February 2013. Vol. 1, No.1 ISSN 2307-227X
International Journal of Research In Social Sciences

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THE DEVELOPMENT OF PANT SIZING SYSTEM FOR SRI LANKAN FEMALES

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ABSTRACT

Mass production in the garment industry requires pre-defined size charts based on up-to-date anthropometric data. These standard size charts provide information for manufacturers and retailers to plan the production and the inventories. Every country must have their own sizing systems based on the target population to provide better fit for ready- to – wear clothing which improves customer satisfaction.

An anthropometric survey of Sri Lankan females aged 20-30 years was conducted. 645 females were selected for a pilot study representing 5 provinces in Sri Lanka. Eight major measurements of female lower body were taken following the ISO 8559:1998 standard. Principle Component Analysis was used to reduce the variables in to 2 major components and identify key variables. Two- stage Cluster analysis; Hierarchical cluster analysis and K-means algorithm, was used to find the body types and segment the data into more homogeneous clusters. Five different body types were identified and under each body type, many sizes were built up based on three key measurements. Sizing system for Cluster 1; Body type D, was shown with the percentage of population for each size which will be useful for manufacturers and retailers to plan production and inventory.

Keywords: Anthropometric data, Data mining techniques, size chart, two-stage cluster analysis

1. INTRODUCTION

The greatest challenge that apparel companies face today is providing quality fit to its target consumers. Reasons for poor fitting garments are the lack of up to date anthropometric data and non-availability of data on issues pertaining to fit of garments.[1] Since the ready-to-wear clothing industry uses mass production systems which follow certain standards and specifications, each country should have its own standard sizing systems for manufactures to follow and fit in with the figure types of the local population [2] .

According to Pechoux and Ghosh there are several factors that affect the body measurements, such as individual variability, gender variability, race variability, generational variability, changing life styles, racial mixes, and demographics. Due to these reasons human body measurements and body shapes change dramatically even within a region.[3] According to Ashdown, it becomes necessary for every country , and even regions within countries, to establish their own sizing systems based on the target population to provide a good estimation of fit and size of ready- to – wear clothing.[4]

1.1 Problem Identification

Since the unavailability of up-to-date anthropometric data and hence the size chart for Sri Lankan females, variety of problems related to garment size and fit have arisen. The size charts that are used today for Sri Lankan females' clothing are based on UK size charts which do not meet the required size and fit expectations.

" Comparisons of body sizes between developing countries (including Sri Lanka) with those of developed countries revealed wide variations" [5]. Asian women are shorter, and lighter than European women, but have a higher waist-to-hip ratio(WHR)[6]. Hence, according to the above facts, it is clear that the Sri Lankan female consumers need their own size chart which is based on their up-to-date anthropometric data .

1.2 Objectives

Objectives of this ongoing research are to determine the relationships which exist among female lower body measurements, to classify female lower body types and to develop a sizing system for female pants. The article includes the results of a pilot study done with a sample of 645 females.

2. REVIEW ON EXISTING SIZE CHARTS

When the garments production system changes from customized production to mass production leading to cost reduction, the necessity of pre-defined size charts arises.

According to Ashdown, in 1958, the USA developed the CS 215-58 standard sizing system based on the manufacturers experience using anthropometric data of 10,042 women. In 1970, the PS 42-70 standard size chart of the USA was developed additionally incorporating military anthropometric data. American Society of Testing and Material (ASTM) developed a new standard ;D5585-94 which was cross –checked with US Army and Navy anthropometric databases.[4]

Tryfos proposed an "Integer Programming" approach to get optimal sizes formulating "minimum aggregate discomfort or loss" for any number of control measurements which calculate the distance between the person's measurements and allocated size. The probability of the sale of a garment from one category to a person falling in another category is modeled as a simple function of fit. The goal is then to choose the sizes in order to optimize sales of the garments.[7]

In another study, McCulloch, introduced a novel approach for the construction of apparel sizing systems using "Nonlinear optimization techniques" to derive the sizing system. The core of the approach is to fix the number of sizes and the non-accommodation rate and optimize the quality of the fit.[8]

