Accommodation Assessments for Vehicle Occupants using Augmented Reality

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Abstract. This paper presents a new accommodation assessment method for vehicle occupants using a statistical body shape model in an augmented reality (AR) environment. Vehicle occupant accommodation assessment is an important aspect of vehicle interior design. Variability in body dimensions of the target population is a key component in determining the overall user accommodation. Statistical body shape modeling enables quantitative representation and assessment a wide range of variability in anthropometry and posture. These statistical models provide a way to efficiently generate a realistic 3d body shape surface along with the standard body dimensions, anatomical landmark locations and joint locations. In the current study, an automotive posture body shape model based on data from 255 men and women ages 20 to 95 years old was used in a demonstration of AR technology. Typically, quantitative assessment of a physical vehicle requires time-consuming scanning to obtain a computer model that can be used with virtual assessment tools. We addressed this issue by using AR to enable assessment without explicit model building. Apple ARKit on an iPhone was employed in this study to implement the model in an augmented vehicle environment. The system allows the user to place a human model in a vehicle by detecting the seat surfaces. The user is able to manipulate the body shape to assess accommodation across the range of anthropometric variability. Interior accommodation was assessed by measuring the distances between the certain points from both the model and the augmented physical environment, in addition to a qualitative visual inspection. Opportunities and impacts of the proposed AR approach with digital human models in more applications are discussed.

Keywords: Augmented Reality, Accommodation, Seat, Digital Human Models.

1 Introduction

Accommodation assessment plays important role in automobile interior package design practices and vehicle occupant safety [1]. Typically, quantitative assessment of a physical vehicle in a virtual environment requires time-consuming scanning and manual processing to obtain a precise computer model of the vehicle that can then be analyzed using virtual assessment tools. In this paper, we bypass the generation of the vehicle model using augmented reality (AR). AR provides an interactive experience of a physical environment whose elements are *augmented* by computer-generated images. We implemented AR-based accommodation assessment using Apple ARKit to assess accommodation between a digital human model and a physical vehicle interior. An automotive posture body shape model based on data from 255 men and women ages 20 to 95 years old was utilized in this study. UMTRI has developed a range of statistical body shape models based on 3d anthropometric data for children and adult men and women with a wide range of body size and age. The models, some of which are available online (http://humanshape.org), provide a way to efficiently generate a realistic 3d body shape surface along with the standard body dimensions, anatomical landmark locations and joint locations. In the current proof of concept, a mobile app for iPhone was developed, allowing for generating a subject-specific avatar and positioning the avatar on a target seat position. Opportunities and impacts of the proposed AR approach with digital human models are discussed.

2 Methods

2.1 Statistical Body Shape Model

The current analysis was conducted using data from 255 men and women ages 20 to 95 years old. Standard anthropometric measures were also obtained and each participant was scanned minimally clad using a VITUS XXL laser scanner in a seated posture (Figure 1). The scan data were fit using a homologous template mesh and procedures published previously [2]. The template-fitting procedure produces a watertight mesh with 14427 vertices and 28850 polygons. Following the fitting, the meshes were made symmetrical by averaging the corresponding left and right vertices.

The processed template fits were then analyzed along with the measured landmark and joint locations to develop a statistical body shape model (SBSM) using a method presented in our previous work [3]. In brief, a principal component (PC) analysis was used to represent the variability in the processed data with a few PC scores. A total of 60 PCs that together explain more than 99% of the data variance were retained from the PCA. A regression analysis was applied to associate the PC scores and the anthropometric predictors, such as stature, body mass index (BMI), age, and sitting height to stature ratio.

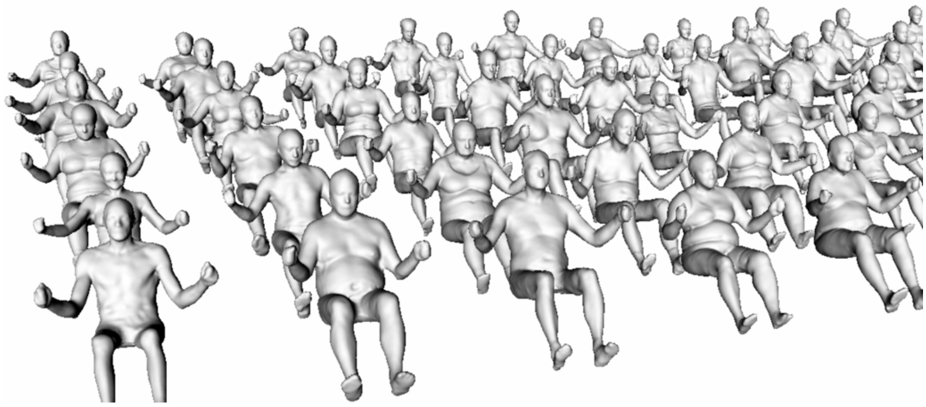

Fig. 1. Body shape measurement data of seated adults.

