Modeling Body Shape from Surface Landmark Configurations

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Abstract. Detailed statistical models of body size and shape are valuable for wide range of statistical analyses. Most body shape models represent a single posture, usually standing. Previous efforts to model both posture and body shape have parameterized posture using joint angles. This paper presents a statistical model of body shape in supported seated postures using a posture measured derived from surface landmarks rather than internal joint locations and angles. This method is not limited by a particular kinematic linkage deformation and so is particularly well suited to model the effects on body shape of posture changes in complex linkages such as the spine or shoulder.

Keywords: body shape, laser scanning, anthropometry, posture.

1 Introduction

Advances in whole-body surface measurement and associated data processing techniques have provided the opportunity to create parametric statistical models of the human body form that allow representation of the wide range of human body shapes in digital human figure models. The parametric models allow body shapes to be predicted as a function of gender, stature, body weight, and other variables. However, the scanned postures are rarely the postures of interest for ergonomics analysis, so some mechanism for altering the posture is needed.

Several research groups have developed methods for parameterizing the external body shape in terms of posture variables defined by linkage joint angles as well as standard anthropometric descriptors [1, 2]. The development of these models requires a rich scan database containing many postures for many individuals. One limitation of this method is that the resulting models are parameterized in terms of the joint angles of a particular kinematic linkage. Generalizing such a model to a different kinematic linkage requires mapping the associated angles between the two linkages, and may be particularly challenging in the torso and shoulder, for which many different linkage definitions are in use.

This paper presents an alternative approach to modeling body shape and body shape change with posture. Conceptually, we represent posture by the 3D locations of a set of body surface landmarks, rather than by the angles of a kinematic linkage.

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Body shape is then predicted using the landmark configuration, potentially in combination with overall target body dimensions such as stature or body weight.

To illustrate the method, we present an example application in which a kinematic linkage based on the skeleton is unnecessary and even problematic. Standard anthropometric data contain little information that is directly applicable to the design of seat backrest contours. In previous work, we used a parametric model based on scan data from a single seated posture to assess seat back fit [3] and measured multiple postures per subject to build a database that could be interpolated [4]. To improve on this approach, we used data from a recent study of body shape that included multiple supported seated postures per subject. We use surface landmark locations, or relationships among them, to predict the body shape assocated with a particular posture. An important advantage of this method is that our prediction of torso shape change across conditions is not limited by an approximating kinematic linkage. This is particularly valuable in the shoulder and spine, where the true number of degrees of freedom is much higher than that provided by a few rotational joints.

2 Methods

Data Source. The results in this paper were generated using data from an unpublished study of soldier anthropometry. Whole-body scan data were gathered using a VITUS XXL laser scanner in a range of postures. For the current analysis, data from four postures from 126 men with a wide range of body sizes were used. Figure 1 shows the four postures. The range of postures is critical, because the analysis procedure is fundamentally a data interpolation method.

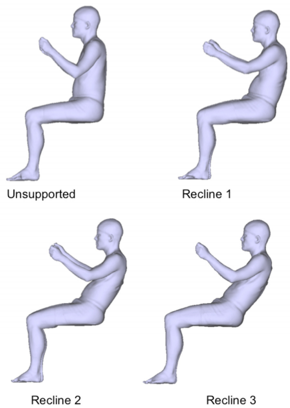

Fig. 1. The four postures used for the current analysis from one subject

Figure 2 shows a flowchart of the data analysis procedure. Each scan was cleaned and processed, including hole-filling and manual extraction of up to 140 three-dimensional landmarks from each scan. Landmarks included major bony landmarks such as acromion and lateral femoral condyle that define skeletal posture. A template mesh with 38038 vertices was fit to each scan using an implicit-surface method. A principal component (PC) analysis was conducted on the vertex data to obtain a reduced-basis representation of the data. For the current work, 300 PCs were retained.

