World Applied Sciences Journal 13 (8): 1807-1813, 2011
ISSN 1818-4952


# Development of Sizing Systems for Iranian High-School Male Students

[1]M.M. Majidi, [2]M.B. Moghadam, [2]G. Nourani and [2]R. Pourtaheri

[1]Department of Textile, Islamic Azad University, Yazd, Iran
[2]Department of Statistics, Allameh Tabataba'i University, Beheshty Ave., Ghasir St. Tehran, Iran

**Abstract:** This study aims to develop sizing systems for Iranian high-school students. A total of 380 male students' anthropometric data covering their ages from 15 to 17 years were used in this study. Certain advantages may be observed when size charts are developed, using a cluster-based data mining approach. These include being able to cover a higher percentage of the population, using fewer sizes and providing manufactures with reference points to promote products, according to body type and distribution. Since an anthropometric database must be repeatedly updated, size charts may also be continuously renewed via application of the proposed data mining cycle. These newly developed size charts will remain continually beneficial for both production planning and reducing inventory costs, while facilitating the production of garments.

**Key words:** Anthropometric data · Size charts · Student clothing

## INTRODUCTION

Standard size charts can correctly predict numbers of items and ratio of sizes to be produced, resulting in accurate inventory control and production planning. Due to differences in the body types of people in different countries, each country must have its own standard size charts for manufactures and consumers to follow. Under traditional production procedures, Iran has not yet developed its own size charts. Most garments are manufactured using revised overseas sizing data; as a result, garment sizes differ from factory to factory, with no consistent standards. Apart from the fact that most overseas sizing data do not correspond to Iranian body types, domestic manufactures have been inconsistent in their size classification, so consumers must choose suitable clothes by trial and error, resulting in enormous inconvenience, not to mention wasted time and money. Thus, the development of standard size charts for garment manufactures and consumers is long overdue.

Emanuel *et al.* [1] recommended the use of the difference in figure types as the classification of ready-to-wears and developed a set of procedures to formulate standard sizes for all figure types. In early times, the classification of figure types was based on body weight and stature. Later on, anthropometric dimensions were applied for classification. Some optimization methods have been proposed to generate a better fit sizing system, such as an integer programming approach [2] and a nonlinear programming approach [3].

**Cluster Analysis:** One of the most important data mining methods is cluster analysis, which is a data reduction technique for huge amounts of data, used to solve classification problems. Cluster analysis seeks to minimize within-group variances and maximize between-group variances, including both hierarchical and non-hierarchical methods.

Agglomerative hierarchical algorithms are commonly used with hierarchical methods, to calculate the distance between observations; the two nearest observations are combined into a cluster. This procedure continues until all observations are appointed in one cluster. Ward's minimum variance is an important agglomerative hierarchical algorithm method, as the smallest increase in total within-group variance has the highest priority of combination. On the other hand, the most widely used method for non-hierarchical algorithms is the K-means method. In this case, the initial clusters and the number of clusters are randomly chosen.

### The Data Mining Process

**Data Preparation and Analysis for Data Mining:** Anthropometric data of 380 Iranian high-school male students from Yazd province were obtained. The age of the students ranged from 15 to 17 years. Before mining the data, it had to be checked and processed, with all abnormal or missing data being separated out. As a result, 56 out of the 380 samples of students which had missing or abnormal data, were deleted; this left a total of 324 valid samples.

**Corresponding Author:** M.M. Majidi, Department of Textile, Islamic Azad University, Yazd, Iran.

Table 1: Factor Analysis Results

Component Matrix[a]

| | Component | |
|---|---|---|
| | 1 | 2 |
| Bust Girth | .905 | -.097 |
| Waist Girth | .876 | -.098 |
| Chest Girth | .903 | -.122 |
| Body Height | .377 | .628 |
| Hip Girth | .732 | -.018 |
| Arm Girth | .615 | -.239 |
| Neck Girth | .603 | -.120 |
| Arm Length | .296 | .660 |
| Waist to foot length | .112 | .752 |

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

Not all of the anthropometric variables were suitable for use in developing the size chart. Therefore, in coordination with the judgment of domain experts, as well as international standards, this study identified 9 anthropometric variables. These 9 anthropometric variables included 3 linear measurements and 6 girth measurements.

