ORIGINAL ARTICLE

PRELIMINARY STUDY ON VISUAL TECHNOLOGY IN HUMAN ANTHROPOMETRY MEASUREMENT FOR AUTOMOTIVE DESIGN

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ABSTRACT

This paper reviews various papers since the year 2000 until 2016 regarding visual technology in human anthropometry study, and discusses three major points; (1) the methods and objectives of the research, (2) the subjects of the experiments and (3) body parts involved in the anthropometrical measurements. Measurement using visual technology is claimed to be more accurate in obtaining anthropometrical data compared to the conventional method using manual tools. However, commercial visual technology system can be very costly. Based on the reviewed studies, a significant amount of research has adopted various visual processing methods to predict the human's body measurement. All of the studies utilized the applications of enhanced technologies that are able to reduce time and human errors that normally occur during traditional hand-operated measurement. Usually, in order to prove that their result is promising, the studies compared their results with the results gained from manual measurement. The finding from this review is a preliminary step towards developing a camera-based system in anthropometry measurement for the use in automotive ergonomics design.

Keywords: *anthropometry; human body measurement; ergonomics; camera; automotive ergonomics*

INTRODUCTION

Anthropometry is a scientific study of the measurements and proportions of the human body. It establishes the physical geometry, mass properties, and strength capabilities of a person. The terms 'anthropometry' itself is the combination between two Greek words; which are 'anthro', referring to 'man', and 'pometry' which is referring to 'measure')[1]. This study mainly uses the anthropological classification and comparison.

Anthropometric data informs a range of enterprises that depend on knowledge of the distribution of measurements across human populations. For example, in human-factors analysis, a known range for human measurements can help guide the design of products to fit most people[2]. In medicine, quantitative comparison of anthropometric data with patients' measurements before and after surgery furthers planning and assessment of plastic and reconstructive surgery. Current technology offers the collection of highly accurate anthropometric data through image analysis processing method[3-7], 3 dimensional (3D) body scanner[8-11], Microsoft Kinect tools[12]and digital/web camera. This significantly decreases the duration of the process and provides less error in measurement compared with the traditional method; hence it is very beneficial to be applied in the designing process[13].

The objectives of this paper are to collect information on current visual technologies used in human body measurement applications and to identify advantages and limitations for each application. Screening done by sorting to the visual technology application since the year 2000 until 2016 including both 2 dimensional (2D) and 3D applications. To achieving this purpose, we have used Google Scholar and Mendeley search engines. To perform these searching we used keywords such as 'anthropometry', 'visual technology', 'camera' and 'human body measurement technology'. The searched had found more than 15 papers and 14 of them were selected in this review study based on their focus area of application using camera in ergonomics study. The focus of this review is the methods used, and the output of the experiments conducted.

METHODS

Since the year 2000, several enhanced methods used to improve the conventional method of anthropometry that involves direct measurement on human body. A study that aims to assess the performance of 2D image-based anthropometric measurement systems[4] has been done. This study presents a technique for simultaneous anthropometry and poses estimation from the first frame of an image sequence. The input to the algorithm is the image coordinates of the visible landmarks from the human subject (as selected by the user) in the image under examination. A generic stick human body model (SM) developed specifically throughout this project together with the selected image as shown in Figure 1.