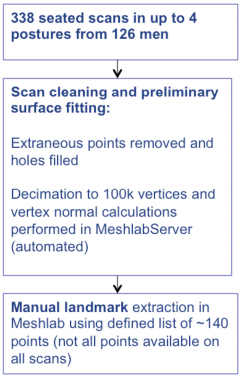

Fig. 2. Flowchart of data processing method

Figure 3 shows a flowchart of the data analysis method. Each study participant is characterized by standard anthropometric dimensions. The current analysis used stature, body mass index, and the ratio of erect sitting height to stature as predictors. The surface landmarks could be used to estimate internal joint center locations, and those joint center locations could be used to define joint angles according to a particular rotation sequence. However, an alternative is to define posture using solely external body landmarks. This avoids the need to estimate joint center locations and to use a particular joint rotation sequence.

For the current demonstration, two simple measures of torso posture were defined. Torso recline was defined as the angle of the vector from the L3 surface landmark to the C7 surface landmark with respect to vertical. Lumbar flexion was defined by the angle between lumbar and thoracic surface vectors. The lumbar vector was defined from the L3 surface landmark to the T12 surface landmark, and the thoracic vector was defined from T12 to C7. Figure 4 shows the definitions of these variables.

A linear regression was conducted to predict the principal component scores as a function of the three anthropometric and two posture variables. Exercising the model with combinations of these variables enables a wide range of seated body sizes and postures to be represented.

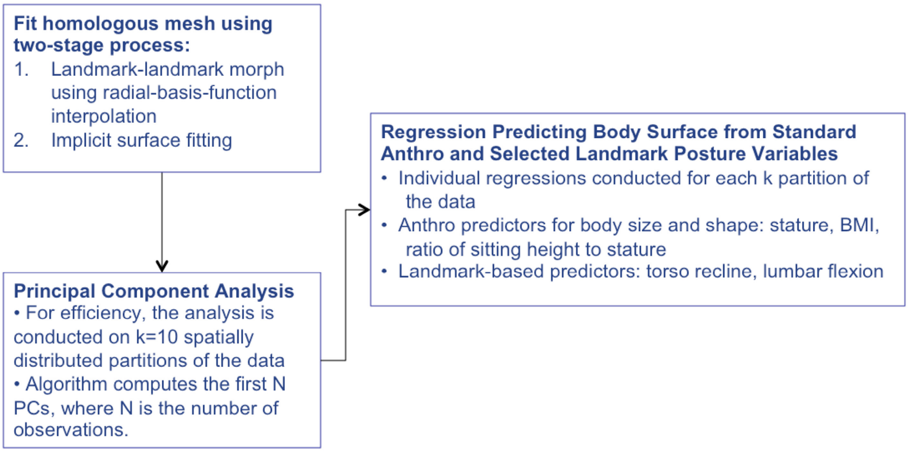

Fig. 3. Data analysis method

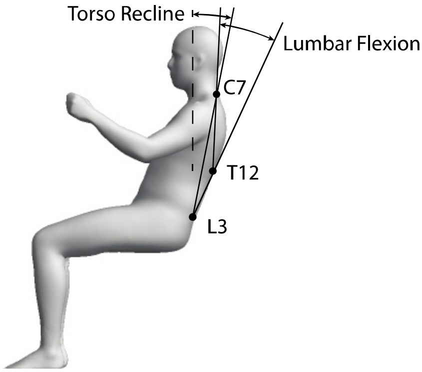

Fig. 4. Torso posture variables

3 Results

Figure 5 shows the anthropometric effects in the model, demonstrating the effects of stature, BMI, and the ratio of sitting height to stature. For these illustrations, the posture variables are fixed at the median values. Figure 6 shows the posture effects in the model, demonstrating the effects of torso recline and lumbar flexion. For these illustrations, the anthropometric variables are fixed at the median values. Figure 7 shows the combined effects of body dimensions and posture, illustrating the wide range of postures and body shapes that can be represented.

