A method to reduce the number of sizes in apparel industry

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Abstract. The aim of this research is to define a methodology for reducing the number of garments sizes after building a sizing system for a given population. Thus, we introduce the process of development of sizing system in accordance with the literature. Despite the importance of developing appropriate sizing systems in the textile industry, there has been very little research focused on the task of reducing the huge number of sizes generated. The intention to keep the number of garment sizes to a minimum is to reduce confusion among customers, in addition to the logistics costs associated with maintaining a large number of sizes. Therefore, we propose a method to reduce the number of sizes by removing the sizes that cover fewer people. The challenge is to find the most convenient order of removal, how to maintain the linearity of the sizing system as well as to accommodate a larger number of people in the population.

1. Introduction

A sizing system can be defined as a table of numbers that represents the value of key measurements used to classify variety bodies in the target population into homogenous subgroups [1]. People of the same subgroup have the same body shape characteristics, and share the same garment size.

The main aim of a body sizing system is to provide the best fit for most customers with the optimum number of sizes that benefit both consumers and manufacturers. Since too many sizes to choose from will lead to confusion in finding the right size and economically unfeasible, in contrast too few sizes will yield dissatisfaction because of loosing of fit. Therefore, the most important criteria for evaluating sizing system are the percentage of population covered, number of sizes proposed and goodness of fit [2]. Some research has been done and improved throughout the years to find a compromise between these conflict criteria. Consequently, different methods were used: statistical techniques such as principal component analysis (PCA) and factor analysis [1,3]; data mining techniques such as cluster and decision tree analysis[2,4]; and artificial intelligence techniques like self-organization methods (SOM)[5]. Some of these techniques are briefly outlined in the following paragraph to highlight the range of methods available for the development of a sizing system.

Salusso et al. [6] pointed out that a well-designed sizing system should be based on a classification of data covering the largest part of the population with a minimum number of sizes. In this perspective, some researchers start with a segmentation of the population into groups. Afterwards, they establish a sizing system.

Gupta [7] propose a simple statistical approach for developing a sizing system from anthropometric data for Indian women. Principal component analysis was carried out to identify the key body measurements: bust girth for the upper body and hip girth for the lower body were identified as the critical dimensions affecting garment fit. The population was divided into three height categories were
determined based on the standard deviation values of the height of the subjects and six bust categories based on the bust to waist girth ratio. Validation of sizing system was done by calculating the aggregate loss of fit, which means determining the fit of clothing by measuring the distance between actual body measurement and assigned sizes introduced by McCulloch et al. [8]. Euclidean distance is one fundamental and the most popular way used to determine this distance. The aggregate loss should be as low as possible for conformance to better fit. According to him, an efficient and effective sizing system must satisfy the following criteria:

- The sizing system must be in accordance with body measurements to ensure the best fit.
- The coverage of the target population should be at the maximum.
- The number of sizes proposed should be at a minimum.

Doustaneh et al. [5] use a two-stage self-organizing maps to generate a sizing system. They start by using SOM on the height attribute to generate three sizes, and then for each size, they use second SOM on the bust girth, also with three sizes.

Chung and et al. [3] established systems for Taiwanese by performing a two-stage cluster analysis. The number of sizing groups for all the developed sizing systems was between 20 and 36. The same clustering method was used for girls aged 13–20 years in Croatia[9]. As a result, three body types were obtained named T1, T2, T3 and 56 sizes for a girl’s lower body with a coverage rate of 77.7% were determined. Following the practice as adopted by Petrova and Zakaria [1,10] the size categories which cover less than 2% of the subjects in the class has been excluded from the sizing system as an attempt to reduce the number of sizes. The problem of this method resides in finding many sizes with less than 2% coverage rate and if the size to delete is in the center of the sizing system, it will lead a non-linear system (holes in system). This has the disadvantage of difficult labelling and size grading.

A variety of methods have been experimented to develop effective sizing system. However, research on reducing the number of sizes is lacking. Hence, this paper proposes a neighbor sum matrix method to delete the size with minimum persons inside.

2. Methodology

The process of sizing system development has been the subject of much work exposed in the literature [1,11]. The general principal is divided into three steps:

i) Sizing system development: define key measurements or control dimensions that are required to be measured on the person intended to be fitted. These are usually body girth (bust, waist, hip, neck) or height measurements according to ISO 8559-2:2017 [12-14]. This standard specifies primary and secondary dimensions for specified types of garments to be used in combination with ISO 8559 1 (anthropometric definitions for body measurement). Deciding the size range and size intervals for each dimension. For example, if the size ranges of height for a sample group is 145–185cm that makes a range of 40 cm. The size interval is set at 8 cm, thus, the number of sizes is estimated to be five sizes. Therefore, the development of a good sizing system depends heavily on the size range and size intervals.

ii) Sizing system validation: validate the system by calculating the coverage rate, the aggregate loss, and the number of sizes. A size system with a coverage rate between 65% and 80% is considered satisfactory by Petrova [10]. The aggregate loss represents the distance between the actual measurement of the human body and the assigned sizes.

iii) Sizing system designation: labelling the system. Size labelling can be numeric, alphabetical or graphic. One of the methods is the use of pictograms introduced in standard NF EN 13402-3 with key measurements in cm.