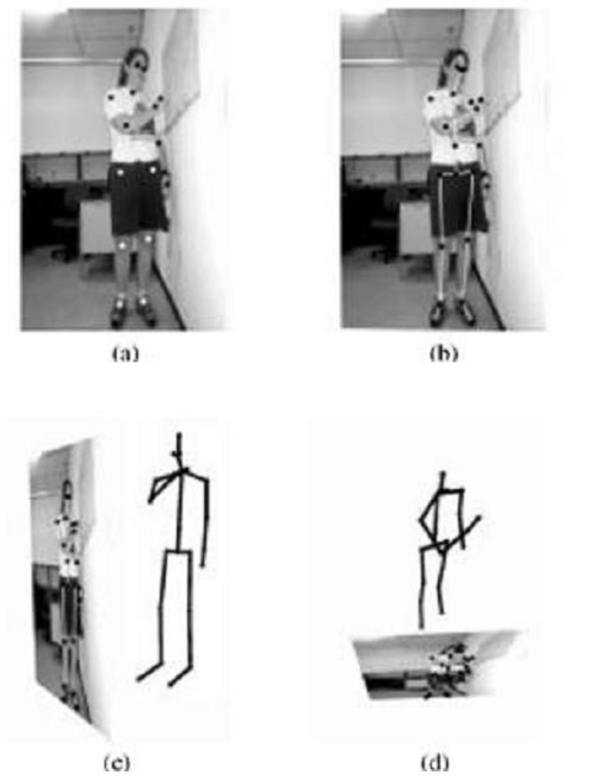

Figure 1 - (a) Selected points, (b) reconstructed model over layered to the image, and (c,d) the model from novel views[4]

Four-step technique introduced for simultaneously estimating a human's anthropometric measurements (up to a scale parameter) and pose from a single image. The user initially selects a set of image points that constitute the projection of selected landmarks. Using this information, along with prior statistical information about the human body, the authors manage to generate a set of plausible segments of lengths estimates. The third step produces a set of plausible poses based on joint limit constraints using a geometric method. In the fourth step, pose and anthropometric measurements obtained by minimizing an appropriate cost function subject to the associated constraints. Although the accuracy of this method is encouraging and has lesser error compared to the conventional manual measurement method[4], the limitation for this study is the initial length estimates on the SM based on the projected length of the segments whose orientation is almost parallel to the image plane only.

Another anthropometry study on a 2D image has been done for the benefit of clothing/garment industry[3]. Meunier and Yin[3] has aimed to propose a means to obtain anthropometric measurements from photographic images through the application of real life photo capture using personal computer (PC) system with 2 cameras and a backdrop to gain neck circumference, chest circumference, hip circumference, and sleeve length of the subject/respondent. In total, there are 254 males and 95 females test subjects in this study. The research concluded that image based system can provide a comparable data to the traditional manual measurement method. Figure 2 shows the study's setup for the experimentation.

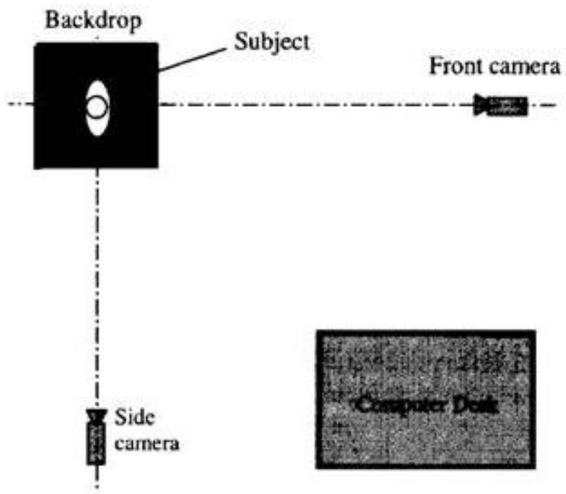

Figure 2 - Meunier and Yin's Study Setup That Includes A Subject, A Backdrop and 2 Cameras[3]

In 2002, a patent for anthropometric measuring device using a computer system and a digital camera, has been registered for the application in a bicycle design industry[5] as shown in Figure 3. This system involves a set of two mirrors and a podium system for a subject to take his place during the experiment. The podium also aims to accommodate in succession the individuals subject to specific measurements. This system intended for anthropometric measurements for determining characteristics relating to the skeleton of an individual, with the purpose of manufacturing a bicycle, which fits his morphology. The patent is also involving marks by fluorescent ink, with each mark being applied relative to the body of the individual at locations of joints including at least two or more of a left shoulder, a right shoulder, a left wrist, a right wrist, a left hip, a right hip, a left knee, a right knee, a left ankle and a right ankle. These marks help to measure desired parameter for any experiments related to this patent.

