction where it is held by the collector then it is put in the tensile testing machine in a way that 10 cm of it is placed between the two jaws. Then the tensile testing machine examined the samples with a constant rate of elongation (CRE) and data were recorded. The results are shown in Table 5.

Thereafter the ribbon put on the collector is fastened to the jaw of the tensile testing machine from one side and the other side is fixed in the fixture of tensile testing machine. The tensile testing machine is designed in a way that can measure strain changes of ribbon in 50 centimeters. The results are given in Table 6.

Table 5: Results Obtained from tensile testing of the fabric

Tests data			
Test	Strength (N)	Elongation (mm)	Work of Rapture (cN*cm)
001	212.958	37.000	213.75
002	327.532	36.299	335.74
003	318.239	35.700	905.56
004	323.478	38.599	885.35
005	263.694	34.500	436.69

Table 6: Fabric in collector machine

Tests data			
Test	Strength (N)	Elongation (mm)	Work of Rapture (cN*cm)
001	6.699	487.00	89.81
002	4.039	470.20	87.02
003	4.109	469.20	106.57
004	4.211	469.00	132.80
005	3.927	470.50	77.98

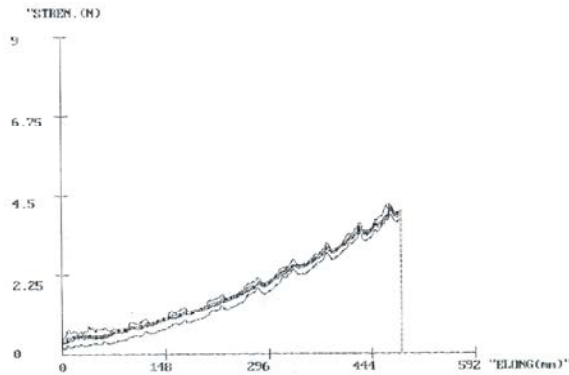


Fig. 5: Strain-Stress curve in fixed length of 50 cm

On the basis of the results obtained from stress-strain curves (Figure 5), it can be found that the applied tension to strips by the spring affects neither the length of the ribbon nor change of distance. This finding was proved by measuring the distances in certain time periods.

Table 7: Picture processing duration

Sample	Time (second)
1	7.30
2	7.10
3	6.50
4	6.50
5	6.50
Mean	6.78

**Picture Processing Time:** In order to determine the duration of picture processing, the mean value of 5 measurements from different people was calculated and reported. The results showed that the measurement data can be processed in less than 7 seconds (Table 7).

**Reliability Test:** The authors have made an approach that can calculate three important measurements, i.e., chest, waist and hips. It is claimed that the measurements obtained have not any different from the data obtained by

Table 8: Descriptive Statistics of Image Based Measurement and Manual Measurements<sub>[D15]</sub>

		P Value	M.M	D.M			P Value	M.M	D.M
101	Chest	0.84	87.56	87.408	116	Chest	0.2	90.6	89.458
	Waist	0.86	69.66	69.568		Waist	0.15	68.74	67.648
	Hip	0.13	88.6	87.826		Hip	0.54	77.94	80.514
102	Chest	0.27	88	87.586	117	Chest	0.75	88.68	88.924
	Waist	0.8	64.8	64.972		Waist	0.05	69.42	68.348
	Hip	0.09	82.6	81.336		Hip	0.72	83.14	82.922
103	Chest	0.24	88.56	89.258	118	Chest	0.2	87.68	87.424
	Waist	0.26	67.6	66.83		Waist	0.23	65.38	64.74
	Hip	0.09	80.4	79.166		Hip	0.12	82.88	81.11
104	Chest	0.17	95.78	95.146	119	Chest	0.91	87.58	87.666
	Waist	0.3	73.58	74.196		Waist	0.95	64.88	64.932
	Hip	0.12	86.66	85.986		Hip	0.9	82.64	82.546
105	Chest	0.2	86.36	85.396	120	Chest	0.18	87.6	86.638
	Waist	0.47	67.68	67.434		Waist	0.17	68.52	67.442
	Hip	0.13	81.78	82.468		Hip	0.1	83.56	82.47
106	Chest	0.76	87.34	87.252	121	Chest	0.13	86.96	86.144
	Waist	0.45	64.8	64.352		Waist	0.69	69.36	69.048
	Hip	0.25	83.14	81.812		Hip	0.22	83.58	82.658
107	Chest	0.62	90.46	90.012	122	Chest	0.2	87.3	86.65
	Waist	0.51	67.22	64.878		Waist	0.19	73.66	67.726
	Hip	0.19	77.72	78.392		Hip	0.18	83.46	82.498
108	Chest	0.5	89.44	89.02	123	Chest	0.14	86.4	85.456
	Waist	0.84	67.96	67.866		Waist	0.13	68.64	67.358
	Hip	0.39	79.94	79.464		Hip	0.57	82.52	81.97
109	Chest	0.2	88.76	88.396	124	Chest	0.06	87.3	86.256
	Waist	0.59	66.1	66.45		Waist	0.08	66.36	63.818
	Hip	0.18	77.42	76.472		Hip	0.06	84.26	83.414
110	Chest	0.25	88.98	88.236	125	Chest	0.12	87.22	86.344
	Waist	0.9	67.52	67.438		Waist	0.41	68.68	68.234
	Hip	0.34	78.54	79.436		Hip	0.26	84.78	83.644