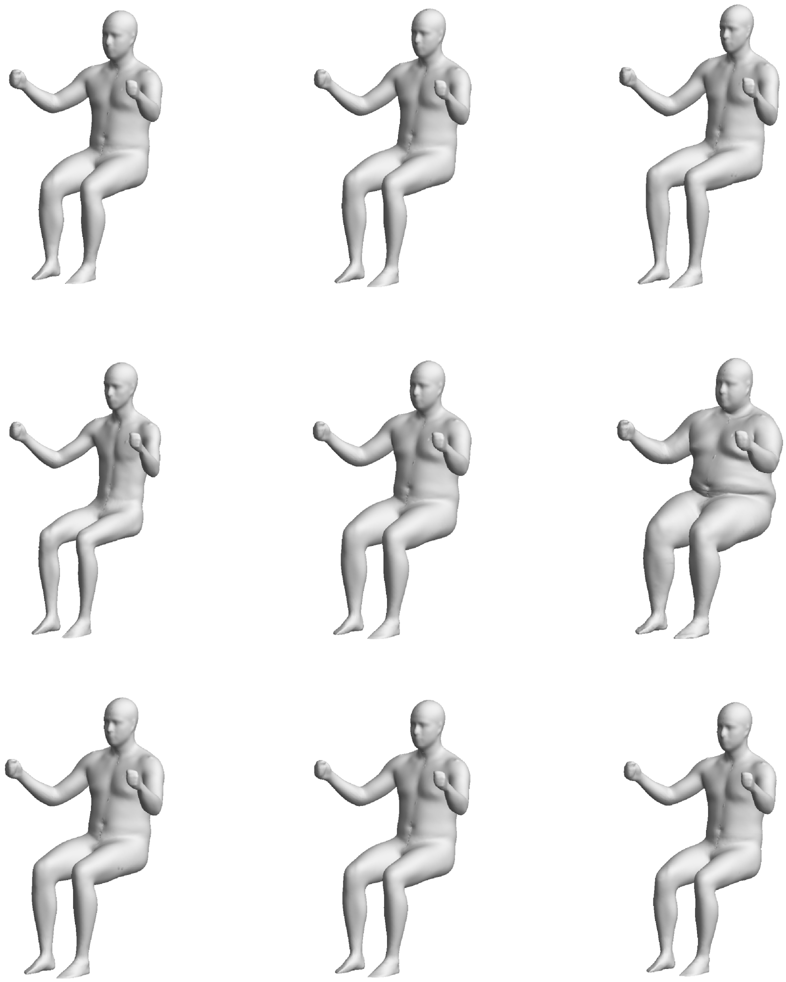

Fig. 5. Anthropometric effects. Top row: Stature 1600 to 2000 mm. Middle row: BMI 18 to 40. Bottom row: ratio of sitting height to stature 0.48 to 0.56.