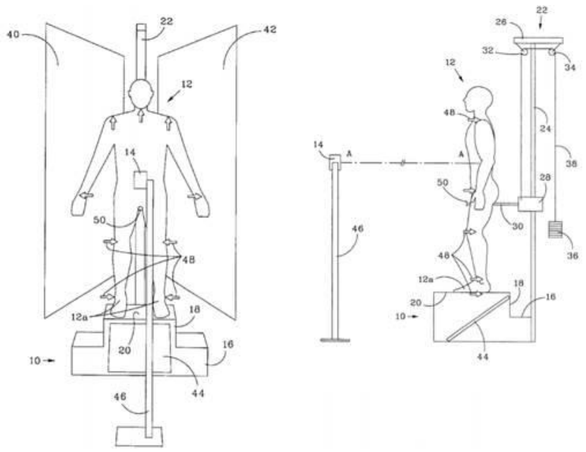

Figure 1 - Winkerbach's Anthropometry System Setup[5].

Following the Meunier and Yin[3] study, a research has been done in 2004 with the aim to obtain anthropometric measurements from photographic images and to develop a simple system with lower cost of development[6]. Hung et al.[6] used 20 males between the ages of 20 and 38 years with a mean age of 24.15 years as test subjects in his research. Ten (10) parameters has been selected in this study which are neck front to waist, nape -waist centre back, scye depth, cross shoulder over neck, arm length, body rise, chest circumference, neck circumference, wrist circumference, and palm circumference. Hung et al.[6] used a digital camera to capture the front, side and the back view of each test subjects. From this experiment, Hung et al.[6] concludes that linear and circumferential measurements (which involve the 10 parameters) can be obtained using an image-based system; but within certain accuracy and reliability and the project needs further investigations.

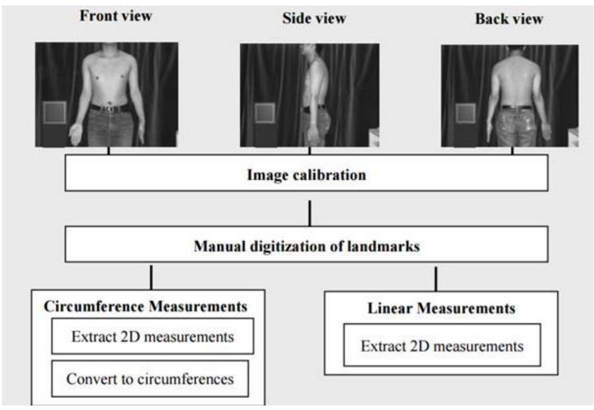

Figure 2 - Hung et al. Study Workflow of Research that Involves Image Calibration and Manual Digitization[6]

Later, the human measurement technology was extended to the 3D human model construction from multi-camera images. A study in the shoe design industry has been done to capture accurate shape of human foot, using 2D images acquired by multiple cameras, which can capture dynamic behaviour of the object[11]. Wang et al.[11] study involved a PC system with multiple cameras that capture the image of a subject's foot. The 3D active shape model was used for accurate reconstruction of surface shape of human foot. Wang et al.[11] applies the Principal Component Analysis (PCA) of human shape database, so that they can represent human's foot shape by 12 principal component shapes. A foot database of 212 males and 185 females has been used in Wang et al.[11] experiment. From their experiment, Wang et al.[11] can efficiently recover the object shape from multi-camera images by more effective and general parameters. By using this model, we can obtain a stable object shape, even though the object shape is partially occluded in some of the input views.

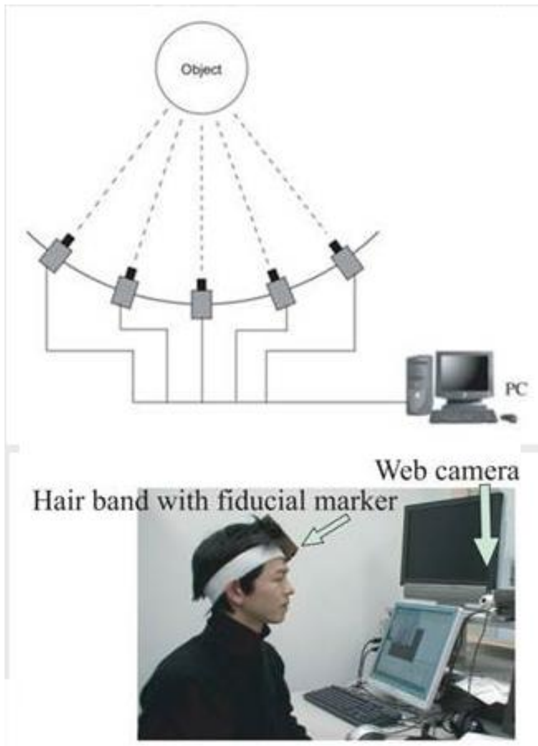

Figure 3 - The Setup Of (Left) Wang's Team Research And (Right) Saito's Team Research[10,11]