To use all of the 9 anthropometric variables, as a basis for developing size charts, would make things too complicated; therefore, the more important factors were identified first.

Factor analysis is a multivariate statistical analysis method that examine the inter-relationships among a large number of variables and extracts the underlying factors.

Based on the results of Bartlett's test which is less than 0.05 ($p<0.01$), these 9 dimensions were all suitable for factor analysis. Anthropometric variables were found to be clustered within Factors 1 and 2, as shown in Table 1. The major anthropometric variables concentrated within Factor 1 were bust girth, waist girth, chest girth, hip girth, arm girth and neck girth; those in Factor included body height, arm length and waist to foot length. It can be seen that all the anthropometric variables related to girth were concentrated together, as were those related to height. Therefore, two important factors were determined, with Factor 1 being named the girth factor and Factor 2, the height factor.

**Data Mining by Cluster Analysis:** Through factor analysis, the girth factor and the height factor were found to be the most important factors in garment making. Subsequently, data mining was undertaken, using a two-stage cluster analysis, which included both hierarchical and non-hierarchical clustering. Ward's minimum variance method was integrated with the K-means method, to mine the patterns of anthropometric data, for developing garment-size charts.

**The Ward or Minimum Variance Algorithm:** Here, the distance between two clusters $C_i$ and $C_j$ , $d_{ij}^{/}$ , is defined as a weighted version of the squared Euclidean distance of their mean vectors, that is,

$$d_{ij}' = \frac{n_i n_j}{n_i + n_j} d_{ij}$$

where $d_{ij} = \left\| m_i - m_j \right\|^2$ .

Cluster analysis involves two fundamentals: the measure of similarities within observations and the clustering algorithms that are selected to produce a rule of classification [4].

**Similarity Measure:** The distance between two observation represents the closeness of this pair of observations and can be used as a measure of similarity or dissimilarity between observations.

The Euclidean distance is known as the major classification criterion for clustering sample points. So we use the squared Euclidean distance as the distance between members 9. We have normalized the original parameters of the samples before defining the distance between groups.

$$D^2 = \sum_{i=1}^{k} (x_{il} - x_{jl})^2$$

**Hierarchical AgglomerativeCluster Analysis:** Allmembersare gradually merged in accordance withtheir similarities in Anthropometricvariables. The whole procedure can be drawn in to a clustering tree, whichmaybeviewedasadiagrammatic representation of the results of the clustering process. Hierarchical cluster analysis is based on the theories of multivariate statistical analysis [5].

From the results of the two-stage cluster analysis, three clusters were extracted. A tree diagram, shown in Figure 1, presents the results.

To gain a better insight in to the differences between the three clusters resulting from the two-stage cluster analysis, a line plot was drawn of the averages of the three clusters and the nine anthropometric variables, also discriminant analysis was used to determine average of each anthropometric variable for each cluster (Table 2). The three clusters bear marked differences, displaying a trend of cluster 3>cluster 2>cluster 1.

From the analysis of variance results, the height anthropometric variables did not have significant differences, as shown in Table 3. Therefore, according to the ISO/TR 10652, this study defined the body type based on girth variables. Fig. 2 illustrates the distribution of waist girth (x-axis) vs chest girth (y-axis) for all three clusters. The cluster with 159 samples was defined as *M* type. The cluster with 125 samples having smaller girth anthropometric variables was defined as *S* type. Similarity, *L* type with 40 samples was identified with larger girth anthropometric variables.

These three body types were produced by cluster analysis. Because chest girth, waist girth and body height are the most important anthropometric variables in garment manufacturing throughout the world, this study drew a distribution graph of all three body types, with waist girth and chest girth.