Guptha and Gangadhar proposed a statistical approach to develop a size chart which is the first size chart for Indian women, getting anthropometric data from 2,095 Indian women. Multiple correlation analysis and principle components analysis were used to identify key dimensions and classify body measurements into 5 principle components. The size chart was validated using "aggregate loss of fit" factor.[9]

Chung, Lin, & Wang developed a size chart for Taiwanese elementary and high school students using factor analysis, which is to examine the inter-relationships among variables and a two–stage cluster analysis, which combines hierarchical and non- hierarchical methods to classify figure types.[10] Lin used a decision tree method to develop a standard sizing system for army soldiers' uniforms.[2]

In another study, Hsu proposed a data mining approach which include two- stage clustering, that is Ward's minimum variance method combined with K-means algorithm to create a size chart for Taiwanese females.[11] Mpampa et.al. used basic statistical analysis to provide a sizing system for mass customization of garments.[12]

3. METHODOLOGY

A sample of 645 females, aged between 20 – 30 years , were selected. Eight major dimensions of a female's lower body were measured by using a retractable metal tape measure. All anthropometric measurements followed the ISO 8559:1989 standard. SPSS version 16.0 was used to analyze the data.

February 2013. Vol. 1, No.1 ISSN 2307-227X
International Journal of Research In Social Sciences

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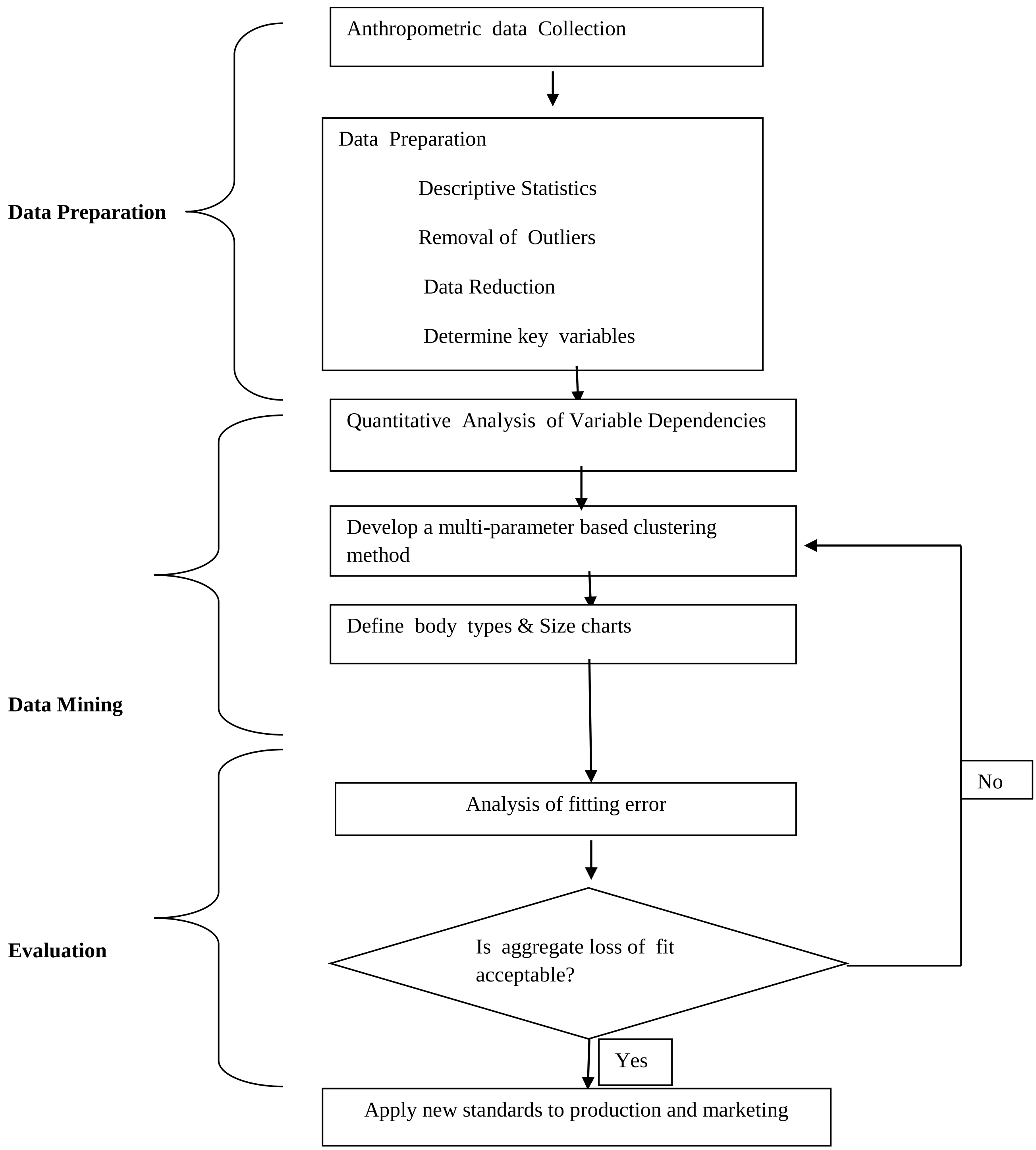
Data Mining Process



