DIGITIZING THE FIT MODEL USING 3-D BODY SCANNING TECHNOLOGY

Susan Ashdown, Suzanne Loker & Erica Carnrite

ABSTRACT

Body scanning technology allows us to digitize the three-dimensional surface area of the human body in minimal clothing for body measurement or in clothing prototypes for fit assessment. With specialized computer software, a variety of good resolution 3-D visualizations can be created from the data such as triangulations around the coordinate points and smoothed surfaced three-dimensional images. Results of our research evaluating these digital images as tools for fit analysis support the use of digital fit models to improve clothing fit in a target market.

1. INTRODUCTION

One of the greatest challenges facing apparel companies today is to provide quality fit to a broadly defined target market. Two issues have limited the resolution of this problem:

- Lack of current anthropometric data to describe the civilian population
- Lack of data on fit characteristics of garments for a variety of different body sizes and shapes, and also for different body positions and movements

Affordable anthropometric studies conducted using 3-D body scanning have been conducted, and are addressing the first issue (Zernike, 2004). 3-D body scan data also have the potential to provide new insights into apparel sizing and fit issues. Our research is developing ways to objectively quantify and assess fit for a target market of a specific apparel firm using both visual analyses and statistical comparisons of objective measurements.

The 3-dimensional body scanner is a promising new research technology that will contribute to revolutionary changes in the conception, design, manufacture, and distribution of apparel. As we reported earlier (Ashdown, Loker, Schoenfelder, & Lyman-Clarke, 2004), the use of 3-D scans can also supplement the fit analysis process in research and industry. This technology can be used:

1) to capture one single instance of fit, and to rotate and enlarge the image to view specific areas for analysis,
2) to create databases of scans of a variety of models with different body shapes wearing a single size (in essence, testing multiple fit models),
3) to scan garments on fit models in multiple poses to evaluate garment/body relationships during natural movements such as sitting and reaching, and
4) to hold virtual expert panels at multiple locations to assess fit and recommend changes to the pattern design or grading process.

For our research we initially developed methods to visually analyze fit using 3-D scans of clothed subjects (see Figure 1). Then, we determined the reliability of the fit ratings at different body areas to establish the number of judges needed for reliable results overall.

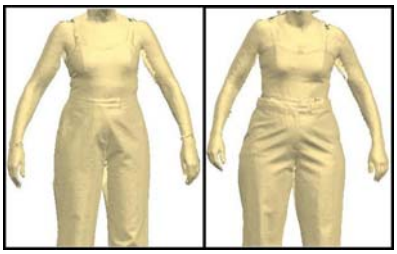

Figure 1. Visual analysis of 3-D scans can be used to asses fit, as stress folds, areas of tight and loose fit, and the balance of the garment on the body are clearly visible in the scanned image.

We conducted visual fit analyses on 3-D scans to determine:
1) how many judges are needed to perform a reliable fit analysis and
2) the reliability across judges' ratings of fit at various locations on the body -- overall, front, back, and individual body area ratings.

2. METHOD

2.1 Sample

The sample for this study was a set of 3-D scans of 153 women, 35-55 years of age who wore Misses pants in sizes from 4 to 16. They were scanned in a pair of flat front test pants with no pockets from a standard set of ready-to-wear pants. The pants were selected from the size range for each subject by finding the pair that fit best at the hips.

Fit judges and fit judging procedure
A set of five fit judges assessed the fit of the garments from the 3-D scans. The fit judges all had experience ranging from 8 to 25 years both with fitting and teaching the fit of clothing. Each judge rated the fit of the pants at 15 body areas (see Figure 2). The rating scale had five choices ranging from much too loose, through correct fit, to much too tight (see Figures 3 and 4)

Front	Back	Area
√	√	Waist
√	√	Waist Placement
√	√	Abdomen
√	√	Hip
√	√	Crotch
	√	Below Buttocks
√	√	Thigh
√	√	Overall