For the size interval, a smaller interval with more size groups can provide a better fit, but it may also increase the production and inventory cost. In general, the size interval between 4 and 6 cm for girth dimension seems to be adequate for a wide range of adult garments [6,7]. The size interval for body height was from 5 to 10 cm in current sizing standards (e.g. ISO/TR 10652). After coordinating this with the experts' judgment, as well as following the principle of "covering as many people as possible with the least number of sizes", this study set 8 sizes (72cm, 77cm, 82cm, 87cm, 92cm, 97cm, 102cm and 107cm) as representative chest girth sizes and set 7 sizes (74cm, 79cm, 84cm, 89cm, 94cm, 99cm and 104cm) as representative waist girth sizes and set 5 sizes (155cm, 163cm, 171cm, 179cm and 187cm) as representative body height sizes, for three body types.

Regarding the data coverage, some samples were not included in determining the size charts for the three body types, because they are far from the scale for the size charts. The sample was eliminated, as it was felt to be unwise to add another group of sizes for such measurements, as it would increase costs. Table 4 shows the body size distribution for all three body types. Out of the 324 samples, only 12 samples were excluded. Therefore, the coverage of the proposed " waist girth and chest girth" size charts was 96.88%. When the three sizing variables, waist girth, chest girth and body height, were taken into account, the total coverage of population was 85.44%.

Size label is an important interface for customers to quickly locate the right garment size for further consideration. This study used size labels as follow: For example: MR(163) 92-84 indicates that this size is suitable for the medium figure type with "regular" body height between 155 and 163cm and waist girth between 92 and 97cm and chest girth between 84 and 89cm. Table 5 presents the summarized results for the sizing systems of high-school students. As we can see, the coverage of the sizing system was over 85%. The number of sizing group was 57.

Table 6 gives an example of size charts for body type L. Manufacturers can make different types of garments with various allowances, by referencing these size charts.