3.1 Data Preparation

Based on descriptive analysis, the outliers which are out of " mean ±3σ" were removed representing 99.9% of the sample. First the normality test was carried out on the data. Kolmogorov-Smirnov test significance > 0.05 for all variables and normal Q-Q plot showed that all variables were normally distributed. Pearson Product –Moment Correlation showed that all girth and length variables have good correlation among themselves and poor correlation in between girth and length variables. This shows that growth in length and girth measurements will not follow linearity and hence this should be addressed in size chart developments.

3.2 Principle Component Analysis

This was used to reduce the number of variables and identify key variables. Number of components were decided using Eigen value > 1 criterion and Scree plot . Variables with the highest loading in each component in Varimax Rotated matrix were chosen for the selection for key variables.

3.3 Two-Stage Cluster Analysis

Two– stage cluster analysis, Ward's minimum variance method combining with K-means algorithm was used to uncover the patterns and rules within the anthropometric data and to cluster the data. The initial clustering was done with the use of Ward's minimum variance method and final clusters by K-means algorithm.

4. RESULTS AND DISCUSSION

Principle Component Analysis was used to identify the key dimensions. Kaiser-Meyer-Olkin measure of sampling adequacy is 0.726 and Bartlett's test is $p < 0.01$. Since KMO > 0.5 and Bartlett test Sig < 0.05 all variables are suitable for factor analysis. Two components, Girth component and Length component are selected based on Eigen value > 1 criterion and based on scree plot.

Two Key variables were selected from each component based on higher factor loadings in each component; Waist for Girth component and Inseam for length component. Table 1 illustrates the rotated component matrix that shows 2 major components.

Rotated Component Matrix[a]

	Component	
	1	2
WAIST	.908	-.043
HIP	.884	.226
THIGH	.823	.215
KNEE	.812	.097
INSEAM	.021	.916
OUTSEAM	.236	.900

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Table 1. Rotated Component matrix

Two – stage cluster analysis was used to segment the body types based on girth measurements. Hierarchical clustering was used as first step to find the number of clusters. Dendogram shows that 3-7 clusters can be achieved. However, more body types will result a very complex sizing system. Hence, 4- 5 body types (clusters) will be more practical.(Figure 1).

