# Algorithms behind a body measurement app built on smartphones from supplied color-coded garments for online apparel purchasing platforms

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Keywords: Measurement, images, e-commerce, apparatus

Body measurements have been used in various fields for multiple applications. In the apparel industry, body measurements have been combined with customers' preference data to draft pattern pieces, generate grading and sizing rules, help make manufacturing decisions, customize clothing, assist in selecting a size to purchase, and to do the virtual fitting (Gill, 2015; Gupta, 2014). Body measurements are so valuable because it is one of the key factors to determine fit and ill-fit is one of the main issues that cause apparel returns. The typical range of online clothing return rate is 20 to 50% (http://www.iqmetrix.com/blog/how-e-tailers-personalize-outfits-to-customers-taste). Return rates for e-retail fashion companies are significantly higher than in-store sales. This is because when shopping online, most consumers have significant difficulty trying to take their own measurements when attempting to figure out the size of a garment that they should purchase. Many customers even buy a style in multiple sizes and return the ones that don't fit, which adds cost and waste.

Tape measures have been used to measure human bodies manually since the nineteenth century (Bye, Labat, & Delong, 2006). Such a method has a low cost but is time-consuming and subject to the skills of the measurer (Bond, 2008). The 3D scanning technology has been used in the apparel industry since the 1990s to capture body information. Such technology is fast and can generate accurate body measurements (Gill, 2015). However, it is not suitable to be used by apparel shoppers due to its high cost and large size. The 3D handheld scanner was once explored as an alteration for the 3D stationary scanners because of its advantage on cost and size (Xia, Guo, Li, & Istook, 2017). However, researchers have shifted their attention towards the 2D image technique because it adds almost no additional cost to smart device users and the technology advances quickly. Examples of 2D body measurement system include the ZOZO suit (https://zozo.com/us/en) that was released recently and the Elasizer (http://www.elasizer.com/) that is still under development. An apparatus has been used to alleviate privacy concerns and assist on developing the computer algorithms.

This research focused on developing a fast-personal body measurement system using RGB images (or 2D images) taken with cameras embedded in most smart devices, combined with essential anthropometric information input by users and a designed apparatus. The system required front and side images taken of the user wearing the apparatus standing underneath a doorframe with known dimensions. The doorframe in the images worked as a reference scale. The demographic information included age, height, weight, and ethnicity. The apparatus was designed with marks at specific locations for the developed computer program to track the body measurements. It also worked as a fashionable item to be attractive to the users and protect their privacy at the same time. Artificial neural network frameworks implemented in TensorFlow (https://www.tensorflow.org/) was used to train the doorframe and apparatus detection models. Transfer learning (https://www.tensorflow.org/hub/tutorials/image_retraining) was made on existing neural networks trained from millions of images. To help build the doorframe detection model, the training images were manually marked with four boxes (Figure 1a-b) with centers demonstrating the four corners of the doorframe. To help build the apparatus detection model, contours of the apparatus (Figure 2a-c) were manually drawn for each of the training images. The resulting models were then able to detect the doorframe (Figure 1c-d) and the apparatus (Figure 2c-d) automatically.

By the time of this abstract was written, four representative body measurements were tested on the develop body measurement system. The system was able to accurately detect hip girth measurements, with an R2 value of 0.94. There still existed room for improvement at the bust girth, waist girth, and inseam leg lengths. Improvement can be made on the design of the apparatus, the posture of how images were taken, and the pipeline of the neural network models, which are where the effort of future research will placed. Over time the accuracy will increase as more data is mined.

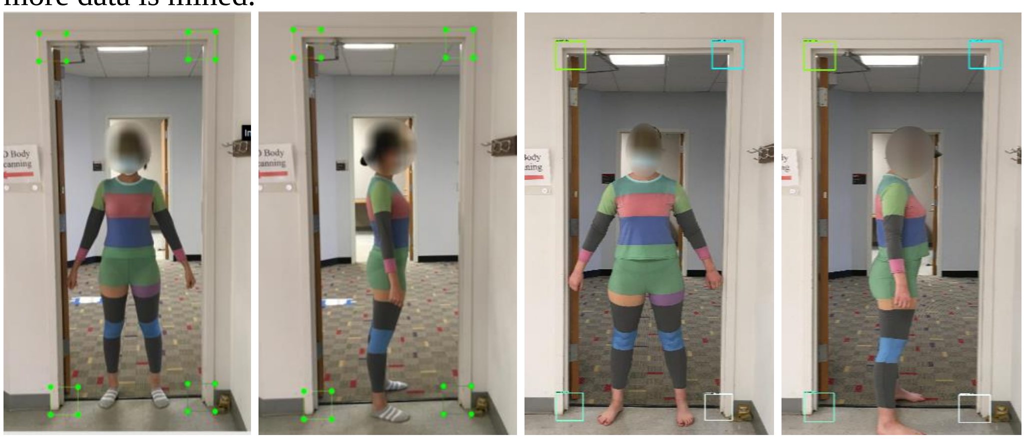

Figure 1. Door frame detection.

Figure 2. Apparatus detection.

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