******* HIERAARCHICAL CLUSSTER ANALUYSIS *******

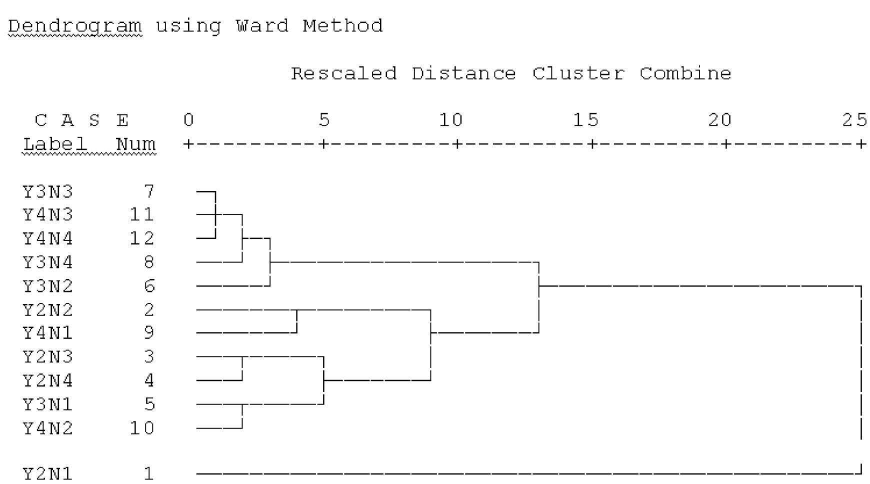


Fig 1: Hierarchical Cluster Analysis

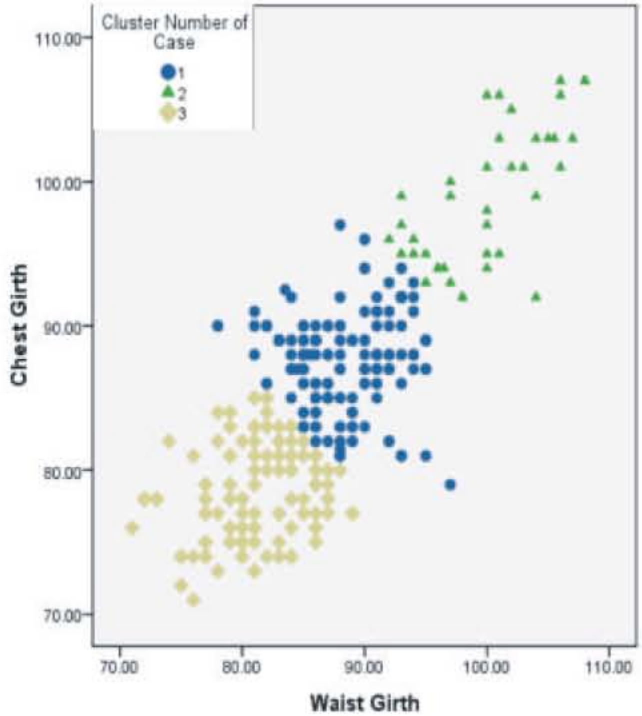


**Fig 2: The Scatter Plot of Chest vs Waist Girth for the Three Figure Types**

Table 2: Discriminant Analysis

| | Group Statistics | | | | |
|---|---|---|---|---|---|
| | | | | Valid N (list wise) | |
| | Factors | Mean | Std. Deviation | Un weighted | Weighted |
| 1 | Bust Girth | 92.4480 | .92551 | 5 | 5.000 |
| | Waist Girth | 85.9200 | 1.00082 | 5 | 5.000 |
| | Chest Girth | 84.5800 | .84794 | 5 | 5.000 |
| | Body Height | 1.7212E2 | 1.40030 | 5 | 5.000 |
| | Hip Girth | 49.0900 | 1.10673 | 5 | 5.000 |
| | Arm Girth | 26.0920 | .53401 | 5 | 5.000 |
| | Neck Girth | 33.7560 | .29913 | 5 | 5.000 |
| | Arm Length | 61.7380 | 1.00991 | 5 | 5.000 |
| | Waist to foot length | 99.7760 | 1.26769 | 5 | 5.000 |
| 2 | Bust Girth | 94.7240 | 1.94952 | 5 | 5.000 |
| | Waist Girth | 88.5160 | 1.83443 | 5 | 5.000 |
| | Chest Girth | 85.8000 | 1.87647 | 5 | 5.000 |
| | Body Height | 1.7094E2 | 2.24577 | 5 | 5.000 |
| | Hip Girth | 49.5800 | 2.15195 | 5 | 5.000 |
| | Arm Girth | 28.9440 | 2.52937 | 5 | 5.000 |
| | Neck Girth | 34.5580 | .52628 | 5 | 5.000 |
| | Arm Length | 63.4100 | .69105 | 5 | 5.000 |
| | Waist to foot length | 1.0093E2 | 2.12551 | 5 | 5.000 |
| 3 | Bust Girth | 98.2900 | 2.77186 | 2 | 2.000 |
| | Waist Girth | 90.6900 | .08485 | 2 | 2.000 |
| | Chest Girth | 89.4300 | 3.98808 | 2 | 2.000 |
| | Body Height | 1.7348E2 | 5.51543 | 2 | 2.000 |
| | Hip Girth | 54.5250 | 4.20729 | 2 | 2.000 |
| | Arm Girth | 27.5000 | .00000 | 2 | 2.000 |
| | Neck Girth | 34.8050 | .98288 | 2 | 2.000 |
| | Arm Length | 63.5250 | 2.79307 | 2 | 2.000 |
| | Waist to foot length | 1.0218E2 | 2.92742 | 2 | 2.000 |

Table 2: Continued

| | Group Statistics | | | Valid N (list wise) | |
|---|---|---|---|---|---|
| | Factors | Mean | Std. Deviation | Un weighted | Weighted |
| Total | Bust Girth | 94.3700 | 2.63097 | 12 | 12.000 |
| | Waist Girth | 87.7967 | 2.22412 | 12 | 12.000 |
| | Chest Girth | 85.8967 | 2.45966 | 12 | 12.000 |
| | Body Height | 1.7186E2 | 2.49066 | 12 | 12.000 |
| | Hip Girth | 50.2000 | 2.80613 | 12 | 12.000 |
| | Arm Girth | 27.5150 | 2.06853 | 12 | 12.000 |
| | Neck Girth | 34.2650 | .65642 | 12 | 12.000 |
| | Arm Length | 62.7325 | 1.42342 | 12 | 12.000 |
| | Waist to foot length | 1.0066E2 | 1.95287 | 12 | 12.000 |