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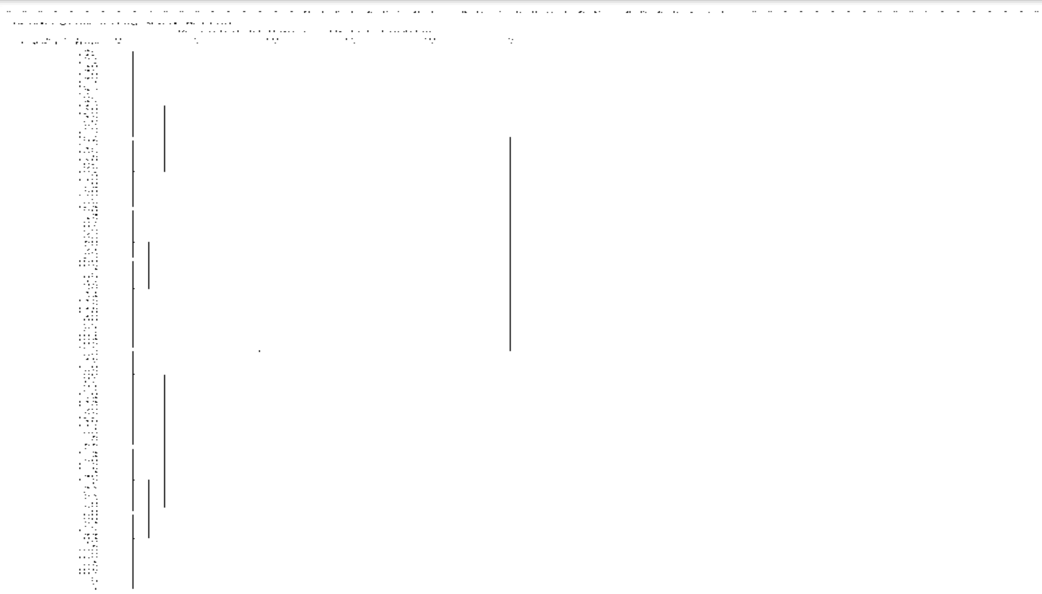

Figure 1. Girth variables Grouping- Hierarchical Clustering

K-means algorithm was used to segment the data based on number of clusters guessed above. Resulted 5 clusters' size interval is more practical than 4 clusters.(Table 2)

Final Cluster Centers

	Cluster				
	1	2	3	4	5
waist	77.1	70.3	66.0	60.2	86.1
hip	98.6	93.4	86.4	77.7	103.6
thigh	59.1	57.2	51.5	48.0	62.5
knee	37.0	36.7	34.4	31.6	39.1
ankle	22.8	24.1	22.2	21.7	24.3

Table 2. Girth Variables Clustering – K- means algorithm

Figure 2 shows the line plot of the means of girth variables for each cluster. It clearly shows that based on girth variables, five different body types can be achieved. Table 3 gives five different body types and number of cases for each cluster.

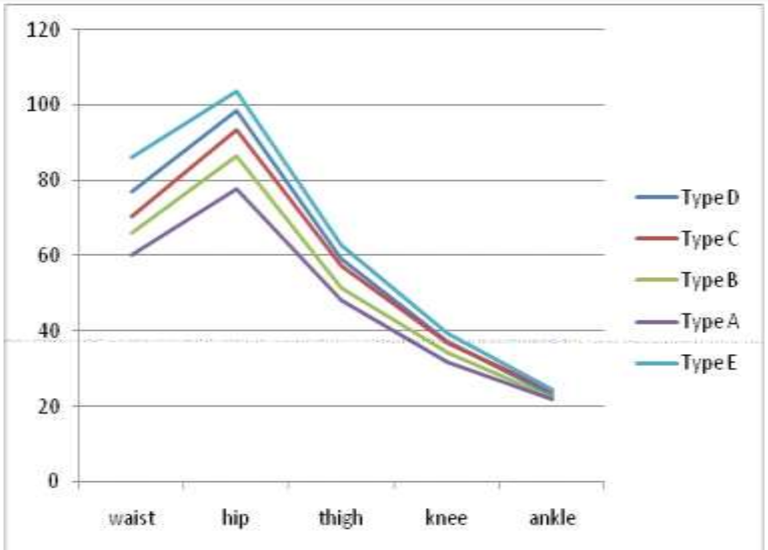

Figure 2 .The line plot of the means of anthropometric variables for each Body Type

	Cluster 4	Cluster 3	Cluster 2	Cluster 1	Cluster 5
Numbers	92	197	132	134	90
Girth variables	Extra Small	Small	Medium	Large	Extra Large
Body type	A	B	C	D	E

Table 3. Body types based on Girth variables

Inseam is the key variable in Height component. Hence, inseam was grouped using two-stage clustering and 4 major inseam groups have been found. Figure 3 shows the dendogram of Hierarchical clustering and Table 4 gives resulted clusters in K-means algorithm.

