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FITME: BODY MEASUREMENT ESTIMATIONS USING MACHINE LEARNING METHOD

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Abstract

Online shopping platforms have been attracting many customers since they were introduced in the last decade of the 20th century. Using online shopping platforms, customers can purchase any merchandise anywhere and anytime without the need to physically go from store to store to find a product or wait in lines to check out. Despite their advantages in comparison with instore shopping, customers often have concerns when they shop for products that require measurements estimation such as furniture and clothes. Choosing the wrong clothing size, in particular, is a common issue experienced by many online shoppers. Therefore, in this research, we proposed a model that estimates human body measurements from human real-time pictures using Haar Cascade classifier and support vector machines.

Keywords: Estimate Body Measurements; Image Processing; Support Vector Machine;

1. Introduction

Shopping is the activity in which customers browse presented products or goods by some retails with the intention to purchase them. Shopping is one of the most important necessities of modern life, where people purchase items that met their needs and interests. This process may take different forms, and online shopping is one of them. Online shopping has been sweeping the world at a rapid pace especially in the in recent years. Customers prefer online over in-store shopping since online shopping requires less time and effort. Customers with online shopping

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can search for any product in many stores and purchase online with only a few steps instead of going to retails store to find their desired products and standing in a line to check out. Despite the many benefits of shopping online, some customers may encounter difficulties as they are unable to assess the quality of the product which might lead to receiving a wrong, damaged, or delayed product. Clothes shoppers, particularly, encounter problems of different nature. Clothes shoppers might prefer in-stores shopping rather than online shopping for many reasons that includes the inability to determine their proper clothing size accurately, try clothes on to see whether they are suitable or not, and assess the quality of the material of clothes.

In the case of determining the proper size, customers either determine their clothing size by measuring their body manually or choose a size they are accustomed to wearing. The manual measurement is usually obtained using a measuring tape and physically measuring the height, the shoulder width, the bust, the waist, and the hip areas. These measurements, however, are not always accurate and suitable for all types of clothing. Customers may also need to measure additional parts of the body if they were buying more specific clothes (e.g., suites or long-sleeved dress). For example, when a customer wants to buy a dress or a jacket, she or he needs to measure the bust, waist, and hip. To measure the waist area, for example, the customer needs to measure the waist around the body tightly and fully. While when measuring the thigh, the customer needs to measure the largest point in the thigh. After measuring body parts, the customer may need to convert the measurements and choose the proper size accordingly. Differences in measurements, body areas measured, and clothing types often lead to inaccurate manual measurements and require time.

Several studies have investigated the possibility of automatically estimating body measurements from customers images. Most of these approaches utilize specialized devices (e.g., in-depth camera) to capture 3D images of the human body. Despite the measurements accuracy that 3D based method provides, these methods are not applicable for all users who want to estimate their sizes on-the-go while purchasing items online. Only a few studies have used 2D images to estimate the body measurements. Studies that considered the 2D images estimate some basic measurements of human bodies or classify the human body into some predefined classes.

Therefore, in this research, we aim to build a smartphone system that allow users to estimate their body measurements and predict their body sizes by taking a 2D picture of the body using typical smartphone camera in one distinct direction (e.g., front view). To build a robust application and to train the algorithm on some real-world data, we first conducted an experiment in which we took pictures of a number of participants along with their body measurements. Then, the proposed approach extracts the features from pictures using computer vision and machine learning techniques to estimate the body measurements (e.g., waist and bust). After that, the approach uses support vector machine (SVM) to estimate the appropriate size of the shoppers. Using such a system will help online shopping customers to estimate their body measurement accurately and improve the online shopping experience eventually.