2.2 AR-based Assessment Tool

An AR-based assessment tool for mobile devices was developed using Apple ARKit. ARKit recognizes notable features in the scene image and tracks differences in the positions of those features across video frames to create a correspondence between real and virtual spaces. Figure 2 shows feature points tracked by ARKit and an estimated floor plane based on the tracked feature points. These tracked feature points on the objects in the scene were used to place our body shape model and also to detect reference point to measure a distance between the model surface.

One of the key factors for accurate accommodation measurement in AR is to place the virtual body shape model in a proper position in the augmented 3d space of the vehicle. We used a plane detection function of ARKit to detect the vehicle floor. An occupant posture prediction model developed in a previous study [4] was used with the estimated floor plane to roughly estimate the model position in the occupant space. The app interface allows the user to adjust the human model position and orientation manually.

Unity3D, a cross-platform game engine developed by Unity Technologies, was used for visualizing and manipulating the seated body shape model in the AR. To measure the distance between a point on the vehicle interior surface and a point on the body shape model, a ray casting method was used. In brief, when a user touches the screen on the vehicle part, the system converts the picked two-dimensional coordinate into a 3d ray in the AR space and finds the interacting point between the ray and a surface fitted to neighbored feature points. When another point is selected on the model, the Euclidean distance is computed from the selected points.

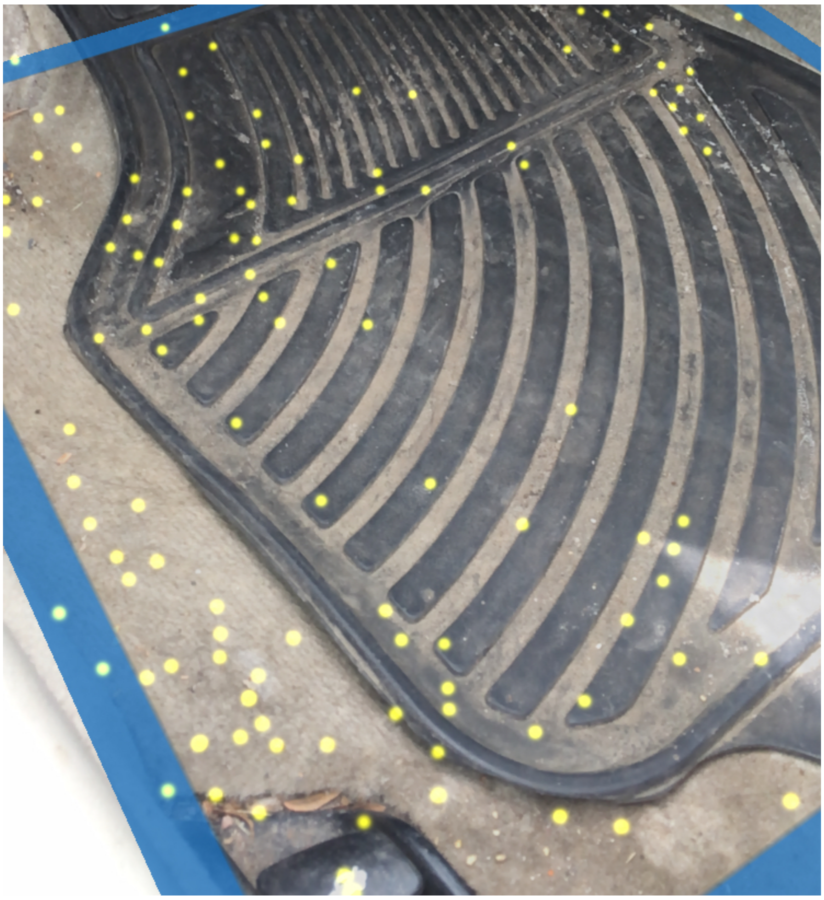

Fig. 2. Tracked feature points (yellow dots) and estimated horizontal plane (blue square) on a car floor.

3 Results

3.1 Representing Posture and Body Shape

Figure 3 shows a range of body shapes generated using the statistical body shape model (SBSM). The figures were obtained by manipulating the body mass index and gender parameters over a wide range while holding the stature and age parameters constant. The 3d body contours were generated by the SBSM along with 114 body landmarks and joint locations.

