

Development of a positioning aid to reduce postural variability and errors in 3D whole body scan measurements



Frank Schwarz-Müller^{a,b,*}, Russell Marshall^a, Steve Summerskill^a

^a Loughborough Design School, Loughborough University, Leicestershire LE11 3TU, UK

^b Federal Ministry of Defence, Fontainegraben 150, 53123 Bonn, Germany

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ABSTRACT

Three-dimensional (3D) body scanners have the potential to evaluate changes to the human form through different clothing configurations, the use of protective equipment, or the effects of medical interventions. To achieve this, scans of an individual need to be superimposed for each experimental condition. The literature highlights that one of the limiting factors is postural variability. This paper describes a newly developed 'positioning aid' that stabilises the posture during the scanning process and is invisible on scans. The results of a study evaluating the efficacy of the positioning aid showed that it reduces postural variability for all body parts in lateral and longitudinal directions. A reference test with a rigid mannequin indicated that the 'technical' variability due to the scanner hardware and software significantly contributes to the residual variability. Furthermore, the study showed that the newly developed positioning aid overall increased the precision of the software-assisted extraction of body dimensions.

1. Introduction

1.1. Factors influencing precision of data captured with 3D body scanners

The introduction of 3D body scanners has revolutionised the capture of anthropometric data since they allow automatic, rapid and contact free data collection (Daanen and van de Water, 1998; Robinette and Daanen, 2006). These significant advantages compared to the traditional manual anthropometric measurements have resulted in the use of 3D body scanning technology in numerous anthropometric surveys worldwide (Lu et al., 2010; Treleaven, 2004).

As a result, the number of anthropometric databases based on data obtained with 3D body scanners is constantly growing. It is therefore of particular importance that these data exhibit a high degree of accuracy and precision. ISO 20685, the standard for 3D scanning methodologies for internationally compatible anthropometric databases, defines accuracy as the extent to which a measurement extracted from a 3D scan approximates the reference value (EN ISO, 2010). The reference value of body dimensions is determined by a skilled researcher utilising traditional instruments such as callipers, stadiometers, anthropometers, sitting height tables and measuring tapes. The precision of scan derived measurements, also referred to as repeatability, is defined as the difference between multiple measurements with the same 3D scanning system (Lu and Wang, 2010).

Accuracy and precision of the data ascertained with 3D body scanners are influenced by the factors listed in Fig. 1 and are broadly split into two main categories: Technical Variability and Human Variability (Kouchi and Mochimaru, 2011, 2008; Mckinnon and Istook, 2002):

Previous studies have shown that body dimensions extracted from 3D body scans regularly fail to satisfy the accuracy requirements laid down in ISO 20685 for the use in anthropometric databases (Han et al., 2010; Lu and Wang, 2010; Mckinnon and Istook, 2002). Thus, those of the aforementioned factors need to be identified, which potentially inhibit achieving the desired level of accuracy and precision.

Most manufacturers offer their 3D body scanning systems as a package comprising of the scanner, controllers to operate the scanner as well as IT for data processing and storage. In the majority of cases they also provide a proprietary software package dedicated to data acquisition, anatomical landmark detection and automatic measurement of body dimensions (D'Apuzzo, 2007). Thus, it can be inferred that the factors influencing the technical variability (Fig. 1) are system inherent. The only remaining option for users to reduce the technical variability is to make sure that their scanning system is as up-to-date as possible and calibrated appropriately.

ISO 20685 stipulates that "for all postures, quiet respiration (normal breathing) should be adopted". This is in line with the findings of the study conducted by Mckinnon and Istook (2002), who scanned subjects

* Corresponding author. Loughborough Design School, Loughborough University, Leicestershire LE11 3TU, UK.

E-mail addresses: F.Schwarz-Muller@lboro.ac.uk (F. Schwarz-Müller), R.Marshall@lboro.ac.uk (R. Marshall), S.J.Summerskill2@lboro.ac.uk (S. Summerskill).

FACTORS INFLUENCING PRECISION AND ACCURACY		RESULTING EFFECT
Precision of the 3D scanning hardware	Technical variability	
Performance of the data acquisition and visualisation software		
Performance of the landmarking and measurement extraction software		
Variability of the inhalation level of the human subject	Postural variability	Human variability
Ability of the human subject to replicate postures		
Body sway of the human subject		

Fig. 1. Factors affecting precision and accuracy in 3D body scanning.

holding their breath at different inhalation levels and when breathing normally. They found that humans are unable to reliably replicate a certain respiration level and that continuing breathing normally during the scanning process compromises the data integrity least.