2. Related Work

Estimating body measurements from 2D images is a very challenging task and only a small number of studies investigated this particular problem. While the rest of the studies used more complex and in-depth cameras to obtain 3D images that then are used to estimate the body measurements. In this section, we present the research effort that focus on estimating clothing size or body parts measurements using 3D and 2D images. Chang, et al. [9] proposed a dynamic fitting room that utilizes Microsoft Kinect and augmented reality technologies to allow individuals to visualize a real-time image of themselves while trying on different digital clothes. The system evaluates the user's body height according to head/foot joints and the depth information using two Kinect cameras one for taking a front image and the other for side image. The result of evaluating the proposed model shows that the estimated size is quite close to users' claimed sizes. This study however requires sophisticated hardware (i.e., Kinects cameras) to estimate the measurements.

Xiaohuia, et al. [8] proposed method aims to provide an automatic way to extract feature points and measure the sizes on 3D human bodies. The feature extraction and measurement estimation stage are usually serving as a pre-processing step for garment designer or virtual fitting application. The proposed method is automatic in a data-driven way, and it is insensitive to postures and different shapes of 3D human body. The approach also requires depth camera to estimate body measurements which is not appropriate and easy to use for online shoppers who want to estimate their body measurements. Another research Mojarrad & Kargar [10] proposed an approach that examine various images of people and estimate the size, body measurements, and other properties of the body (e.g., tall fat, short fat, tall thin, and short thin). The model starts by using many remote sensing applications such as image registration, image segmentation, and object detection and recognition as a pre-processing stage for feature extraction. Then, the model extracts feature and detect the edges and points of the body using canny edge detector approach. The findings of the study revealed that the proposed method was able to work on all of the human sizes. The limitation of this approach is that they didn't focus on specifying all the measurements of body parts.

One of the most related research works to our proposed approach is developed by Chandra, et al. [5] who presented an approach that estimate human body measurements by utilizing phone cameras. The proposed method tracks the photographed bodies using full body detection methodology to determine if there is a human body in the photo or not. The system then uses upper body detection to identify the face, neck, and shoulders then the system activates the upper body marker. Then, the body part will be estimated by calculating the difference between the most left-side and most right-side of any body part (e.g., shoulders). They also applied the golden ratio of human body to estimate the body measurements. Despite of the automated functionalities of their proposed system, the application recommends user to use some specific environmental settings (i.e., background and light). The method also only detects the upper body of customers while the lower body is still very important to estimate the proper size. Another limitation of the system is that the detection and measurement have to be repeated five times, and the system will find the mode of the results to give the user the most accurate size.

3. Methodology

To estimate human body measurements and predict their body size from 2D images taken from regular smartphones, we utilized computer vision and machine learning techniques. To estimate human body measurements, the model 1) detects the human body from the images, 2) extracts the features of the body from the picture, 3) determines the focal points in the human body, and 4) calculates the body measurements by computing difference between the focal points. To predict the proper clothing size of a given individual, the models use a support vector machine that is trained on some body measurements and body size of customers. In this section, we provide more details about the computer vision and machine learning techniques used in every ta research.

3.1 Body detection

Object detection, in general, is a computer research problem related to computer vision and image processing. The detection aims to identify a particular set of features of an object in images and videos. Most systems that use object detection are using a machine learning-based approach. Using a machine learning approach, the body detection model often starts by determining the features of the desired object and use classification techniques to classify the objects. One of the machine learning approaches to specifying the features of the object is Haar Cascade. The Haar-Cascade classifier is a machine learning based approach for real-time object detection. Haar-Cascade classifier was chosen over other object detection algorithms as it was found to faster and more accurate than their competitors. Haar-Cascade classifier classification process is based on feature values rather than pixels that makes the algorithm 15 times faster than Rowley Baluja-Kanade detector and 600 times faster than Schneiderman-Kanade detector [21]. The algorithm also is considered as good and robust method for object detection due to its ability to provide a very high true positive rate of detection with a very low false rate. The algorithm has been successfully applied to human-body detection in images.