Table 3: ANOVA Table

Tests of Equality of Group Means

| Factors | Wilks' Lambda | F | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| Bust Girth | .346 | 8.522 | 2 | 9 | .008 |
| Waist Girth | .321 | 9.513 | 2 | 9 | .006 |
| Chest Girth | .494 | 4.612 | 2 | 9 | .042 |
| Body Height | .856 | .755 | 2 | 9 | .498 |
| Hip Girth | .475 | 4.978 | 2 | 9 | .035 |
| Arm Girth | .568 | 3.423 | 2 | 9 | .078 |
| Neck Girth | .513 | 4.271 | 2 | 9 | .050 |
| Arm Length | .619 | 2.772 | 2 | 9 | .115 |
| Waist to foot length | .788 | 1.209 | 2 | 9 | .343 |

Table 4: Body Size Distribution with Three Body Types

| | | Body height | | | |
|---|---|---|---|---|---|
| | | 155(H) | 163,171(R) | 179,187(A) | |
| Body types | Waist girth | Chest girth | | | Percentage (%) |
| | 72 | - | 74 , 74 | -,- | 1.45 |
| | | - | 79 , 79 | -,- | 1.45 |
| S | 77 | 74 | 74 , - | -,- | 4.38 |
| | | - | 79,79 | 79,- | 5.83 |
| | | - | -,84 | 84,- | 3.21 |
| | | - | -,89 | -, 89 | 1.45 |
| | 82 | - | -,74 | -,- | 2.63 |
| | | 79 | -,79 | 79,79 | 7.01 |
| | | - | 84,84 | 84,- | 9.34 |
| | | 89 | 89,89 | 89,- | 7.30 |
| | | - | -, 94 | -,- | 0.58 |
| | 87 | - | -,- | -,79 | 3.21 |
| | | - | 84,84 | 84,84 | 8.47 |
| | | - | 89,89 | 89,89 | 7.00 |
| | | - | -,94 | -,- | 1.17 |
| | | - | -,99 | -,- | 0.87 |
| M | 92 | - | 84,- | 84,- | 1.75 |
| | | 89 | -, 89 | 89,89 | 4.37 |
| | | - | -,- | 94,94 | 5.26 |
| | | - | -,99 | -,- | 0.58 |
| | | - | -,- | 94,94 | 1.75 |
| - | 97 | - | -,99 | -,99 | 1.45 |
| | | - | -,104 | -,- | 0.87 |
| L | 102 | - | -,99 | -,- | 0.87 |
| | | - | 104,104 | -,104 | 2.32 |
| | 107 | - | -,104 | 104,- | 0.87 |

Table 5: The Summarized Results of the Sizing System

| Gender | Age (years) | Cover rate (%) | Size interval (cm) | Num. of sizes | Aggregate loss (cm) |
|---|---|---|---|---|---|
| Male | 15-17 | 85.44 | 5 | 57 | 3.93 |

Table 6: Example of a size chart for student's garment-L body type

| Control dimensions | | | | | | |
|---|---|---|---|---|---|---|
| Waist girth | 102 | 102 | 102 | 102 | 107 | 107 |
| Chest girth | 99 | 104 | 104 | 104 | 104 | 104 |
| Body height | 171 | 163 | 171 | 187 | 171 | 179 |
| Secondary dimensions | | | | | | |
| Bust girth | 108 | 58 | 33 | 37 | 66 | 103 |
| Hip girth | 114 | 54 | 29 | 36 | 66 | 103 |
| Arm girth | 113 | 55 | 34 | 40 | 63 | 98 |
| Neck girth | 110 | 63 | 36 | 38 | 69 | 108 |
| Arm length | 112 | 63 | 32 | 38 | 65 | 96 |
| Waist to foot length | 110 | 57 | 33 | 37 | 62 | 105 |
| Percentage (%) | 1.46 | 0.29 | 0.58 | 0.58 | 0.29 | 0.58 |