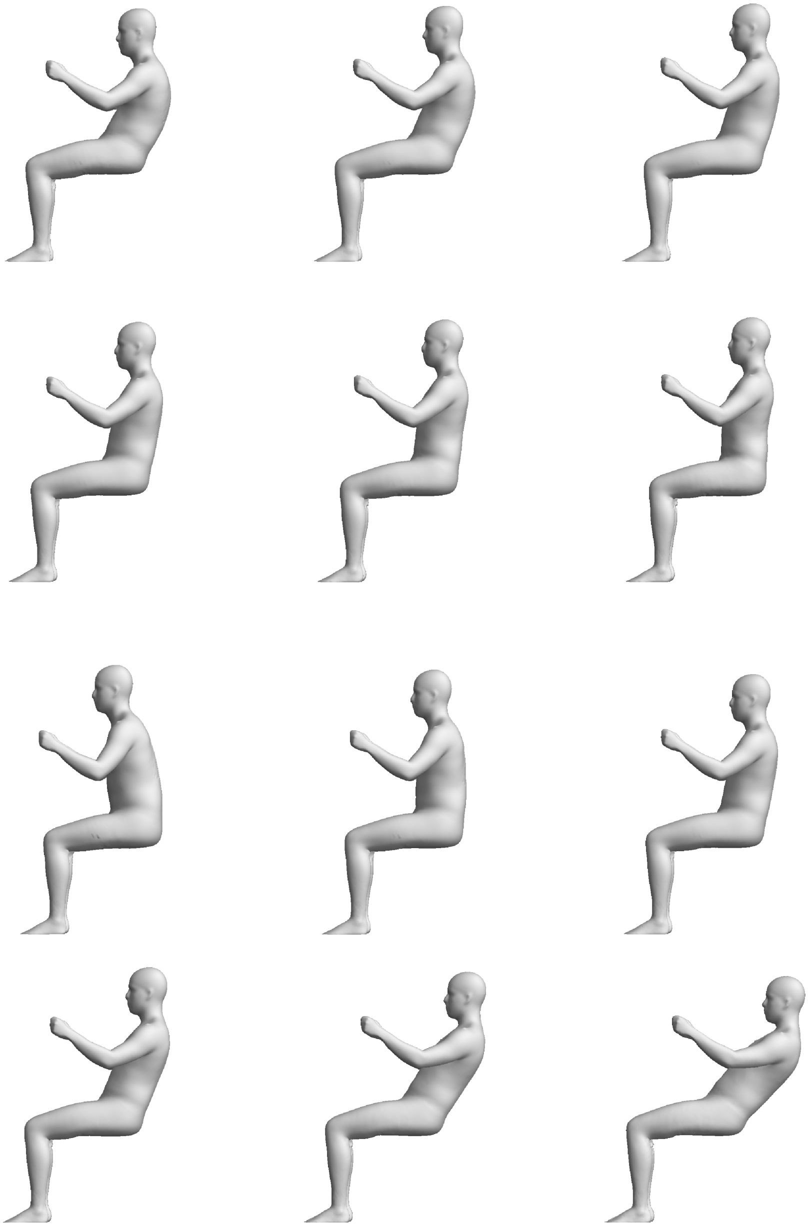

Fig. 6. Posture effects: lumbar flexion (top), recline (bottom)

