

Development of a Methodology for Simulating Seat Back Interaction Using Realistic Body Contours

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ABSTRACT

Seat comfort is driven in part by the fit between the sitter and seat. Traditional anthropometric data provide little information about the size and shape of the torso that can be used for backrest design. This study introduces a methodology for using three-dimensional computer models of the human torso based on a statistical analysis of body shapes for conducting automated fit assessments. Surface scan data from 296 men and 417 women in a seated posture were analyzed to create a body shape model that can be adjusted to a range of statures, body shape, and postures spanning those typical of vehicle occupants. Finite-element models of two auto seat surface were created, along with custom software that generates body models and postures them in the seat. A simple simulation technique was developed to rapidly assess the fit of the torso relative to the seat back. The methodology developed in this study will enable automated virtual fitting trials considering a wide range of body sizes and shapes, allowing statistical evaluations of seat fit within a specific sitter population. Further refinement of the method will allow prediction of seat pressure distribution, which may be usefully related to subjective assessment of seat fit.

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INTRODUCTION

Dimensional mismatch between a seat and sitter can cause discomfort. For example, a backrest that is too narrow can create discomfort at the sides of the body and can also diminish the effectiveness of a lumbar support [5]. Traditional anthropometric data have customarily been gathered using tape measures, calipers, and other simple apparatus to obtain repeatable point-to-point and circumferential measures. These dimensions provide little guidance for seat back design because they are not closely related to seat design parameters. In particular, traditional anthropometric data do not provide guidance on three-dimensional body shape, which can be used for choosing appropriate contours for backrests.

In the past decade, surface-scanning equipment has revolutionized anthropometry by allowing rapid recording of whole-body surface shapes. The Civilian American and European Anthropometry Resource (CAESAR) project was the first large-scale study to scan U.S. civilians [7]. In addition to standard anthropometric measures, scans were recorded in one standing and two seated postures for a convenience sample of 2400 U.S. adults from 18 to 65 years old. Body landmark locations were extracted from the scans.

The application of the CAESAR scan data for seat design has been hampered by difficulties in working with the data and the need to develop new methodologies to apply the data in design. Each set of raw scan data in CAESAR database typically contains over 500,000 unstructured data point and represent a single posture. One approach to using the CAESAR data has been to manually craft manikins based on a small number of selected scans for use in human modeling software packages used for ergonomics, such as Jack and RAMSIS [4]. However, this method takes advantage of only a small fraction of the available information. An alternative approach is to build statistical models of body shape using a large number of subjects. The technical details associated with this approach were first introduced by Allen et al. [1], and have been applied specifically to ergonomic analysis of seating by Reed and Parkinson [6], who developed a statistical model of body size and shape using a combination of principal component analysis and regression analysis (PCAR). For backrest design applications, this model can be exercised to randomly sample the space of body shapes, which will enable automated virtual fitting trials.

The objective of this study was to introduce a methodology for using a statistical body shape model to conduct automated fit assessments for vehicle seat backrest.

