



Development of a digital human model generation method for ergonomic design in virtual environment

Kihyo Jung^a, Ochaekwon^b, Heecheon You^{a,*}

^aDepartment of Industrial and Management Engineering, Pohang University of Science and Technology, San 21 Hyoja-dong, Pohang, Kyungbuk 790-784, South Korea

^bSamsung Electronic Co., LTD. 16th FL., Jungang-Ilbo Bldg. #7, Soonhwa-dong, Jung-gu, Seoul 100-759, South Korea

ARTICLE INFO

Article history:

Received 12 February 2008
Received in revised form
4 February 2009
Accepted 9 April 2009
Available online 20 May 2009

Keywords:

Digital human model
Generation method
Anthropometric design
Hierarchical regression model
Population accommodation

ABSTRACT

A group of digital human models (DHMs) representing the target population under consideration is used to design products and workplaces in virtual environment. The present study proposes a two-step method which generates a group of DHMs in various sizes to properly accommodate the designated level of the human size variability of the target population. In the first step, a designated number of pairs of stature and weight within a specified accommodation range are generated from the bivariate normal distribution of stature and weight of the target population. In the second step, for each pair of stature and weight, the sizes of the DHM body segments are determined using hierarchical regression models and corresponding prediction distributions of individual values. The proposed generation method was applied to the 1988 US Army anthropometric survey data and then implemented to a web-based system for passenger car interior design. This web-based generation system is capable of generating a group of DHMs as nationality, gender, accommodation percentage, and the number of DHMs required is specified.

Relevance to industry: A digital human simulation system has been used as an effective tool for ergonomic design and evaluation of products and workplaces in virtual environment. The human model generation method proposed in the present study is of use to efficiently generate a group of human models representing the target population.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

Digital human model (DHM) simulation systems such as Jack[®] and RAMSIS[®] contribute to the efficiency of product design process. These systems have been utilized as an effective design tool to visualize the interaction of a human and workstation system (such as passenger car interior, fighter cockpit, and factory workplace) and to evaluate the human–workstation interaction from ergonomic aspects (such as reach, visibility and comfort). The ergonomic design methodology using digital DHMs makes the iterative process of design evaluation, diagnosis and revision more rapid and economical (Chaffin, 2001).

Two human model generation methods (percentile and custom-built methods) are commonly implemented in DHM simulation systems (Dassault Systems, 2005; UGS, 2006). The percentile method enables the user to generate percentile human models such as 1st, 5th, 50th, 95th, and 99th percentiles for different genders and age groups using anthropometric information stored in the simulation system. On the other hand, the custom-built method enables the user to create tailor-sized human models by specifying a set of

anthropometric dimensions—missing values of anthropometric dimensions are estimated by regression equations incorporated in the simulation system. The boundary manikin methods (Bittner, 2000; Eynard et al., 2000; Kim and Whang, 1997; Meindl et al., 1993; Reed and Flannagan, 2000) and distributed methods (HFES 300, 2004; Jung et al., 2008; McCulloch et al., 1998) belong to the custom-built method of DHM generation because the body segment sizes of each selected representative case should be manually specified in a DHM simulation system.

The existing human model generation methods are limited in terms of representativeness of DHMs for the target population and efficiency of DHM generation. In the percentile method, only a few (mostly 3) DHMs are created and then simulated for ergonomic design and evaluation (Jimmerson, 2001; Nelson, 2001; Thompson, 2001; You et al., 1997); therefore, the simulation results may not properly reflect the variability of the target population in size and their generalizability can be significantly limited. Next, in the custom-built method, inputting the sizes of the body segments of DHMs is quite time demanding. For example, the values of 21 and 26 body dimensions need to be entered manually to generate a custom-built DHM using RAMSIS and Jack, respectively (Tecmath, 2007; UGS, 2006).

* Corresponding author. Tel.: +82 54 279 2210; fax: +82 54 279 2870.
E-mail address: hcyoun@postech.ac.kr (H. You).

The present study proposed a novel method to generate a group of human models with various sizes which statistically represent the target population under consideration. Then, for efficient human model generation, this study implemented the proposed method into a web-based system, which automatically generates a group of human models as nationality, gender, accommodation range (the range of percentiles accommodated by a particular design) of the target population, and the number of human models required are specified.