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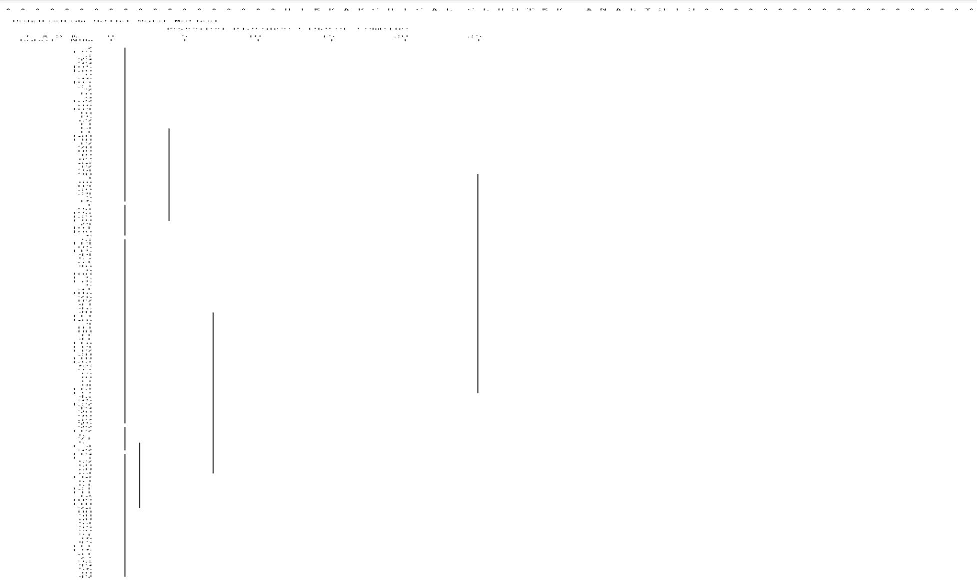

Figure 3. Height Categorization-Hierarchical Clustering

Final Cluster Centers

	Cluster			
	1	2	3	4
inseam	64.4	70.8	76.5	81.5

Table 4. Height Categorization-K-means Clustering

Using these two –stage clustering, height can be divided into 4 main clusters maintaining 6cm size interval. (Table 5)

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Inseam	64 cm (61 – 67cm)	70 cm (67 – 73 cm)	76 cm (73- 79 cm)	82 cm (79 – 85cm)

Table 5. Inseam segmentation based on Two-stage Clustering

Sizing system for Cluster 1- Body Type D is shown in Table 6 below. 16 sizes are available for body type D and percentage of the population for each waist measurement is given. This percentage value is useful for manufacturers for their production planning based on the target market.

	← Inseam →			
	(67-73) 70	(73- 79) 76	(79- 85) 82	
Waist	← Hip →			percentage
74 (72-76)	*	96	96	6.9%
	100	100	100	28.6
	*	104	104	6.9%
78 (76- 80)	92	*	*	3.4%
	96	96	*	10.1%
	100	100	100	30.6%
	*	104	*	3.4%
82 (80-84)	*	96	96	10.1%
percentage	20.6%	55.1%	24.1%	

Table 6. Cluster 1- Body Type D- Sizing system

5. CONCLUSION

This study reveals that within the age group of 20 – 30 years of Sri Lankan females, five distinct body types can be identified. For female pants, waist, hip and inseam measurements are identified as key measurements which affects the fit of the pant. Prevailing pre-defined size charts used in Ready-To-Wear clothing industry leads to customer dissatisfaction due to poor fitting. Those size charts do not represent the majority of population with different body types. Hence, this new approach to create a sizing system for Sri Lankan Females' pants sizing using up to date anthropometric data will be useful for manufacturers as well as retailers to plan their production and inventories.

This ongoing research is limited to females' lower body measurements only . The study can be extended to create a size chart for female upper body as well by getting anthropometric data from larger sample covering all regions of Sri Lanka.

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