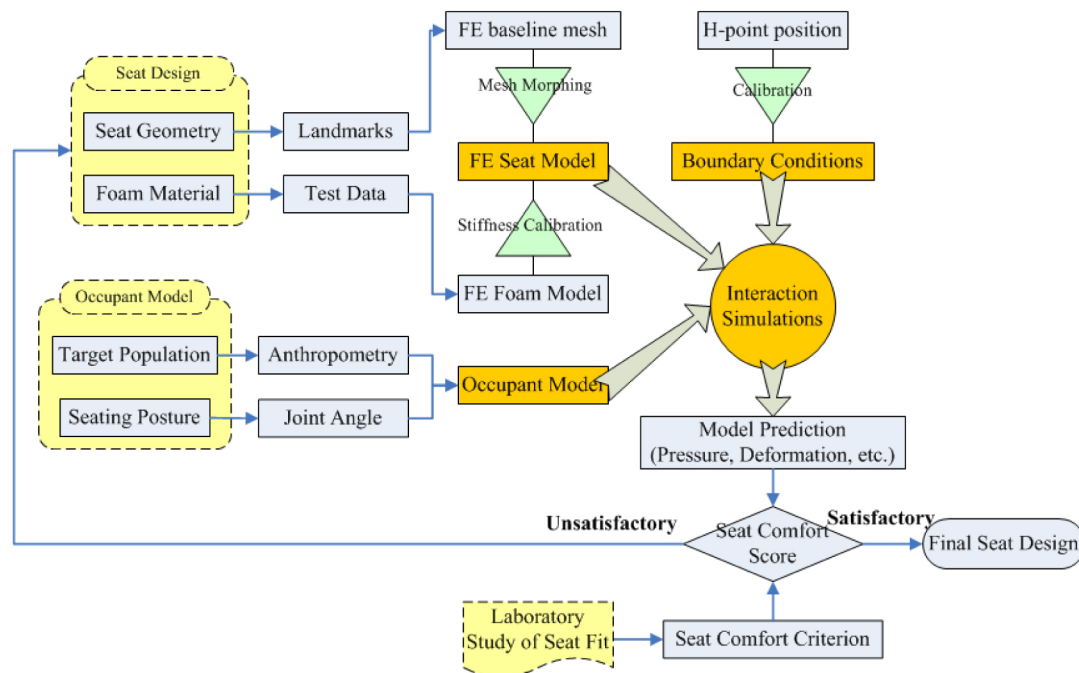


Figure 1. Flowchart of virtual fit methodology.

Specifically, the previously developed torso shape model was augmented to predict body shape as a function of recline, lumbar spine flexion, stature, and BMI for both men and women. Finite-element (FE) models of two seat contours were created. An automated software procedure was developed to simulate the movement of the sitter, defined using the statistical body shape model, into the seat model. The resulting penetration was assessed with respect to seat fit.

METHODS

Framework for Virtual Seat Fit Testing

A framework was developed in this study to conduct virtual fit assessments using a wide range of body sizes and shapes selected to represent the target user population. Each virtual fit predicted the seat surface deformation and pressure for a particular occupant in a seat with a specific posture, and statistical evaluation can be performed with multiple simulations for occupants with different body sizes and shapes.

Figure 1 shows the virtual fit process using FE seat models and human body contour models representing different body sizes and shapes. The core of this process is the interaction simulation using the parametric seat FE model and the body shape model. In this study, a program was written in Scilab, a free, open-source computing environment (www.scilab.org), to automatically generate the occupant FE body contour models with specific body size, shape, and posture; integrate the seat FE model into the simulation; and setup the boundary conditions of virtual fit simulations. To make this method useful, validation of the seat model, boundary condition setup, and the seat comfort evaluation are

necessary. However, in the current study, we only focused on setting up the framework for virtual seat fit testing.

Posturable Torso Model

Figure 2 shows the methodology of generating a posturable torso model in the current study. Torso data from relaxed seated scans for 296 men and 417 women, including all of the obese subjects in the U.S. CAESAR sample, were extracted for analysis. Surface data for the arms and legs were removed to isolate the parts of the body that normally interact with seats. A uniform mesh was fit to the data (60 slices $\times$ 60 points per slice), exploiting the fact that the data were sampled in horizontal slices. A statistical analysis was then conducted on the vertices of the mesh, along with the associated body landmarks and internal joint locations estimated from the surface landmark locations. The analysis method (PCAR) uses principal component analysis to obtain a simpler representation of the data, followed by a regression analysis to predict the body shape from subject covariates such as stature and body weight [6].

The previously developed statistical model of torso shape represented only the scanned posture, which is not typical of vehicle occupant postures. For the current study, the original data were reanalyzed using a novel methodology. Each subject's scan model (a set of 3600 vertices representing the surface and associated landmarks) was articulated to a set of postures relative to the scanned posture, defined by two variables.

The entire model (thighs through head) was tipped rearward from zero to 30 degrees. The lumbar spine was flexed, relative to the measurement posture, by -15 to 30 degrees, with the lumbar motion evenly distributed between