It is common practise that the subjects are verbally instructed by the scanner operator how to adopt the scanning posture. Since they are either standing or sitting unrestrained on the scanner platform, variations in the posture due to body sway and the user's inability to replicate postures are inevitable. Thus, in a number of studies postural variability was found to compromise the integrity of the scan derived anthropometric data considerably (Han et al., 2010; Lu and Wang, 2010; Mckinnon and Istook, 2002).

Therefore, to achieve greater precision in body scan data capture, the main focus should be to address the replication of a consistent posture.

1.2. Reduction of human variability by means of a positioning aid

Although a number of researchers called for measures to stabilise the human posture during the scanning process (Lu and Wang, 2010; Mckinnon and Istook, 2002; Tomkinson and Shaw, 2013), so far only a few attempts have been made to counter body sway and poor posture replication. Exceptions are handles to stabilise the arm posture that can be found in body scanners manufactured by TC² and Size Stream or rudimentary fixation elements used in studies conducted by Reed and Guitierrez (Guitierrez and Gallagher, 2008; Reed, 2012). A reason for a lack of research in this field might be the fact that mechanical positioning aids potentially compromise the scan data by obscuring relevant body parts. As a result, the software-assisted extraction of body

dimensions does not work reliably anymore.

In their article “The Evaluation of Scan-Derived Anthropometric Measurements” Lu and Wang (2010) reported that they used a rigid mannequin to entirely eliminate the effects of the human variability. In contrast to the scan derived measurements obtained from human subjects, those ascertained from the mannequin met the accuracy and precision requirements of ISO 20685 for the use in anthropometric databases. This is a strong indication that scan derived measurements of human subjects can achieve the desired level of precision provided that the human variability can be limited efficiently. It can therefore be inferred that the reduction of postural variability by means of a positioning aid presents an opportunity to increase the precision of scan derived measurements.

An additional driver for the implementation of a successful positioning aid is to address emerging applications of 3D body scanning technology. These emerging applications require the precise superimposition of 3D images of the same subject obtained at different occasions or in diverse configurations. This would for instance allow analysing the effects of medical treatments, diets or workout by comparing aligned scans of the subject before and after the intervention. Another application is “clothed anthropometry” (Hsiao et al., 2014; Stewart et al., 2016). Although it seems to be obvious that wearing personal protective equipment (PPE) leads to an increased space claim there is no standardized methodology in place to quantify it by means of 3D body scanning (Jones et al., 2015). The comparison of subjects scanned in the standard scanning attire (tight underwear) and fully encumbered by PPE would allow the space claim differences to be established. Determining the linear, circumferential or volumetric difference between different clothing configurations obtained in the same

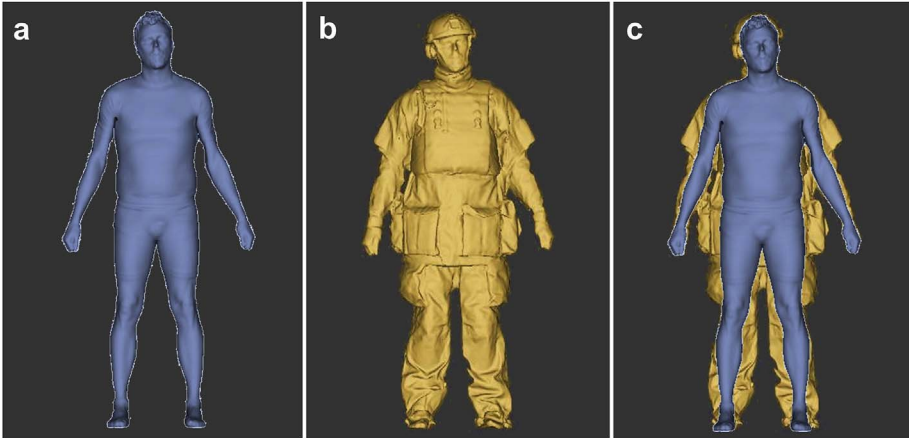


Fig. 2. Superimposition of scans (c) to determine the difference between clothing configurations (a, b).

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