Figure 2. Body area rated

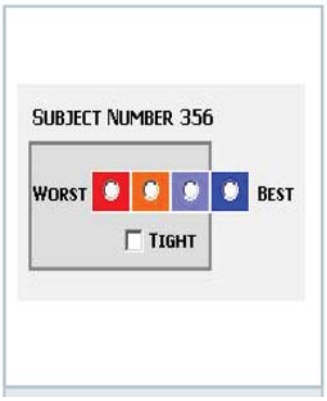

Figure 3. Rating Instrument

Figure 4. Rating Scale

2.2 Preparation

In order to insure that all judges were consistent in their assessment of the fit of the garment pre-test discussions and analyses of visual fit cues were conducted to resolve any variations in interpretation among the judges. The appropriate fit of the test style for the specific target market for which the pants were intended was therefore defined in advance of the fit analysis process. This is an important step in the development of methodologies for research using a panel of judges for sensory evaluations (Ashdown & O'Connell, 2006; Meilgaard, Civille, & Carr, 1987)

The fit assessments were digitally recorded in an instrument developed on Microsoft Access. This software allowed the rater to first rate each of the fifteen areas of the body, and then to sort and view the 3-D images in order by rating for each body area. This sorting tool was very useful for finding inconsistent ratings caused by inattention or by a tendency to gradually shift the judgment of how good or bad the fit was in a certain area (see Figure 5).

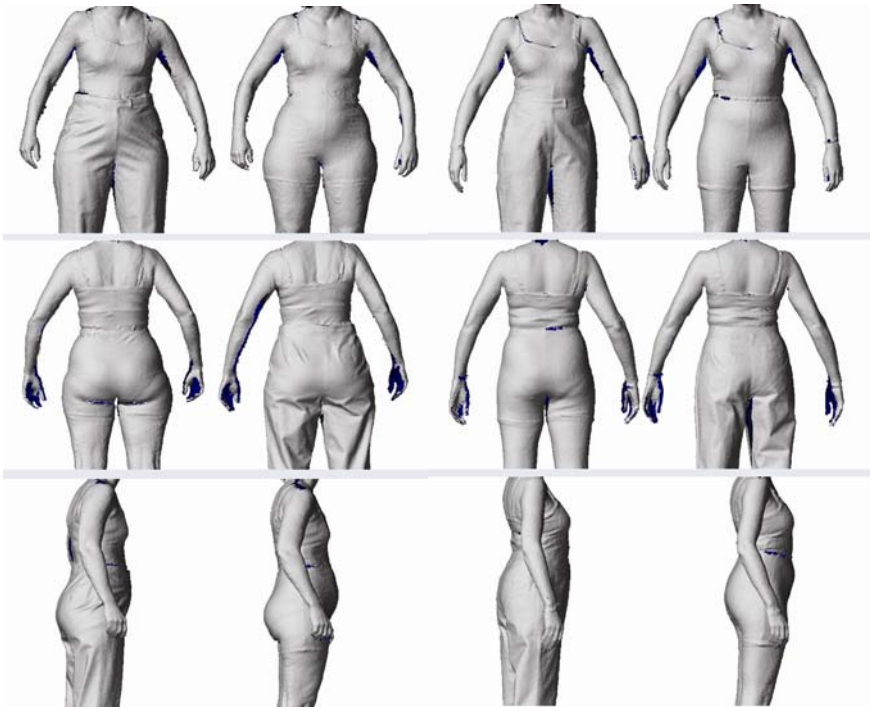

Figure 5. Example of bad fit and of good fit

3. ANALYSIS

Data were analyzed to determine both subject to subject variance and variance among the judges. To determine how many judges are needed to perform a reliable fit analysis, the reliability based on subject to subject variability (σ_s^2) and variability between the judges (σ_j^2) were calculated using the equation:

Reliability = $\sigma_s^2 / \sigma_s^2 + (\sigma_j^2 / \#\ \text{judges})$

It is important to determine the most efficient panel size for fit rating, both for research and for industry purposes. A reliability analysis using Cronbach's alpha was also performed to determine consistency across judges' ratings of fit for all of the areas rated: overall fit, front, back, and individual body area ratings. A multilevel model was used to assess non-independent repeated ratings grouped by judge and by subject.

4. RESULTS

4.1 Subject to subject variance

		Without Covariates	With Covariates
VARIANCE	*residual*	2.006	1.457
	judge	0.119	0.119
	subject	0.37	0.308
RELIABILITY	*5 judges*	0.94	0.928
	4 judges	0.926	0.912
	3 judges	0.903	0.886
	2 judges	0.862	0.838

Table I. Variance and reliability results from the multilevel model

Without considering covariates (i.e., garment size, body area, front or back), the reliability of the judges was acceptable (above 0.80). Even with only two judges, the reliability was high at 0.862. When covariates were taken into account, reliability decreased only slightly for two judges to 0.838. Our conclusion is that only two judges are needed for reliable fit tests if visual fit parameters are established and clearly defined for the judges.