With the aim to acquire 3D shape of human faces with just a general purpose camera without compromising the measurement accuracy, a research has been done in order to support the design and development of products worn on the face[10]. In Saito et al.[10] study, a marker is attached onto the top of the subject's face area, which is captured with a generic, handy camera. The subject needed to turn his head to a desired direction and then return to initial position. Then, a 3D data of the person's head could be generated. Fifty-two (52) Japanese males aged in their twenties participated in this experiment to form the database. This proposed method was claimed to be able to reconstruct face shape within the average error of 2.5 mm by just using a camera and a marker for camera poses and position estimation. The accuracy achieved by the proposed method is appropriate for many practical uses in product measurement. Figure 5 shows the differences in setup for Wang et al.[11] and Saito et al.[10] studies.

The 3D human body parts construction method using camera has been used in other several studies [8,9,12,14]. Colombo et al.[12] study focused more on activity analysis of a supermarket worker while lifting loads on shelves. Colombo et al.[12] proposed 3 optical motion techniques; one used a web camera and another two used Microsoft Kinect tools. The technique setup is as shown in Figure 7. In their study, they are using one Digital Human Modelling software for the webcam technique. As for the Microsoft Kinect tools, they were using two different Digital Human Modelling; Life Mod software and Jack software. These software were used to create the desired 3D human model for posture and motion analysis including Rapid Upper Limb Assessment (RULA) analysis.

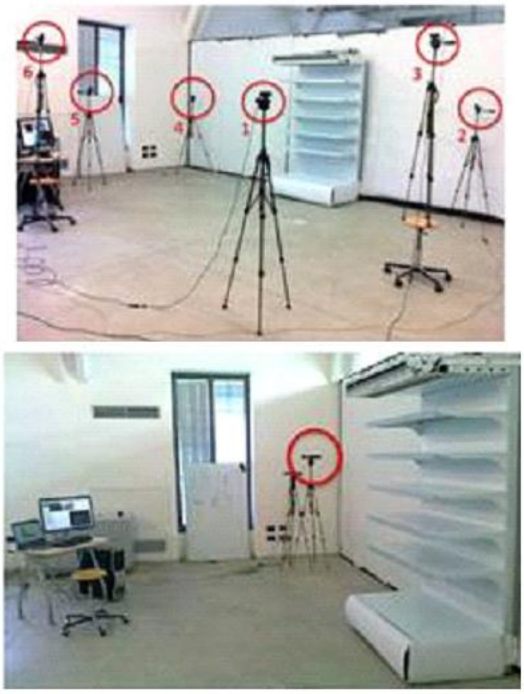

Figure 6 - The Equipment Setup for Study. (Left: Using Webcam,Right: Using Microsoft Kinect's Tools)[12]

Taha et al.[8] research had also used the Microsoft Kinect tools by placing the Kinect sensor onto a scanner rig that rotated (if activated) by the subject's foot. The rotating motion helped to scan and generate a 3D foot model for the footwear design application. Five parameters were measured using Computer Aided Design (CAD) software which are foot length, foot width, heel width, lateral malleolus height, foot width circumference, and lateral malleolus height. Li et al.[9] team research had also implemented a rotating 3D scanning method but his team used a static digital camera position and the subject was required to stand on a simple rotating disk. The camera captured multiple images all around the subject's body to generate a 3D whole body measurement. Li et al.[9] focused on six circumference parameters which; hip circumference, waist circumference, waist-to-hip ratio, neck circumference, chest circumference and arm circumference. Figure 8 depicts the rotating scanning techniques for both experiments.