To detect the human body from the images, we use a pre-trained Haar-based detector that provides three detectors: *Upper body detector* which used for detecting the upper body part, *Lower body detector* which used for detecting the lower part from the body and the last one is *Full body detector* which used to detecting the whole human body as shown in Fig. 1. These detectors may include some of the backgrounds when detecting the body that reflects the training data. However, the detectors have some other limitations of not being able to detect body from side body accurately as it is mainly trained for detecting the front and back body. Also, the detectors didn't detect the people who wear light colors of clothing (e.g., white or off-white). Due to that, we excluded the participants who wear light colors tops or pants from the dataset. We used the detectors on a dataset that contains two images (i.e., front image and side image) of 48 female and male participants. After we did some experiments on these detectors, we found out to enhance and improve the detection results by converting the input image to grey scale color. The final obtained results for detecting the full body show that the model detects 96% of the front body images and only 21% of the side body images. For the upper body detector, the model detects 81% of the front body images and 18% of the side body images. For the lower body detector, it detected 96% of the front body images and 31% of the side body images which is considered the best detections rate for the side images. Based on the low performance in detecting the side image, we decided to be ignored the side images in this research and focus on estimating the measurements from only the front images.

Fig. 1. Original image, full detector, upper detector and lower detector with front image.

3.2 Feature Extraction

Feature extraction is an essential stage in image processing that leads to better understanding and classifying images. The primary goal of feature extraction this research is to extract some interest points (i.e., focal points) from the detected body to be able to estimate the measurements for each part (i.e., shoulders, bust, waist, and hip). We tried several methods to calculate the measurements of human body parts until we reached this current method. The method used in this research is based on two major steps. The first step segments the input image, as illustrated in Fig 2, vertically into parts to specify the interest points. Then, the second step specifies two points from the most left and most right side of each body parts. The chosen points should fall in the closest segment line to the most left side and the rightest side of each body part. For the segmentation, we decided to segment the body image into 40 vertical lines to get the line that fallen in the same interest points or near it. To estimate the measurements for any part from the body, we need at least to extract two reference points that called focal points (e.g., the most left side and the right side of the shoulder). We discuss in the following sections the methods that are used in this paper to extract the focal points and how they are used to estimate the measurements of the body from the images that were accurately classified in the body detection stage.

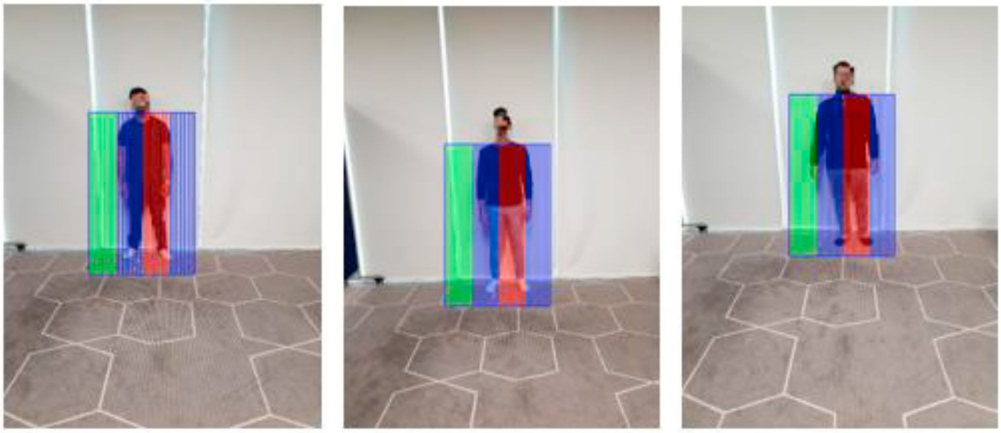

Fig. 2. Features extraction using segmented the detected image into parts.