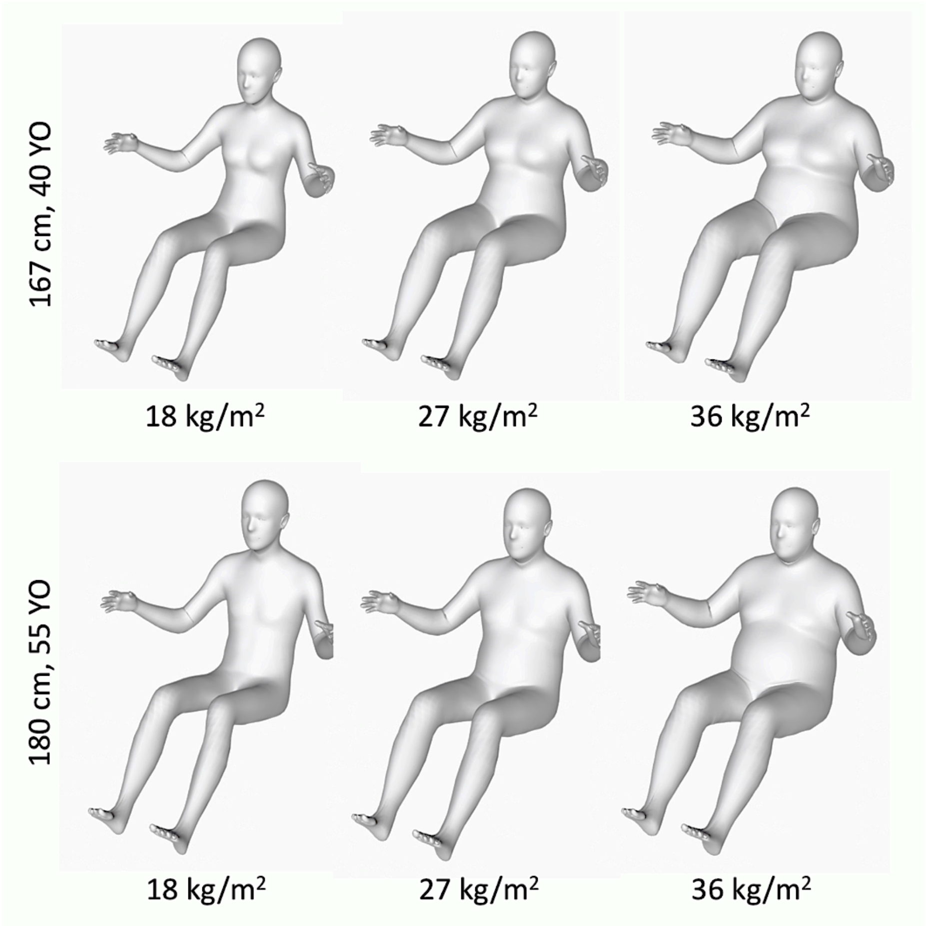

Fig. 3. A series of 3d avatars generated by varying the body mass index and gender while holding the stature and age.

3.2 AR-based Accommodation Assessment

Figure 4 shows an example of occupant accommodation assessment using the developed mobile app. A subject-specific female avatar was generated with the parameters of 167 cm of stature, 28 kg/m^2 of BMI and 40 years old for this assessment. The vehicle floor and the seat plane of a mid-size sedan were detected within a second. The model was positioned on a seat considering a normal sitting position. The model kept in the initial position in the augmented space while moving the phone to visually check the model from various viewpoints. The point-to-point distance measurements returned plausible results.

Fig. 4. Developed mobile app interface and a sample accommodation assessment of an avatar

4 Discussion

To our knowledge, this is the first implementation of AR in vehicle occupant accommodation assessment. A statistical body shape model was utilized to test a wide range of anthropometric variability in body shapes in the AR-based assessment environment. The mobile app demonstrated good performance with minimal user interaction. Since this approach can be applied to any interaction analyses between a statistical human model and physical objects, this will open up various opportunities in ergonomics, anthropometry, product design and system assessment.

Major limitation of this approach is that the reliability of the measurements relies on the tracking accuracy of the device. Once the device lost the trackability of the scene, it is hard to reposition the model at the exact same previous position, and this would result in inconsistency between the measurements. The current system also requires manual adjustment of the model to find a proper sitting position. These limitations can be resolved by using a physical reference in the scene. For example, a statistical model of seat shape [5] could be used to estimate the seat H-point location and back angle, which could improve the posture and position of the model.

To further improve the performance, a depth detection method is needed. The current system does not consider the depths of surrounding objects, so the entire body shape is always shown even though the part of the body shape is occluded by vehicle parts. Using a fully poseable body shape model will allow further assessments, such as reach. We can also incorporate personal protective equipment and body borne gear to simulate occupational vehicle users [6].

References

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