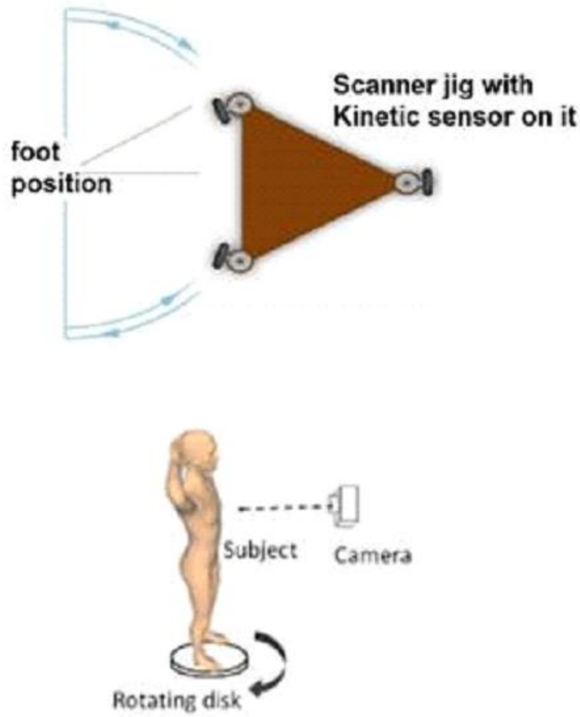

Figure 7 - Rotating Scanning Technique In (Left) Taha's StudyAnd (Right) Li's Study [8,9]

Dindaroglu et al.[14] studied a 3D stereo photogrammetric measurement using 3dMDflex System. Participants of 42 female and 38 males aged between 24 to 45 years old became the subjects of the study. The focus areas for Dindaroglu et al.[14] were 4 different points in the frontal plane and the distance between 7 different points in the sagittal plane on the subject's face. The contribution from his study was mainly for the medical application, regarding face anthropometry.

Even though the 3D scanning method of the human body is widely used in the visual technology for anthropometry study, there were several studies, which are focusing only on 2D image[15]. A PC system fitted with a camera and a calibration board were used to measure 14 body segments: left and right hand, left and right forearm, left and right upper arm, left and right foot, shank, tight; trunk and head with neck segment of three subjects[16]. Mohamad et al.[7] conducted two studies using a measurement software called Vision Assisted Anthropometric

Measurement System (VAAMS) with 45 subjects in the first study and later 100 subjects. This system had analysed images gained from the 2D image captured using digital camera. For the study which is related to seating posture, Mohamad et al.[7] focused on 10 parameters; stature, sitting height, hip height, knee height, shoulder to elbow length, sitting shoulder height, sitting waist height, hip breadth, elbow to grip length and shoulder breadth. For the study related to the breastfeeding support pillow, five parameters on the lower to upper arm area on the subjects were measured. The hardware experimental setup for Mohamad et al.[7] study was almost similar with Stancic et al.[16], except by using a different software and the protocols that need to be followed by the subjects.

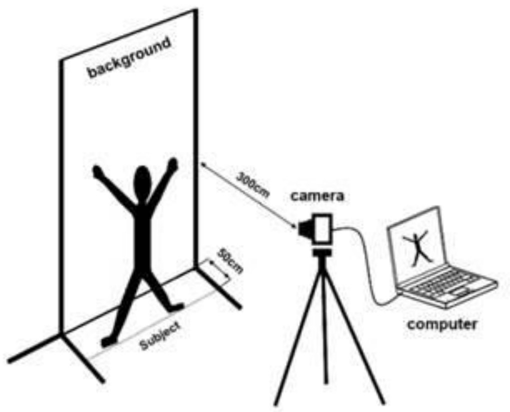

Figure 4 - Stancic et al. Method[16]

As for Habibi et al.[15], 204 industrial and office workers were selected, where 76% of them were males. The aim of the study was to test the efficiency of two-dimensional image processing software in hand photo anthropometry, where 14 hand parameters were measured. Figure 5 shows the experimental setup together with the parameters measured.