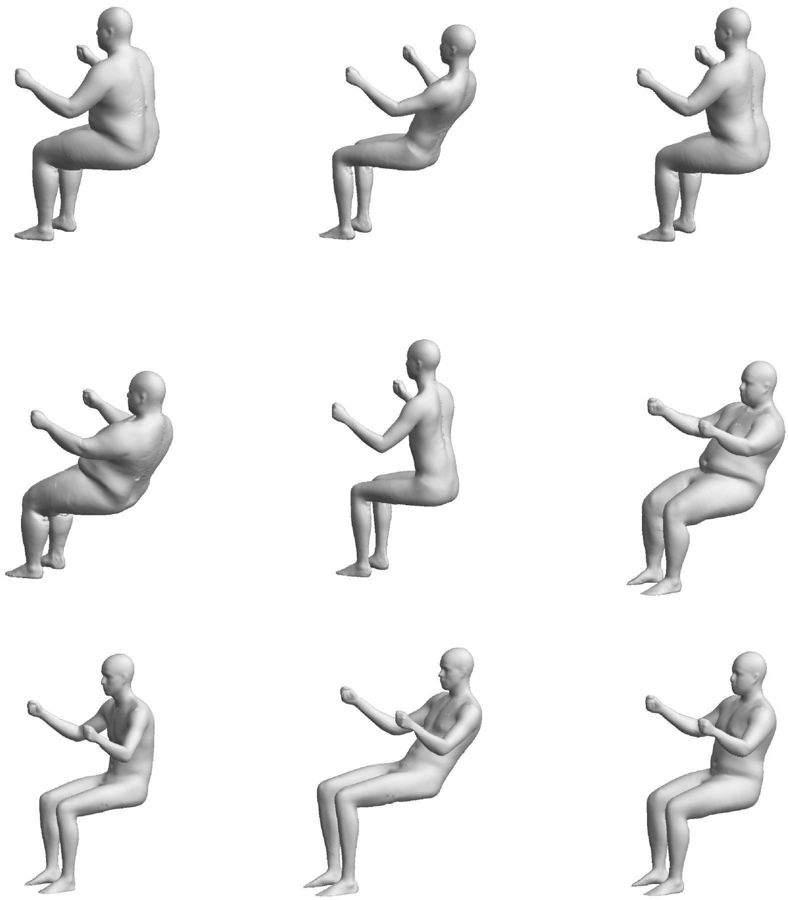

Fig. 7. Model results for a range of postures and body sizes

4 Discussion

The methodology presented in this paper provides a method for representing the combined effects of overall body dimensions and posture on body shape with a large range of flexibility. Previous methods for representing posture in body scan data have parameterized posture using joint angles [1]. This approach is valuable in situations in which the goal is to apply angle-based animation data to the figure. However, the method requires estimating skeletal joint-center locations and calculating joint angles using a particular rotation sequence. These calculations are straightforward for any particular linkage, but generalizing across multiple linkages with different segment and joint-angle definitions can be problematic.

The current method avoids those problems by parameterizing posture using surface landmarks that are independent of the skeletal linkage. The illustrations in this paper were generating using only two variables defined by three surface landmarks, but the calculations scale readily to use 10, 20, or more surface landmarks. The target landmark locations can be generated from other data sources, such as landmark-based posture data from environments in which scanning is not practical, such as vehicles.

The model developed in this paper can be used to create manikins for a wide range of ergonomics analyses of seated tasks. A previous torso-shape model based on scan data did not include the whole body and lacked parameterization for posture [3]. A more advanced version of that model included a posture parameterization based on four variables, but lacked extremities [5]. Importantly, generating a new model using alternative anthropometric variables and body landmarks as inputs is straightforward, simply repeating the regression analysis.

As with any empirical model, the outcomes are dependent on the range of the input data. In this case, the range of postures available in the data is critical. The current model is essentially a linear interpolation model, moving mesh node locations as linear function of the input variables, but nonlinear (e.g., squared) and interaction terms can be included in the regression models to account for more complex relationships between overall body dimensions, posture, and body shape. The terms to include can be selected using standard statistical techniques as well as domain knowledge concerning the needs of the application.

The dataset from which the current data were drawn includes a wide range of upper and lower extremity postures, as well as torso postures with lumbar flexion, twisting, and lateral bending. Extending these methods to include these postures will produce a more general model.

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References

1. Anguelov, D., Srinivasan, P., Koller, D., Thrun, S., Rodgers, J., Davis, J.: SCAPE: Shape Completion and Animation of People. In: Proceedings of the 2005 International Conference on Computer Graphics and Interactive Techniques (SIGGRAPH), San Diego, CA (2005)
2. Allen, B., Curless, B., Popovic, Z.: The space of human body shapes: reconstruction and parameterization from range scans. In: Proceedings of the 2003 International Conference on Computer Graphics and Interactive Techniques (SIGGRAPH), San Diego, CA (2003)
3. Reed, M.P., Parkinson, M.B.: Modeling variability in torso shape for chair and seat design. DETC2008-49483. In: Proceedings of the ASME Design Engineering Technical Conferences. ASME, New York (2008)
4. Reed, M.P.: A pilot study of three-dimensional child anthropometry for vehicle safety analysis. In: Proceedings of the 2012 Human Factors and Ergonomics Society Annual Meeting. HFES, Santa Monica (2012)
5. Hu, J., Reed, M.P.: Development of a methodology for simulating seat back interaction using realistic body contours. SAE Technical Paper 2013-01-0452. SAE International, Warrendale, PA (2013)