Table 8: Continued

		P Value	M.M	D.M			P Value	M.M	D.M
111	Chest	0.41	88.38	87.712	126	Chest	0.26	87.94	86.978
	Waist	0.15	65.82	66.61		Waist	0.13	73.76	69.362
	Hip	0.99	82.06	82.056		Hip	0.18	84.48	83.502
112	Chest	0.35	88.96	88.4	127	Chest	0.15	85.26	83.668
	Waist	0.42	71.38	67.848		Waist	0.94	65.04	65.074
	Hip	0.46	81.12	80.534		Hip	0.06	81.26	79.738
113	Chest	0.75	88.46	88.196	128	Chest	0.44	89.24	88.66
	Waist	0.18	67.2	67.866		Waist	0.29	68.1	67.056
	Hip	0.72	79.38	79.57		Hip	0.19	79.82	79.506
114	Chest	0.35	88.36	87.362	129	Chest	0.09	86.46	85.636
	Waist	0.77	65.64	65.422		Waist	0.26	68.96	68.11
	Hip	0.81	79.8	79.958		Hip	0.2	83.12	81.878
115	Chest	0.21	88.74	87.758	130	Chest	0.07	88.02	86.576
	Waist	0.89	66.86	66.76		Waist	0.21	67.06	66.702
	Hip	0.38	78.56	79.11		Hip	0.92	86.3	86.228
131	Chest	0.22	89.64	88.072	136	Chest	0.06	92.92	91.194
	Waist	0.58	67.6	70.172		Waist	0.86	72.58	72.382
	Hip	0.11	83.28	82.476		Hip	0.13	89.66	87.86
132	Chest	0.79	88.44	88.266	137	Chest	0.6	88.18	87.758
	Waist	0.11	68.9	67.198		Waist	0.3	66.5	65.668
	Hip	0.43	86.56	85.056		Hip	0.74	81.5	81.858
133	Chest	0.24	89.16	88.036	138	Chest	0.1	87.16	85.806
	Waist	0.86	66.64	66.462		Waist	0.52	66.5	65.852
	Hip	0.82	83.5	83.2		Hip	0.26	81.6	80.34
134	Chest	0.34	91.6	90.694	139	Chest	0.83	86.14	86.268
	Waist	0.16	70.64	69.442		Waist	0.12	70.9	68.592
	Hip	0.49	88.78	88.14		Hip	0.13	86.8	85.158
135	Chest	0.07	87.94	86.912	140	Chest	0.07	87.82	86.314
	Waist	0.7	67.38	67.62		Waist	0.56	65.78	65.232
	Hip	0.9	83.58	83.768		Hip	0.09	84.8	83.468

manual method. In order to examine its reliability, measurements of 40 manikin's were done. Each manikin's measurements were taken 10 times, 5 times manually and 5 times automatically by this approach and the measurements were reported. T-test statistical analysis was employed to compare the two sets of data. By using the t-test statistic, a p-value that indicates chance of our conclusion being wrong (less than 0.05) was obtained. If the p-value is more than 0.05 (significance level), there is not statistically significant difference between the two groups and vice versa.

The statistical analysis carried out for all the people to evaluate the reliability of the test. Since in all the cases P value was greater than 0.05, it can be concluded that there was not significant differences between the image based measurements and the manual measurements (Table 8).

## CONCLUSION

The first stage in garment production is taking body measurements. There are different ways for it. Nowadays, body measurement is done automatically. The automatic methods of taking body measurements can be classified into different categories such as light-based systems, laser-based systems, millimeter wave-based systems and systems which are based on modeling and picture processing. As mentioned before, all devices of three-dimensional measurements are quite expensive, except for millimeter wave-based system which they require the person to be naked. These two factors are considered as limitations of these devices. Nowadays, picture processing has many applications in different fields such as textile industry, garment industry and measurement. Among the uses are: automatic measurement of coverage

factor, control of thread defects, measurement of length and diameter of thread and fibers, measurement of shining index, investigation of the thickness of the cloth and its other features, measurement of torsion angle of cloth and measurement and modeling the body. The purpose of modeling and processing pictures is to create three-dimensional models of the body. In this case, the three-dimensional measurements are not taken directly, rather obtained from two-dimensional measurements. In this paper a method is presented which is based on picture processing. It can take pictures and process them with low cost and high speed and body measurement can be obtained on the basis of Muller method. In this method three-dimensional measurements can be elicited from two-dimensional pictures. Among its advantages are low price and its simple algorithm compared to other devices. Moreover, this paper takes into account other issues such as testing the strength of ribbon and the tension exerted by spring so that the change made to the cloth by spring force can be determined. The results showed that spring force did not affect the length of the cloth. A T-test statistical analysis at  $p=0.05$  level was carried out which showed that the measurements taken by proposed approach did not differ significantly from the manual measurements.

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