

**Improved Apparel Sizing: Fit and Anthropometric 3D Scan Data**

<http://www.human.cornell.edu/units/txa/research/ntc/S04-CR01.pdf>

<http://www.explore.cornell.edu/bodyscanner>

*Susan Ashdown & Suzanne Loker, Cornell U.; Carol Adelson, Fashion Institute of Technology*

Project Manager: *Katherine Schoenfelder*

Graduate Student: *Lindsay Lyman-Clarke*

**GOAL**

To extend and improve our fit analysis process, establish our sample of 203 women as statistically representative of the USA population using SizeUSA scan data, to confirm the mathematical model of fit analysis developed from our sample, and develop a process by which apparel firms can interpret and apply body scan data in the development and assessment of their pattern making, grading, and sizing systems.

**ABSTRACT**

This project extends the research from our original NTC project by developing methodologies for applying a combination of fit data and anthropometric population data to the problem of developing effective sizing systems for apparel products. We plan on identifying sets of critical measurements for effective sizing for specific target markets and document the process of applying them to the development of base patterns, grade rules, and sizing systems. These objective measures of the target population can be used to refine the traditional method of pattern and sizing system development based on one fit model, standard grade rules, and descriptive demographic data, such as age and income. We have begun work on the first of the following three objectives of this study:

1. Link our mathematical model of fit analysis based on scan data to anthropometric data of the U.S. population.
  - A. Establish relationships between body characteristics of that portion of the target market that are poorly fitted and a statistically representative sample of the target market in the U.S. population.
  - B. Determine each possible pattern making and grading decision variable in the sizing system that improves fit for the greatest number of targeted individuals from the population.
2. Extend and improve our fit analysis process based on scans of different target markets and apparel styles.
3. Identify and generalize critical scan measurements, anthropometric data, analysis methods, and strategies in order to develop a process by which apparel firms can interpret body scan data to optimize an existing sizing system for a specific target market.

**BACKGROUND**

One of the greatest challenges facing apparel companies today is finding a cost-effective method to provide quality fit in apparel. Repeatedly studies of degree of satisfaction with apparel have found that about 50% of women cannot find satisfactorily fitting clothes (Goldsberry, Shim, & Reich, 1996; LaBat, 1989). Lack of good fit is often the reason given by consumers for deciding not to purchase clothing, and it is estimated that as much as 35% of clothing purchased from catalogs is returned because of problems with fit (Chapman).

The creation of an effective ready-to-wear sizing system is a complex undertaking. The great variation in sizes and shapes of people in the population and the need to keep stock keeping units (SKU's) to a minimum in order to control inventory costs are in direct conflict with one another. Because of the variation in the population, a change in the base pattern shape or the grading of a pattern has the potential to improve the fit of the garment for one segment of the population at the expense of another segment.

Two issues have limited the ability of apparel companies to make informed decisions about their sizing systems. First, there is a lack of data on fit characteristics of garments for a variety of different body sizes and shapes. Second, there has been a lack of current anthropometric data to describe the civilian population. Apparel companies typically only attempt to fit one body type, developing base patterns and grade rules matching the proportions of their fit model. The fit model is chosen to represent the target market but little information is available to help choose a fit model with the appropriate body characteristics. The marketing of apparel typically focuses on the age, income, and lifestyle choices of the target market, which are not necessarily a predictor of body size and shape. Three-dimensional scanning systems can provide both anthropometric and fit information but the tools and processes to analyze and apply these data are still needed. Developing quantitative models of fit applicable to multiple target markets and styles, and new analysis processes that link fit data and anthropometric data will ultimately result in better sizing and fit methodologies. The creation of better sizing systems for the apparel industry will result in a reduction in unsold or discounted garments.

The 3-D body scanner is contributing to research for the apparel industry and holds promise to revolutionize the way apparel is manufactured and sold. Two recent anthropometric surveys of the civilian U.S. population (CAESAR and Size USA) using this technology have been conducted (*CAESAR: Civilian American and European Surface Anthropometry Resource Project, SizeUSA Info*). These are the first attempts to collect anthropometric data from a representative U.S. adult population relevant to apparel since the 1940's and are made possible with body scanning technology. These data have the potential to provide new insights into issues of sizing and fit of apparel. The apparel industry has not had access to reliable, representative data from body scans, so tools and methodologies to harness, apply, and interpret this information are critically needed. Previous work at Cornell funded by NTC has focused on the development of mathematical models and statistical techniques for analysis of fit using body scan data (Ashdown, Loker, & Adelson, 2002). Our research is developing ways to objectively quantify and assess fit for the segment of the population identified by an apparel company as its target market using body scan data to visualize and quantify garment fit. Multiple scans of 203 research participants were analyzed to quantify fit issues for two different size categories and styles of women's pants. By merging and analyzing two 3D entities (a minimally clothed body and the same body in a garment) we have begun to describe the complexity of fit in terms of its surface and volumetric characteristics. However in order to translate this information into valid recommendations for determining optimal sizing groups within a target market, it is necessary to relate these data to the configuration of the target market in the U.S. population. Creation of new sizing systems based on fit characteristics for the actual target market anthropometrics should lead to improved fit and boost the competitiveness of the U.S. apparel industry.