3.3 Extract the focal points

In this section, we will discuss and illustrate the followed method we used to extract the focal points after the segmentation stage. After we segment the image into 40 parts, we color every ten lines with the same color to facilitate counting them. After that, we select the nearest segment line to the interest points manually by observing all participants pictures and determining the closest line to the focal points of each body parts. After deciding the lines, we compute the mean of the left and right focal points of all participants for each body part. For the shoulders, we observed that all left focal points for all male participants fall between line 11 and 16 and all right focal points fall between line 28 and 34. So, we considered the average of these values as a left focal point and the right focal point for the shoulder, respectively. The same process applied to specify the left and right focal points for the bust, waist, and hip. For the bust, we observe that all left focal points fell between line 14 and 17, and all right focal points fall between line 27 and 32. For the waist, we found that all left focal points fall between line 13 and 17, and the right focal points fall between line 27 and 32. Finally, for the hip, we noticed that all the left focal points fall between line 13 and 17 and all the right focal points fall between line 28 and 31.

For the female participants' shoulders, we observe that all left focal points of the shoulder fall between line 11 and 18 and all right focal points fall between line 29 and 37. Then we observe that all left focal points for the bust fall between line 12 and 19, and all right focal points fall between line 28 and 35. For the waist, we found that all the left focal points of the waist fall between line 12 and 19, and the right focal points fall between the 28 and 34. Finally, we observe that the left focal points of the hip fall between line 11 and 18, and right focal points fall between line 28 and 36. This process were performed manually and can be estimated automatically in the future works. The following section shows how we used these focal points of each the part from the body to estimate their measurements.

3.4 Estimate the measurements

After specifying the left and right focal points for all parts of the body, we need to find the distance between these points by finding the difference between them. The result of difference is representing the width of the area by pixel unit, but the system deals and works on cm unit. Thus, we need to convert the results from pixel to cm. To convert the width from pixel to cm, we multiply the difference with 0.0264 according to the equation (1). The result we obtained after converting the difference represents the width of the area inside the body image by cm, and we want to use this value to estimate the real measurements of the body. To estimate the real measurement of a body area knowing the distance between the focal points in the image, we need to specify a reference point (e.g., the ratio of the distance between focal points inside the image to the distance between the real focal points for the fixed distance between the body and the phone camera). So, we fixed the ratio between the width of focal points inside the image (cm) and in the real (cm) (i.e., the ratio between the width of shoulder inside the image and the real measurements of shoulders, the ratio between the measurements of bust inside the image and in the real and the same way in the ratio for the waist and hip). The values of the reference points (i.e., the fixed ratios for each part from the body) is the values of a single participant selected randomly from the male and female. This value is then used to estimate the measurements for all participants. To estimate the measurement of the shoulder, we are using equations (2) and (3). Also, we are using the equations (4) and (5) for estimating the bust measurements, equations (6) and (7) to estimate the waist measurements, and equations (8) and (9) to estimate hip measurement. The equations are represented as follows.

$$1\ px = 0.0264\ \text{cm} \tag{1}$$
$$Estimate\ Shoulder\ (male) = 11.862 * width(cm) \tag{2}$$
$$Estimate\ Shoulder\ (female) = 13.63 * width(cm) \tag{3}$$
$$Estimate\ Bust\ (male) = 29.03 * width(cm) \tag{4}$$
$$Estimate\ Bust\ (female) = 36.18 * width(cm) \tag{5}$$
$$Estimate\ Waist\ (male) = 26.01 * width(cm) \tag{6}$$
$$Estimate\ Waist\ (female) = 14.66 * width(cm) \tag{7}$$
$$Estimate\ Hip(male) = 31.15 * width(cm) \tag{8}$$
$$Estimate\ Hip(female) = 39.05 * width(cm) \tag{9}$$

3.5 Predict the size

We built a machine learning models to predict the size of shoppers that suitable by training and testing the models on a real-world dataset of the body measurements of participants along with their clothing sizes. A supervised machine learning method was used in this phase as the dataset contains features (i.e., body part measurements) and labels (i.e., standard sizes of clothes). We implemented SVM classifiers that can predict the clothes size for the shopper. Support Vector Machine (SVM) is a type of supervised machine learning classification algorithm introduced in the 1960s. It is one of the most robust and fast algorithms among the other classification methods and gets brilliant results. We built several SVM models each of them to predicts one of the standard sizes (e.g., XS, S, M…etc.) for each clothing category (i.e., upper pieces clothes, lower pieces clothes, and full pieces clothes) and used a one-versus-all multiclass classification approach. Finally, the output of the models represents the predicted size of the clothes.