4.2 Variance due to judge

Cronbach's alpha values were used to determine reliability across judges' ratings.

Cronbach's alpha values were evaluated to test whether retaining any specific judge was better than another. Taken as a whole, the judges' reliability scores (Cronbach's alpha = 0.831) were acceptable. Alpha values for the front and back ratings respectively, 0.824 and 0.828, were also acceptable. Judges were consistent in their ratings overall, ranging

from 0.757 to 0.859, so any combination of two judges would have the same fit analysis results.

		AREA		
		All	Front	Back
Cronbach's alpha with 5 Judges		0.831	0.824	0.828
Alpha if item deleted	*Judge 1*	0.757	0.749	0.75
	Judge 2	0.859	0.855	0.858
	Judge 3	0.792	0.79	0.789
	Judge 4	0.783	0.771	0.779
	Judge 5	0.789	0.779	0.785

Table II. Cronbach's alpha values for each area

Cronbach's alpha was used to identify the most consistently rated body areas.

AREA	CRONBACH'S ALPHA
Waist Front	0.912
Waist Back	0.832
Waist Placement Front	*-0.04*
Waist Placement Back	*-0.06*
Abdomen Front	0.857
Abdomen Back	0.856
Hip Front	0.739
Hip Back	0.849
Crotch Front	*0.68*
Crotch Back	*0.51*
Below Butt	0.871
Thigh Front	0.835
Thigh Back	0.849
Overall Front	0.898
Overall Back	0.737

Table III. Cronbach's alpha values for specific body areas

Ratings for most body areas indicated high reliability ranging from 0.912 for waist front to 0.737 for overall back fit. Front and back crotch ratings were less consistent (0.680 and 0.510 respectively). Rating crotch fit is difficult, as visual cues to crotch misfit are subtle and are frequently complicated by interactions with fit at other areas.

Front and back waist placement ratings were negative which is highly unusual (-0.04 and -0.06 respectively). Subsequent discussions with the judges revealed that the scale was interpreted differently by each judge. In this case the fit issue was how the height of the pant waist related to the body waist. The item on the instrument for rating the waist height was not distinguished from the other items that were used to rate tightness or looseness so it was not clear which end of the scale was appropriate for the choices 'too high' or 'too low'. Though this was discussed before the ratings began, the scale was not intuitive, resulting in different use of the scale by different judges

5. CONCLUSIONS

Our results suggest that two judges are sufficient for reliable ratings if visual fit parameters are established and clearly defined for judges. Complex areas of misfit that are difficult to rate visually, such as the crotch, may require different assessment methodology. It is important to ensure that all judges use the instrument scale in the same manner**.**

Reliability of fit assessments improves the predictive value of mathematical models developed to adjust existing sizing systems of apparel firms. Recognizing that two judges achieve reliable ratings can streamline the fit rating process for many types of research studies and for industry fit assessments.

5. RECOMMENDATIONS

The use of 3-D body scan images of target market subjects in ready-to-wear apparel for fit assessments has been shown to be a powerful tool for research in sizing and fit. The scan provides a clear image of stress folds that reveal tight and loose areas of the garment. The balance of the garment on the body is also easy to see in a 3-D image that can be rotated to view from every angle. The use of a scan image for other types of visual analysis has been shown to be superior to the use of a 2-D photograph (Ashdown, Slocum, & Lee, 2005). It is likely that viewing a 3-D scan of the clothed figure along with a minimally clothed scan of the same subject can provide a powerful tool for analyzing and categorizing the fit of ready-to-wear on the full range of body types that exist in the target market (see Figure 1). Scanning is a rapid, precise, and simple way of capturing images rich in information about fit that could then be viewed by designers and patternmakers at convenient times. Portable body scanners could be used to capture scans of customers at retail locations for later analysis. A study of patternmaker's and designer's responses to scans is currently underway that will help determine the usefulness of this new image capture tool for the apparel companies. Any tool that can help with the complex task of providing well fitting clothing for the target market of an

apparel company is welcome as a way to improve apparel offerings in today's marketplace.

6. REFERENCES

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CORRESPONDENCE AUTHOR:

Susan P. Ashdown
Department of Textiles and Apparel
327 MVR Hall
Cornell University
Ithaca, NY 14853