## METHODOLOGY AND PROGRESS

We are building on our previous work to improve current ready-to-wear sizing systems by developing protocols and methodologies to analyze fit based on fit analysis of garments from an existing sizing system. In doing so, we are using new measurements—surface and slice area and volume—that garner the power of scan data.

### *Establishing Sample as Statistically Representative of the USA Population*

In order to relate these data to population data we are collaborating with [TC]<sup>2</sup> to compare the scan measurements from our data base for the target market of 34-55 year old women to the corresponding segment of the population data from the Size USA study. Our scans were taken using the Human Solutions TechMath scanner while the SizeUSA study measurements are generated from the [TC]<sup>2</sup> scanner. Automated landmark placement and measurement extraction procedures for the two systems are different resulting in non-valid measurement comparisons. We have also developed new measurements and methods for extracting these measurements that result in surface area and volume measurements that do not have any equivalent in the [TC]<sup>2</sup> database. A comparison of the different measurement procedures from the two studies showed large differences in landmark placement and measurement methodologies (see Table 1). As a comparison of these different sets of measurements would not be valid, we have sent scans of 203 women [TC]<sup>2</sup> for processing to extract a set of measurements using identical procedures as those used in the SizeUSA study. Using the comparable age group for Size USA, we will statistically compare our sample's measurements with the SizeUSA population's to determine how well our sample reflects the larger population. In addition, we will investigate how closely our measurements correlate with shared landmark and measuring methodologies. One hundred and sixty eight measurements will be evaluated to determine the degree to which our sample and existing mathematical model methodology could be relevant to the general U.S. population.

Table 1. Comparison of Measurement Systems

Shared Measurements	Measurements Unique to Cornell	Measurements Unique to SizeUSA
<b>Girths</b>		
Waist	Waistband top <sup>a</sup>	Midriff <sup>a</sup>
Abdomen	Waistband bottom <sup>a</sup>	Thigh <sup>b</sup>
Hip (Seat)	Abdomen <sup>b</sup>	
	Thigh <sup>b</sup>	
<b>Heights</b>		
Waist	Waist <sup>c</sup>	Waist minus seat <sup>a</sup>
Abdomen	Abdomen <sup>b</sup>	Abdomen from waist <sup>a</sup>
Hip	Hip <sup>c</sup>	Midriff <sup>a</sup>
Crotch	Crotch <sup>d</sup>	Thigh <sup>b</sup>
<b>Additional</b>		
Rise/Crotch Length	10 mm Sagittal Crotch Strip <sup>a</sup>	Straight Body Rise <sup>d</sup>
		Abdomen Seat Depth <sup>b</sup>
		Back Seat Angle <sup>d</sup>
		Arc measurements:
		Waist <sup>b</sup>
		Abdomen <sup>b</sup>
		Hip <sup>b</sup>

<sup>a</sup> Different measurements (no equivalent in other system)

<sup>b</sup> Different landmark, same measurement procedure (i.e., thigh measurement taken with same method in different location)

<sup>c</sup> Same landmark, different measurement procedure (i.e., waist landmarked at greatest lumbar curve: tilted in one system and parallel in the other)

<sup>d</sup> Different landmark, different procedure

*Comparing Standing and Seated Scans*

We have begun a study to measure the change in body measurements between sitting and standing positions. A pilot test with eight subjects was completed to develop test methodologies and potential analysis strategies. A clear acrylic table was designed and used to capture as much data as possible when subjects were scanned in the sitting position (see Figure 1). The laser lights of the scanner travel through acrylic and capture scan data from all angles of the seated figure.



Figure 1. Acrylic table used for sitting scans.

Various types of landmarks and methods of adhering them to the subject were tested in the protocol testing stage to ensure that the landmarks would be visible on the 3D scan. The final choice used two star shaped reflective sequins, interlaced to create a single circular shaped landmark with dimension (see Figure 2). Depending on the orientation of the landmark with respect to the laser beam, the landmark was visible in the 3D scan, usually appearing as a bump on the skin surface, but sometimes as an indent or hole. A variety of close fitting garments were tested with landmarks to address modesty concerns but it was determined that the landmarks had to be placed on the skin to accurately track the change at the skin's surface. Before registering for the study, subjects were personally briefed on the scan process, which required scans to be taken with the subjects in their underwear and upper body crop tops. For this reason, we decided to recruit subjects familiar with the scanner and our study. All but one subject had previously been scanned. Subjects were targeted for recruitment to cover the full range of target sizes and ages but it was more difficult to find subject in the larger sizes (Table 2).