4. Dataset

The dataset plays a significant role in the performance of any machine learning-based system. To build a robust system that helps online shoppers to estimate their body measurements from an image taken by smartphones, we need to develop a machine learning algorithm trained on a dataset that consists of individuals images along with their body measurements. The dataset divided into two parts: the training part and the testing part. The training part will be used to train the model, and the testing part will be used to test and evaluate the model after the training stage. In this research, we need a dataset that contains human body images and basic measurements for each body. The measurements we needed to achieve the goal of this research must contain shoulders width, bust circumference, waist circumference, hip circumference, and some other measurements. Most of the available datasets either have missing basic values such as bust, shoulder, waist or lack of real structured data that helps achieve the main objective of this research. So, we decided to build our own dataset. We collected our dataset according to scientific research procedure. Participants in the dataset are volunteers from genders, males and females who are over the age of 12. We have 34 participants from the male and 26 participants from the female. The male weight ranges between 52 and 103.5 and the length range between 151 and 190.

We took the body's measurements of the participants manually using a measuring tape to measure their shoulder, bust, waist, hip, and length with centimeter as the measurement unit. A scale was also used to determine the body weight of each volunteer in which kilogram as the unit for the weight. Participants were photographed in the same place with the same environmental conditions such as light, background, and distance (3.5 meters). Images were taken using smartphones because of they are the most widely used in the region, more convenient to be used by the online shopper, cheaper than other professional digital cameras, and often provide a quite good quality picture. The devices used are Galaxy S9+ with Android platform. Galaxy S9+ camera has a resolution of 1440x2960 pixels, iPhone 8 with IOS platform. The resolution of its camera is 750 x 1334 pixels. iPhone 7 with IOS platform and a resolution of 1,334 x 750 pixels. The Rear camera for all devices is 12 megapixel, and Rear flash is LED. We hide or blur the faces of the volunteers to preserve their privacy using the editing and coloring property of the same device Galaxy S9+, iPhone 7 and iPhone 8.

5. Results / Discussion

In this section, we present the results of the prediction size using the estimated measurements. We predicted the clothes size for different pieces (i.e., upper piece clothes, lower piece clothes and full piece clothes) and we compare the estimated size with the true size of clothes that the participants wear it. We experimented the model on a sample of participants consist of 34 participants, 22 out of them are males and 14 females. For the first category, we used the shoulder width and the bust circumference as features to predict the upper piece size. The results of the first model that predict the upper clothes size show we got the 9 out of 22 males are predicted the same true size, that means the accuracy of the model is 41%. For the other, we got only 3 out 14 females are true to size predictive, that means the accuracy of the model is 21.4% and the most predict sizes are different from the true size.

For the second model, we used the waist circumference and the hip circumference as features to predict the lower piece size. The result shows that 16 of the males had their lower size predicted accurately in which the estimated size is identical with the true size of lower clothes (i.e., the model gave an accuracy of 72.7%), while that only 4 females are got the true size equivalent to 28.6% from the model accuracy. For the third model, we used the bust circumference, the waist circumference and the hip circumference as features to predict the full piece size (e.g., dresses size), so, we exclude the males from this model. The results of the model represent that 4 of females are got the true size from the model prediction which is equivalent to 28.6% from its accuracy. The below Table 1. shows the predict sizes for each category of clothes (i.e. upper piece, lower piece and full piece) comparing with real size of each participant following with Fig. 3. that represents the results of the models for, male, female and after aggregate both.

Table 1. Predict the size of clothes (i.e. upper clothes, lower clothes and full clothes).

