Improved Apparel Sizing:  
Fit and Anthropometric 3D Scan Data  
**Susan Ashdown, Suzanne Loker, co-leaders (Cornell);**  
**Margaret Rucker (UC Davis)**

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 data on fit characteristics of garments for different body sizes and shapes  
- lack of current anthropometric data to describe the civilian population.

The three-dimensional body scanner is a promising new research technology that will contribute to revolutionary changes in the conception, design, manufacture and distribution of apparel. Three dimensional body scan data have the potential to provide new insights into apparel sizing and fit issues. We are developing ways to objectively quantify and assess fit for a target market of a specific apparel firm through visual and statistical comparisons of objective measurements. Figure 1 presents our approaches, both numeric and visual, as well as specific applications that have resulted from scan data analyses. Currently, the quantification of fit is complex and ambiguous; and objective methods, such as comparison of linear measurements, are inadequate. Our ultimate goal is to improve fit by adjusting existing sizing systems for specific target market populations of individual apparel firms.

Our research extends the findings from our first NTC project (S01-CR01) by developing methodologies for applying a combination of fit and anthropometric population data to the problem of developing effective sizing systems for apparel products. Measurement data can be collected for target markets by gender, age and niche functional markets relevant to clothing fit and for the wearer is in active positions. We are also linking our scan data set with the SizeUSA anthropometric data to establish it as statistically representative of the sample of the target market in the U.S. population.

**Mathematical Model**

The goal of the mathematical model is to develop and test a virtual sizing system that compares measurements from a garment created from 3D geometric shapes to the scanned 3D measurements of the target population to improve fit. The results of this fit comparison will govern the 2D pattern changes required to create sizes that fit the highest percentage of the target population.

We used geometric equations such as an ellipse and a stadium to create a 3D model based on test pant specifications. Using the software program Matlab we derive a set of 18 different measurements, shown to be crucial to good fit, from the pant model. These measures include linear measures, surface areas, slice areas and volumes. The 18 pant measures are then compared to the same 18 body measurements from each of the subjects in our extensive scan data base. Subjects whose measurements fit within all our predetermined ranges +/- the ease tolerances allowed are determined to have good fit. The program can be used to increase the number of scanned participants who achieve good fit. Individual measures on the geometric pants can be adjusted by increments and then rerun with the program. This iterative process is repeated to find the best combination of pant measurements that fit the largest (or desired) percentage of people. Once the ideal set of pattern specifications has been determined these pant measurements are transferred to patterns.

The benefits of fitting using the mathematical model and its software program are far-reaching. The mathematical model allows us to test the fit of a garment as a virtual garment on a wide range of real bodies in the form of 3D body scans without ever having to make the garments, recruit subjects or physically try anything on. Currently the program is set up to test a specific style of pants however, due to its flexible nature, the program will ultimately be adapted to variations in style, fit and sizing systems.

**Seated/Standing Measurements by Body Type**

Scans of 49 female subjects aged 34-55 years in standing and seated positions were taken to collect data on body measurement changes in active positions, and to look at the relationship of these changes to body size. The method for categorizing body shape that divided the study participants into the most distinct categories of body circumference and body breadth dimensions was Body Mass Index (BMI = mass/height$^2$ [kg/m$^2$]). Subjects were divided into normal, overweight and two obese groups (no underweight group) based on their BMI values. Increases in hip circumference in the seated position, though with no significant differences among groups. The crotch length was the only measurement to decrease in the seated position, though with no significant differences among groups. Hip and crotch measurements, as well as...
significant differences in waist and thigh measurements, pointed to the difficult fitting issues when considering the variety of body positions and movements.

These results will be used to adjust existing patterns and pattern systems to improve fit for pants during wear in many positions. General conclusions are:

- Circumferences and breadths increase between the standing and seated position, while crotch lengths decrease.
- The data generally show greater differences in measurements as BMI increases.
- Significant differences occur at the hip circumference, waist breadth and thigh breadth.

Visual Analysis of Fit

We developed methods to visually analyze fit using 3D scans of clothed subjects. We assessed the reliability of fit ratings at different body areas and determined that two judges are needed for reliable results overall. Fit assessment ratings of women’s pants for most body areas were reliable if fit parameters and the instrument scale were established and clearly defined for the judges. Crotch ratings were less consistent, and we concluded that different assessment methodology may be required for the crotch and other areas of misfit that are difficult to rate visually. Comparison of the fit of women’s jackets from body scans is currently being assessed for validity by comparing fit assessment data from scans to actual fitting adjustments made on the jackets.

Scanning New Target Markets

We added scans representing new markets to our database. Analysis of the scan process, participant reactions, body type and size and garment style and fit have contributed to greater understanding of diverse target markets.

Teens - Girls ages 10-15: scanned during several on-campus events sponsored by the Cornell Cooperative Extension 4-H Office. The girls were scanned in the Human Solutions scanner in the standard position wearing a Lycra scan suit over their underwear garments. These scans will be analyzed to develop a better understanding of this target market’s body shape, especially as compared to our older female scan data.

Men - Men ages 25-55: scanned at a local retail store with an industry partner, Joseph Abboud. 120 men between the ages of 25 and 55 years were scanned using a [TC] scanner. These scans were used to generate custom shirts which were then compared for fit to a line of ready-to-wear shirts also manufactured by Joseph Abboud. During this study scans from two different manufacturers, Human solutions and [TC]², were compared and tested to identify and resolve differences due to scan position and data format.

Tailored Clothing - In collaboration with industry partner Macway’s Tailors, 11 male and female subjects were scanned using a portable [TC]² scanner. Scan measurements were taken in conjunction with measurements made by a professional tailor. From the scan measurements, patterns for custom fitted suits, shirts, pants and sport coats were created and compared to ready-to-wear garments of the same style.

Occupational Groups and Protective Clothing - Eighteen subjects in California and 30 subjects in New York from three different occupational groups were interviewed, photographed and given questionnaires to complete. Data have been compiled and typical working positions have been identified to be used in a scan study of overall fit in active positions.

Results from scanning diverse target markets included revelations into the interests and motivations of different scan participants. Teens were excited about scanning, especially in their own clothing and in interesting poses. Men’s interest in scanning was linked to the technology.

Next Steps

Modify and test mathematical modeling process by:

- Refining mathematical model and software program
- Developing protocol to transfer pants measurements developed from model to patterns and grade rules
- Establishing goal for percentage of target market to achieve good fit
- Changing garment patterns and creating a new size set of test garments
- Scanning original subjects to test the fit and improvement
- Adjusting model and testing program on other pant styles and sizing systems

We will continue to scan new target markets to refine:

- Scan protocols
- Visual and statistical analysis techniques
- Applications to industry pattern making and grading procedures
- Scan protocols and data analysis to collect data on fit of clothing in active positions

There is also more work to be done to:

- Compare scan measurements used in custom and ready-to-wear applications to extend their use in both arenas
- Identify strategies to gain consumer acceptance of scanning
- Develop easy and comfortable logistics for scanning consumers.
For Further Information:


goto http://www.tx.ncsu.edu/ijatm to see articles in Journal of Textiles and Apparel, Management and Technology

For Research Journal, 22(2), 1-4

Consumer reactions to body scanning, Clothing and Textiles


goto http://www.tx.ncsu.edu/ijatm to see articles in Journal of Textiles and Apparel, Management and Technology