Validation the Sizing Systems: Regarding the performance in good fit, the index of aggregate loss was used for evaluating the developed sizing systems. The aggregate loss was defined as an average Euclidean distance from the actual body dimensions of the assigned size. A good sizing system should have a low aggregate loss [8, 9]. Gupta and Gangadhar [10] proposed the criterion of a good fit by suggesting the benchmark value of $(n)^{1/2}$ inch, where n is the number of body dimensions used in the size chart. Based on the results of factor analysis and the critical dimensions in clothing design, we used waist girth, chest girth and body height from the size charts to calculate the aggregate loss for the garment. Table 5 presents the obtained aggregate loss of the sizing system in this study.

## DISCUSSION

An effective sizing system should satisfy three main criteria, i.e. fewer sizes, higher coverage of the population and better fit. Since these three criteria are in compromising conflict, it is almost impossible to have a perfect sizing system [3].

In fit issues, the aggregate loss was used to validate the sizing system. For the results displayed in Table 5 the aggregate loss value were lower than the benchmark value, 4.39cm ($3^{1/2}$ *2.54cm). Thus, the performance in good fit for the developed sizing system is satisfactory.

Developing an effective sizing system is not only a statistical problem but also a marketing one [11]. The control and reference dimensions provided in tables 4 and 6 can be used to design and produce school uniforms. Moreover, the percentage distribution is very important for the manufactures to estimate the customers' demands and make effective production planning about the quantity for different size groups. The size charts in here only provide the anthropometric dimensions of each size. Some additional steps are necessary to translate the anthropometric dimensions to garment dimensions for effective garment design and production.

## CONCLUSION

This study proposed a two-stage cluster analysis approach to develop sizing system for the high-school students. This well-structured sizing system has the advantages of a high coverage rate(over 85%) with few size groups (57) and a good fit performance. The control and reference dimensions in the size chart can provide very useful information for the design and making of clothing for school students. Also, the percentage distribution information of each of the size groups can help the garment manufacturers to better understand the customer's body size and shape characteristics and to make effective production planning.

## REFERENCES

1. Emanuel, I., M. Alexander, E Churchill and B. Truett, 1959. A height-weight sizing system for flight clothing. In: Wright Air development Center. WADC Technical Report. Wright-Patterson Air Force Base, Ohio., pp: 56-365.
2. Tryfos, P., 1986. An integer programming approach to the apparel sizing problem. J. the Operational Research Society. 37(10): 1001-1006.

3. McCulloch, C.E., B. Paal and S.A. Ashdown, 1998. An optimal approach to apparel sizing. Journal of the Operational Research Society, 49: 492-499.
4. Sami, A., I. Hashim, S. Abbasbandy and M.S. Noorani 2011. Direct Solution of Singular Higher-Order BVPs by the Homotopy Analysis Method and its Modification. World Applied Sciences J., 12(6): 884-889.
6. Eberle, H., R. Kilgus, 1996. Clothing Technology: From Fiber to Fashion, English ed. Europa-Lehrmittel, Germany.
7. Alaeiyan, M., S. Mohammadian and H. Rastegari, 2011. The Dominating Polynomial of LE(Q3) and GLE(Q3), World Applied Sciences J., 13(2): 300-303.
8. Ashdown, S.P., 1998. An Investigation of the Structure of Sizing Systems: a Comparison of Three Multidimensional Optimized Sizing Systems Generated from Anthropometric Data with the ASTM Standard D5585-94. International Journal of Clothing Science and Technol., 10(5): 324-341.
9. Elabbasy E.M. and E.M. Elsayed 2011. Global Attractivity and Periodic Nature of a Difference Equation. World Applied Sciences J., 12(1): 39-49.
10. Gupta, D. and B.R. Gangadhar, 2004. A statistical model for developing body size charts for garments. International J. Clothing Science and Technol., 16(5): 458-469.
11. Beazley, A., 1998. Size and Fit: Formulation of Body Measurement Tables and Sizing Systems-part 2. J. Fashion Marketing and Manage., 2(3):260-284.