2. Development of a human model generation method

The present study developed a two-step human model generation process (see Fig. 1) which forms a group of human models within a designated accommodation range. In the first step, a designated number of pairs of stature and weight within an accommodation range of the target population are generated from the bivariate normal distribution of stature and weight (see Section 2.1 for details). In the second step, the sizes of the body segments of each human model with certain stature and weight are predicted from the sampling distribution of prediction values of corresponding hierarchical regression models (see Section 2.2 for details).

2.1. Generating pairs of stature and weight of representative human models

As displayed in Fig. 2, a designated number of pairs of stature and weight within a specified accommodation range of the target population are formed by an iterative process consisting of: (1) generation of a pair of stature and weight; and (2) evaluation of the generated pair of stature and weight in terms of accommodation percentage. First, a pair of stature and weight is generated randomly from the bivariate normal distribution of stature and weight of the target population. The present study assumes stature and weight have a bivariate normal distribution because stature and weight are generally known to be normally distributed and related to each other to some extent (Roebuck et al., 1975). This assumption was validated in the present study using the 1988 US Army data (Gordon et al., 1988)—stature and weight of the US Army data follow

a bivariate normal distribution with averages 175.6 cm and 78.5 kg, standard deviations 6.7 cm and 11.1 kg, and correlation coefficient 0.5 ($\chi^2_9 = 9.66, p = 0.379$). Next, the generated pair of stature and weight is selected if it belongs to a specified accommodation range ($100p\%, p = 0 \sim 1$). For the accommodation test, the normalized squared distance (D) of the pair of stature and weight from the center of the corresponding bivariate normal distribution is calculated using Eq. (1) (Johnson and Wichern, 1988); if D is less than $\chi^2_2(1 - p)$, the pair of stature and weight is accepted as one within the accommodation range. For example, the values of D for two pairs of stature and weight (182 cm, 60 kg) and (171 cm, 90 kg) from the corresponding bivariate distribution center of stature and weight (175.6 cm, 78.5 kg) in the 1988 US Army data are 6.28 and 3.31; for $\chi^2(1 - p) = 4.61$ at $p = 0.9$, only the latter is selected as one within 90% of accommodation range. The proposed two-step stature and weight generation process is iterated until the required number of pairs of stature and weight are obtained. Fig. 3 illustrates one thousand pairs of stature and weight generated within 90% of accommodation range in the bivariate normal distribution of stature and weight for the 1988 US Army male data.

$$D(S, W) = (S - \mu_s \quad W - \mu_w) \begin{pmatrix} \sigma_s^2 & \sigma_{sw} \\ \sigma_{sw} & \sigma_w^2 \end{pmatrix}^{-1} \begin{pmatrix} S - \mu_s \\ W - \mu_w \end{pmatrix} \quad (1)$$

where,

- D = normalized squared distance;
- S = stature;
- W = weight;
- μ_s = mean of stature;
- μ_w = mean of weight;
- σ_s^2 = variance of stature;
- σ_w^2 = variance of weight;
- σ_{sw} = covariance of stature and weight.

2.2. Estimating body segment sizes of human models

Hierarchical regression models for anthropometric variables are used in the present study to estimate the body segment sizes of

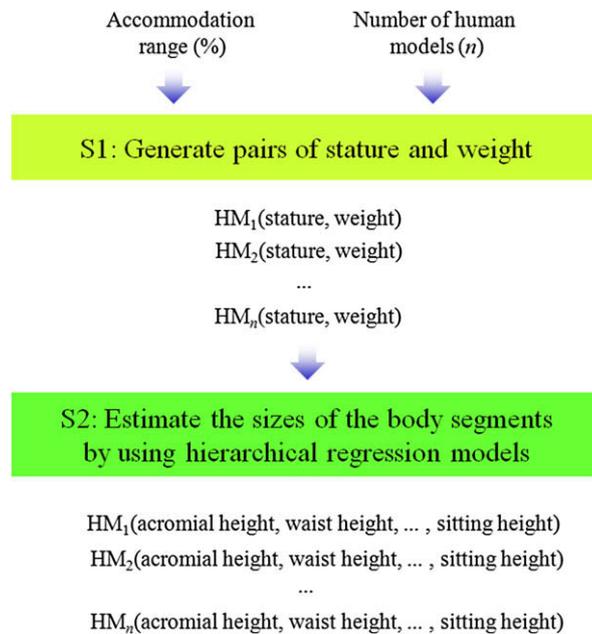


Fig. 1. Two-step human model generation process.

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات