Use of Body Scan Data to Design Sizing Systems Based on Target Markets

Primary Investigators
Susan Ashdown
Cornell University
Suzanne Loker
Cornell University
Carol Adelson
Fashion Inst. of Tech.

Collaborator
Dexter Kozen
Cornell University

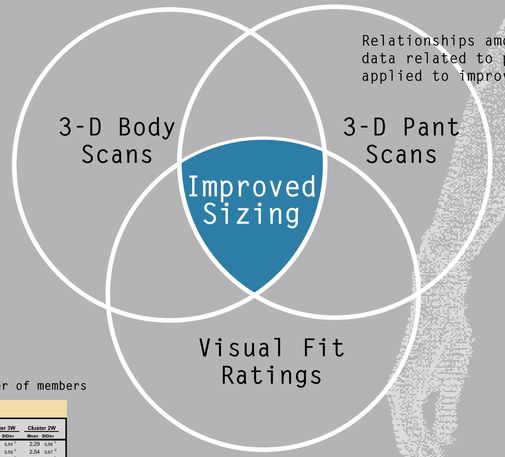
Project Manager
Katherine Schoenfelder

Graduate Students
Adriana Petrova
Eui Choi
Lindsay Lyman-Clark
Jian-Guo Cao
Lucy Dunne
Kirk Mayer
Nami Tanaka
Jeong-Yu Yoo

Undergraduate Students
Janaki Parthasarathy
Erica Lastufka
Natalie Walsh
Orren Wexler
Luisa Avila
Arnab Bose
Stephanie Chan
Fred Fang
Amy Kinateder
Kira Luxon
Ewunike Patterson
Jaclyn Popeil
Erica Richter
Tara Taff
Frankie Tsang

OBJECTIVE

To develop a prototype mathematical process using body scan data to improve a pant sizing system for a specific target market population of an apparel firm.



Relationships among three sets of data related to pant fit and applied to improve sizing

METHODS

Protocol Development

- A pilot study was conducted with 30 subjects
- Protocols were developed, evaluated, and revised for data collection, data cleaning, and initial data analysis

Data Collection

- Industry partner Liz Claiborne provided:
  - Test pants in two size ranges (Misses 4-16 & Women's 14-24)
  - Size specifications and grade rules for the pant styles
  - Access to fit models for 3-D scans (Misses size 8, Women's 18)
- 205 female subjects recruited based on Liz Claiborne target market:
  - Ages: 34-39 (n=42) 45-49 (n=65) μ=44.9
    40-44 (n=51) 50-55 (n=46)
- Scan Process
  - Two scans per subject
    Body Scan: one-piece Lycra scanning suit
    Pant Scan: test pant sized at hip
  - Crotch height of subjects measured manually
  - Demographic questionnaire administered

SAMPLE DISTRIBUTION

SIZE	COUNT Misses	Women's*
4	32	
6	21	
8	20 *	
10	21	
12	24	
14	28	13
16	10	15
18		9*
20		5
22		3
24		4

N = 156 + 49 = 205

* INCLUDES FIT MODELS

Note: Two subjects removed from misses & misfit details due to extreme body asymmetry

Data Cleaning

- Scan files transferred to Polyworks (Innovmetric) software
- Holes in scans manually patched
- Scans cropped above waistband and below mid-thigh

Measurement Extraction

1. Planes set at various orientations:
   - Tilted planes
   - Transverse planes (parallel to floor)
   - Sagittal plane (perpendicular to floor) centered on body at crotch
   - Frontal plane (perpendicular to the floor) between side seams
2. Curves set on pant scans based on pant specs; then optimized to body
   - Top of waistband
   - Bottom of waistband
   - High hip (3" below bottom of waistband)
   - Low hip (7-8" below bottom of waistband)
3. Extracted 1, 2, & 3-D measurements automatically in Polyworks

Visual Fit Ratings

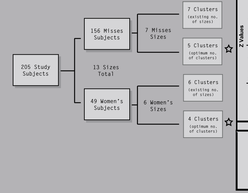
- Three apparel experts visually rated fit of 3-D pant scans
- Front and back views rated separately at 7 critical fit locations
- Three point rating system: Acceptable, Marginal or Unacceptable
- Scores averaged across expert raters

ANALYSES

Cluster

3-D body data were sorted using cluster analysis to group members with the most similar body measurements using 20 measurements from the body scans. Comparing clusters based on existing sizing categories highlights body measurements that are unexpected within the current sizing system and could be an area to improve.

- Waist and abdomen measurements largely determine membership between Misses clusters 1 & 5; note similar distribution of sizes within these two clusters
- Women's clusters did not reveal any new insights, perhaps due to a small number of members in each cluster



SIMILARITY OF MEASURES ACROSS OPTIMUM K-MEANS CLUSTERS

		Misses					Women's				
		Cluster 2M	Cluster 4M	Cluster 5M	Cluster 1M	Cluster 3M	Cluster 1W	Cluster 4W	Cluster 3W	Cluster 2W
		Mean StDev	Mean StDev	Mean StDev	Mean StDev	Mean StDev	Mean StDev	Mean StDev	Mean StDev	Mean StDev
Perimeters	Abdomen	-1.15 0.43	-0.27 0.48	0.91 0.36	0.40 0.45	1.67 0.57	-0.63 0.30	0.16 0.61	1.31 0.54	2.29 0.56
	Hip	-1.25 0.44	-0.22 0.33	0.58 0.42	0.83 0.26	1.62 0.41	-0.67 0.44	0.24 0.32	1.27 0.59	2.54 0.67
	Thigh	-1.17 0.56	-0.21 0.44	0.49 0.58	0.87 0.45	1.44 0.63	-0.54 0.74	0.34 0.82	0.86 0.80	1.80 0.41
	Top of Waistband	-1.11 0.45	-0.34 0.35	1.03 0.38	0.31 0.36	1.76 0.43	-0.47 0.61	-0.02 0.44	0.79 0.71	3.28 0.66
	Natural Waist	-1.09 0.41	-0.34 0.37	1.08 0.35	0.25 0.37	1.73 0.46	-0.45 0.60	-0.01 0.48	0.70 0.65	3.28 0.58
	Bottom of Waistband	-1.17 0.44	-0.30 0.36	0.98 0.44	0.40 0.38	1.72 0.39	-0.55 0.50	0.01 0.43	1.10 0.69	3.01 0.56
Widths	Abdomen	-1.10 0.37	-0.31 0.40	0.92 0.46	0.34 0.42	1.76 0.44	-0.62 0.46	0.13 0.37	1.31 0.62	2.40 0.62
	Hip	-1.22 0.39	-0.27 0.33	0.83 0.43	0.75 0.27	1.73 0.45	-0.67 0.38	0.20 0.31	1.28 0.61	2.69 0.72
	Thigh	-1.15 0.36	-0.24 0.43	0.48 0.57	0.87 0.46	1.48 0.66	-0.54 0.71	0.32 0.86	0.86 0.80	1.90 0.39
	Top of Waistband	-1.07 0.38	-0.37 0.33	1.02 0.41	0.27 0.33	1.85 0.51	-0.45 0.54	-0.07 0.40	0.73 0.74	3.51 0.72
	Natural Waist	-1.06 0.39	-0.37 0.36	1.08 0.40	0.21 0.35	1.79 0.53	-0.44 0.51	-0.05 0.44	0.66 0.65	3.53 0.77
	Bottom of Waistband	-1.14 0.38	-0.33 0.28	0.98 0.47	0.36 0.37	1.80 0.39	-0.54 0.44	-0.02 0.41	1.02 0.71	3.25 0.67
Ratios	Abdomen to Hip	-1.11 0.58	-0.15 0.45	0.33 0.57	0.94 0.51	1.25 1.07	-0.50 0.50	0.05 0.77	0.90 0.87	2.84 0.26
	Hip to Thigh	-1.15 0.47	-0.27 0.37	0.63 0.54	0.66 0.39	1.70 0.62	-0.64 0.46	0.21 0.44	1.23 0.76	2.46 0.42
	Top of Waistband to Abdomen	-0.97 0.44	-0.31 0.55	0.92 0.48	0.20 0.51	1.65 0.89	-0.48 0.54	0.03 0.75	1.32 1.28	1.03 0.46
	Top of Waistband to Bottom of Waistband	-1.12 0.37	-0.35 0.28	1.01 0.45	0.31 0.33	1.85 0.51	-0.50 0.48	-0.03 0.42	0.92 0.73	3.35 0.67
	Abdomen to Hip	-0.83 0.67	0.01 0.60	-0.13 0.65	0.90 0.73	0.35 1.06	-0.13 0.45	-0.09 1.22	0.12 0.73	1.81 1.05
	Hip to Thigh	-1.07 0.48	-0.29 0.42	0.62 0.61	0.57 0.46	1.72 0.81	-0.61 0.44	0.16 0.48	1.18 0.82	2.53 0.46
	Top of Waistband to Abdomen	-0.78 0.47	-0.27 0.63	0.80 0.73	0.08 0.66	1.45 1.26	-0.29 0.51	0.01 0.83	1.20 1.80	-0.99 0.46
	Top of Waistband to Bottom of Waistband	-1.11 0.36	-0.35 0.31	0.99 0.45	0.33 0.36	1.82 0.42	-0.50 0.49	-0.05 0.38	0.92 0.67	3.39 0.77
	Ordinal Pant Size	4.44 0.66	6.13 1.03	12.54 1.06	12.74 1.13	15.33 1.08	15.04 1.03	18.17 1.03	21.75 1.07	24.00 0.00

Size Distribution

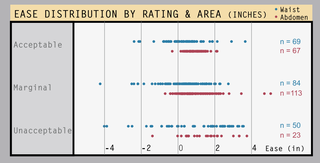
n = 41 n = 47 n = 26 n = 27 n = 15 n = 27 n = 12 n = 8 n = 2

Note. Superscripts unique to one cluster indicate a significant difference between that cluster and all others at p<.05.
A set of common superscripts indicates that the cluster is not significantly different from those clusters with any of the common superscripts.

Ease

Ease values were analyzed for the sample population as a whole, and broken down by size to determine confidence intervals for acceptable fit.

- Variability in ease is lower for subjects rated acceptable at waist and abdomen.
- Isolating acceptable ratings at each location generates a 95% confidence interval of ease values for waist, abdomen, hip, and thigh by size; note the variability in the range of acceptable ease values by size.



95% CONFIDENCE INTERVAL FOR MEAN EASE VALUE FOR SUBJECTS RATED ACCEPTABLE AT EACH FIT LOCATION (INCHES)

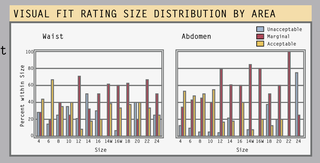
	Size 4 M	Size 6 M	Size 8 M	Size 10 M	Size 12 M	Size 14 M	Size 16 M
Waist	(-0.29 , 0.34) n=14	(0.00 , 0.59) n=14	(-0.30 , 0.52) n=7	(-0.33 , 0.83) n=8	(-13.91 , 11.79) n=2	(-0.48 , 1.25) n=5	(-0.75 , 2.53) n=2
Abdomen	(0.88 , 1.19) n=17	(0.62 , 1.36) n=10	(0.81 , 1.51) n=10	(0.40 , 0.86) n=11	(-0.50 , 1.98) n=4	(0.36 , 1.41) n=5	(0.20 , 1.12) n=4
Hip	(1.43 , 2.09) n=18	(1.70 , 2.17) n=19	(1.72 , 2.19) n=18	(1.24 , 1.85) n=14	(1.27 , 1.77) n=19	(1.49 , 2.38) n=17	(0.51 , 2.80) n=8
Thigh	(4.99 , 6.08) n=20	(5.17 , 6.40) n=19	(5.89 , 7.12) n=19	(5.66 , 7.20) n=19	(5.72 , 7.14) n=22	(5.53 , 7.40) n=26	(4.72 , 10.03) n=6

	Size 14 W	Size 16 W	Size 18 W	Size 20 W	Size 22 W	Size 24 W
Waist	(-2.21 , 3.80) n=5	(-1.93 , 2.46) n=5	(-2.86 , 4.32) n=3	(-5.93 , 8.55) n=2	1.29 n=1	0.91 n=1
Abdomen	0.87 n=1	(1.21 , 2.00) n=3	0.82 n=1	0.61 n=1	n=0	n=0
Hip	(1.08 , 4.12) n=5	(1.71 , 2.77) n=8	(-1.22 , 4.41) n=3	(-13.39 , 19.14) n=2	0.70 n=1	1.85 n=1
Thigh	(7.64 , 11.13) n=10	(5.84 , 10.52) n=12	(5.62 , 12.06) n=8	(4.62 , 14.89) n=4	(-5.45 , 32.98) n=2	13.74 n=1

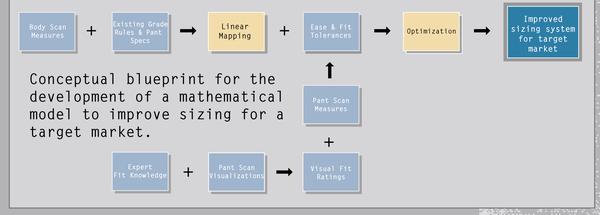
Misfit

Analysis of fit ratings shows differences in percent of target market within size that does not achieve acceptable fit.

- Larger sizes (Misses & Women's) show increased marginal and/or unacceptable ratings; smaller sizes tend to have more acceptable ratings.



DEVELOPMENT OF MATHEMATICAL MODEL



Conceptual blueprint for the development of a mathematical model to improve sizing for a target market.

Linear Mapping Plan

- A multidimensional space of M linear body scan measurements for each subject will be mapped onto a smaller dimensional space of N critical garment measures
- Subjects will be randomly selected into subsets S of size M+1
- Unique matrices A_S will be calculated such that for all x in S, $A_S x = f(x)$ where f(x) is the ideal fit for subject x
- A large number of A_S matrices will be computed and the resulting matrices will be averaged to obtain the best linear mapping solution
- A least squares method for each subject's linear mapping from the M dimensional space to the N dimensional space could result in a goodness of fit metric

Optimization Plan

- Using the results of our various analyses, an optimization model will be developed to improve the pant sizing system for the target market
- Neural network and fuzzy logic methodologies will also be explored

graphic design by eigenimages.com