Once the sizing system is developed, the number of sizes founded is extensive. The idea of this work is to reduce the number of sizes one-by-one and to recalculate the aggregate loss and the coverage rate each time. The question was which size should be deleted first and how to prevent the possibility of a gap in the sizing system.

Figure 1 shows the flowchart for illustrating the overall of our method which ensures that the sizes with fewer number of person inside and fewer person surrounded by it are removed in forward order. This method called Erosion technique. The advantage of this method is to keep the linearity of the
system. For this purpose, a matrix is constructed from a computation of the number of persons in each size (each person is assigned to the nearest size according to his measurements). The initial matrix is therefore a matrix representing in each element the number of person by size. The next step is to calculate for each element the sum of the numbers of people in each element from his neighbors. Then, it is necessary to sort all the elements in ascending order to find the element with the minimum number of surrounds and we save the index of this element in an array. We repeat the process until the condition of stop is reached: there are no more sizes to delete. Indeed the algorithm must take into account the update and it should not give back an already recorded index.

![Flowchart of the proposed method.](image)

The algorithm to calculate the sum of neighboring elements in matrix has been summarized in Error! Reference non valide pour un signet..
Input: m, n   //m: number of height sizes, n: number of bust sizes
M: Matrix of m*n reflecting the number of people at each size

Output T: table containing the index order of the sizes to be deleted

while number of sizes deleted < Total number of sizes do
    For each size i from M do
        \text{Neighbor}[i] = \text{calculate the sum of the neighbors for each size}
    \text{Fin}
    \text{NeighborS} = \text{sort(Neighbor)} // sorting the given matrix in increasing order
    \text{[Index, Value]} = \text{min(NeighborS)} // find the index of the size with minimum number of person size
    Save index in T;
    M[i] = 0 // reinitialize the size to remove
end

3. Results and discussion
A representative sample of 452 French women taken from the anthropometric survey conducted in 2006 by IFTH was used.

To illustrate the algorithm for reducing the number of sizing system for an upper body garment, the height and bust girth are taken as the control dimensions as mentioned in section 2, the population is first divided according to height and then further divided according to bust girth. After examining the range of the control dimensions, size interval for height is 8 cm and 6 cm for bust girth as seen in Figure 2 which depicts the scatter plot of sample size according to the control dimensions of height and bust girth. Overall, 49 sizes to accommodate the entire sample population with an aggregate loss for the assigned sizes equal to 2.82 cm. Hence, the algorithm to reduce the number of sizes was applied. Figure 3 indicates the outcome of the matrix of neighbors by showing the size number to be deleted first and so on. The colorbars display the current colormap and indicate the mapping of data values into the colormap.

\textbf{Figure 2}. Distribution graph of height versus bust girth for upper body.
\textbf{Figure 3}. Reducing the number of sizes step-by-step.
Figure 4 illustrate the distribution of the coverage rate of the population by the number of sizes. It is possible to see that the percentage has a tendency to increase as the number of sizes increases. From this distribution, the textile expert can decide how many sizes to keep according to the desired percentage of coverage he wants, for example if he wants to ensure that his system keeps 80% of the population he can delete 28 sizes.

![Coverage rate distribution](image1)

**Figure 4.** Coverage rate distribution of the population.

Figure 5 illustrates the distribution of the average Euclidean distances between morphological measurements and their closest sizes, by the number of closest sizes. It is possible to see that these distances tend to decrease as the number of sizes increase. This is the expected behavior as the more sizes there are, the bigger the probability that a customer finds a suitable size.

![Distribution of aggregate loss](image2)

**Figure 5.** Distribution of the aggregate loss by the number of sizes.

4. **Conclusion and future work**

A new method of reducing number of sizes was designed and then tested on the French data set. The method can also be used on any other anthropometric data sets and help in creating sizing systems with less number of sizes economically feasible for apparel industry. The method involves a process of selecting key measurements, size interval based on published standards. Once the sizing system is created, the algorithm for calculating neighbor matrix was applied. A very precise order of the sizes to be deleted was implemented.

In a future study, a combination of different size intervals could be applied and compared to see which combination works best. An additional aspect to study would be to determine the best way to apply the sizing system not on the whole population but on the groups representing the result of the clustering.

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