ID	Predict upper	Real upper	Predict lower	Real lower	Predict full	Real full
1	M	M	S	S	-	-
2	M	L	S	M	-	-
3	M	M	S	M	-	-
4	XL	L	S	S	-	-
5	M	S	S	S	-	-
6	M	M	S	S	-	-
7	M	M	S	S	-	-
8	M	L	S	S	-	-
9	XL	S	S	S	-	-
10	M	S	S	S	-	-
11	M	L	S	S	-	-
12	M	M	S	S	-	-
13	XL	M	S	S	-	-
14	M	XL	S	L	-	-
15	M	M	S	S	-	-
16	M	L	S	M	-	-
17	M	M	S	S	-	-
18	M	S	S	S	-	-
19	M	M	S	S	-	-
20	M	L	S	M	-	-
21	M	L	S	M	-	-
22	M	M	S	S	-	-
23	M	S	M	S	M	M
24	M	L	M	L	M	L
25	L	XS	L	XS	L	S
26	L	S	L	S	L	S
27	M	M	M	M	M	M
28	L	M	L	M	L	M
29	M	S	S	S	M	XS
30	L	S	S	S	L	S
31	L	L	S	M	L	L
32	L	M	L	M	L	M
33	S	L	S	L	S	L
34	S	M	S	S	S	M

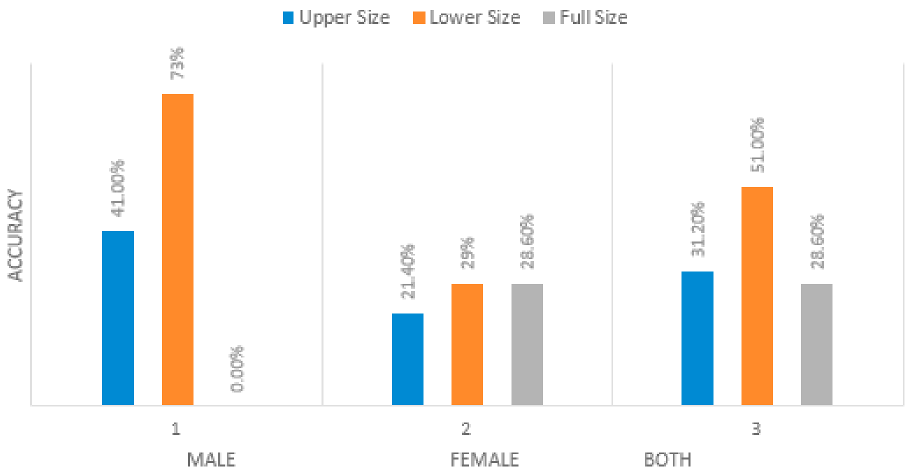

Fig. 3. The results of the predictive models.

6.Conclusion

In this research, we proposed an approach that aims to improve and facilitate the experience of online shopping through estimate the human body measurements from 2D images by photographing the body using a smartphone camera. The experiment was conducted on a sample of volunteers who were photographed, manually measured, and asked to report their real clothing size to compare the result with the model predict size. To implement the study, we used one of the computer vision pre-trained algorithms to detect the human body in images. The detectors are designed to identify three parts of the human body: one detector used to detect the upper body, another detector used to detect the lower part from the body, and the last detector used to detect the full body. After detecting the body major parts, we extract features by segmented each image into 40 parts and determine two points as focal points of each body part to estimate the shoulder width, bust circumference, waist circumference, and hip circumference. After that, we used several machine learning models that are trained on a dataset consists of measurements for predicting the size of clothes depending on the estimated measurements. Each model was trained to predicate size a piece of clothing (i.e., predict size for upper piece clothes, lower piece clothes, or full piece clothes). The results show that most of the sizes we predicated are some differences to the real extent of participants. In the future, we will work on improving the result of detecting the side images and using it to improve the estimating measurements and focusing on decreasing the error percentage. Also, we going to work on improving the results of SVM models to get the best predicting.

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