Table 2. Pant size for study with subject in sitting and standing positions

Size	Subject Count
4	3
6	7
8	3
10	11
12	9
14	2
16	3
18	6
20	2
22	3
24	0

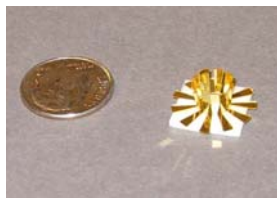


Figure 2. Adhesive landmark placed next to dime for scale.

For the final study forty-nine subjects in the target market, ages 34-55, were scanned six times. One set of scans were made to capture data to be analyzed for breadth measurements using landmarks identified on subjects in a seated position and a second set of scans captured data using landmarks set for traditional apparel measurements. These traditional measurements include waist, abdomen, and hip circumferences identified in a standing position. In total, four scans were taken in the sitting position while only two scans were required to capture all of the landmarks and data in the standing position.

The 3D scans were transferred from the Human Solutions scan system to Innovmetric's Polyworks software suite for alignment and merging of the data from individual cameras. The scans were not smoothed for visual clarity as smoothing had the potential to obscure landmarks. Polyworks' IMEdit was used to set planes and create cross sections based on visual identification of the landmarks (see Figure 3).

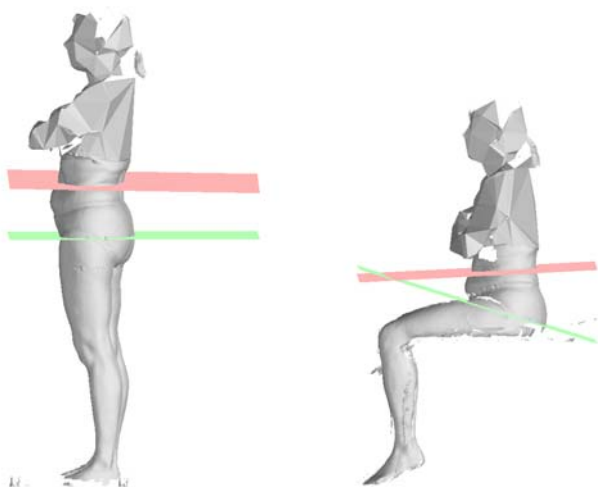


Figure 3. Subject in standing and sitting positions with waist and hip planes.

Twelve cross sections in total were created for each subject, 6 each in both standing and seated positions. Accurate perimeter measures were not possible using Polyworks' measurement tools due to the fact that the sitting scans have significant missing data on horizontal planes (such as the thigh) since the scanner cameras can not capture this data. Because the cross sections were set in 3D space, Polyworks' IMInspect was used to align all cross sections into a 2D plane to measure the curves in 2D software system. The 2D dxf files aligned in IMInspect were transferred into Adobe Illustrator and Bezier curves were used to close gaps in the cross sections.

A CAD plug-in tool was used to measure the resulting closed cross sectional circumference. Analysis of the following circumference measurements will begin shortly:

- Widest breadth
- Thigh at widest breadth
- Natural waist
- Hip
- Thigh
- Crotch length to natural waist

In addition to scanning the subjects in the two body positions, we scanned the subjects who fit into the Misses size range in a new pant style, sizes 4-16. Our industry partner believed that the new style would better fit the target market, through new dart placements and inclusion of a size 4 for the smaller subjects. Thirty-eight out of the forty nine subjects fit into the Misses size range and were scanned once in a standing position and once in a sitting position wearing the new style. Subjects also completed a brief verbal survey in which they were queried regarding “how do the pants feel” at the waist, hip, thigh, and crotch. Subjects rated their impression of the fit of the pants in both the standing and sitting positions as tight, good fit, or loose for a total of eight responses. A fit expert also recorded her visual observations about the fit of the pant for each subject in standing and sitting positions. These data will be analyzed and compared in the near future.

## **NEXT STEPS**

During the next year, we will extend and improve our fit analysis process by using SizeUSA data to better define the 34-55 year target market and add subjects in other selected target markets to our database of scans. Our recent purchase of a portable scanner will allow us to take the scanner to the target groups and will increase our ability to easily collect data. We are in communication with several potential industry partners who are interested in improving their sizing based on our process and whose collaboration will extend our work to different target markets and apparel styles.

We also intend to further develop the mathematical model begun in our 2001–2003 NTC project “Use of Body Scan Data to Design Sizing Systems Based on Target Markets.” We will improve the selection of specific critical measurements to be used to adjust existing size/pattern specifications for individual apparel firms. We will apply these critical measurements and our model to the data available to SizeUSA member firms and propose one or several processes by which the scan data measurements can be interpreted and applied by industry.

## **REFERENCES**

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