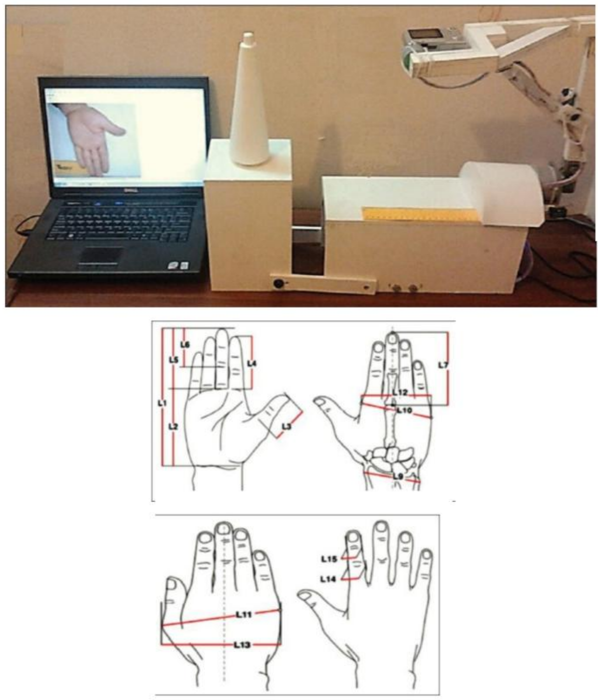

Figure 5 - Experiments Setup (Left) And The Parameters (Right)[15]

DISCUSSION

Summary of Existing Visual Based Methods

All the reviewed studies discussed above are shown in Table 1. The aim of majority of the studies are to compare the results of their visual technology-based anthropometry experiments with the results of the conventional manual method. In 2D image analysis method, the study does not involve 3D human modelling in its methodology, while 3D model generating method involves 3D human modelling by using the Microsoft Kinect tool or 3D scanner or even a digital camera to gain its output.

From Table 1, seven of the studies applied 2D image processing analyses without involving 3D human model. Most studies used digital or web camera to capture the 2D images. In some experiments involving 3D human model, they used multiple 2D image photographs in its application, but the difference is instead of measuring directly from the photos, they add the application of 3D human model creation and development from either a 3D scanner method or Microsoft Kinect tools method. Only one (1) study from Table 1 involved the automotive industry while the rest are studies in garment industry, medicinal, shoes design, other consumer products and workplace design.

Table 1 - Studies for Anthropometry Visual Applications

No	Source	Measuring Method		Bodyparts Measured	Target Area/Field Of Application
		2D Image Processing Analysis	3D model generating method		
1	Barron & Kakadiaris[4]	√		Using segments and joints gained from the stick model developed.	Generic human study
2	Meunier & Yin[3]	√		Parameters on the Upper Limb Body	clothing/garment industry
3	Winkenbach & Ferraroli[5]	√		Body Measurement while riding bicycle	bicycle design field
4	Hung et al.[6]	√		Upper Limb body measurement and circumferences	Generic human study
5	Wang et al.[11]		√	Foot shape parameters	Shoe Design Industry
6	Saito et al.[10]		√	Face shape parameters	For the design and development of products worn on the face
7	Stancic et al.[16]	√		Body segment measurement	Precise garment /clothing manufacturing industry
8	Mohamad et al.[7]	√		Body measurement while seating posture	Automotive industry
9	Holte et al.[17]		√	Body motions and actions	Human Motion Recognition studies
10	Taha et al.[8]		√	Foot parameters	Sport shoes industry
11	Colombo et al.[12]		√	Number of parameters related to postures and movements,	worker in supermarket industry performing task on vertical display unit.
12	Li et al.[9]		√	Circumference measurements on upper limb body.	Private home or clinic applications
13	Habibi et al.[15]	√		Parameters on hand	workplace and industry
14	Dindaroglu et al.[14]		√	Parameters on the face and head	Clinical/ medical studies

All of these studies agreed that the applications of 2D image processing analysis and 3D model generating method have helped to reduce time and human errors in anthropometry activities. The limitation that have been discovered so far is that their study could not cover the whole body anthropometry.

CONCLUSION

From this review, it can be concluded that the application of the visual technology in anthropometry measurement has not been widely researched to gain its benefit. All the studies revealed that the measurement using visual technology brings a better result in terms of time and accuracy compared to the manual measurement method, with some limitations that need to be further improved in future studies. Furthermore, most of the studies do not cover the entire human body measurement. They only managed to focus on certain areas and segments that are related to the field of their study.

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