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Use of body shape information in clothing size selection

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USE OF BODY SHAPE INFORMATION IN CLOTHING SIZE SELECTION

Pierre Meunier
Defence and Civil Institute of Environmental Medicine
Toronto, Ontario

To investigate the role of body shape information on clothing size selection, a sample of 143 males were measured and sized using a computerized digital-image based measurement system. Clothing sizes were initially determined by the system using traditional criteria for the long sleeve shirt, jacket and trousers of a military dress uniform. The best-fitting size was determined by trial and error based on subjective feedback and expert judgement, provided by clothing and sizing technicians. Discriminant function analysis was used to determine sizing rules for each garment, based on different sets of anthropometric input variables. Comparisons were made between the prediction performances of discriminant functions derived from traditional variables and those of functions derived from 3D landmark coordinates. The results indicate that the use of three-dimensional landmark coordinates, as input to a discriminant function analysis, is superior to the use of circumference measurements in predicting clothing sizes. The use of these landmarks is thought to improve the classification of cases by allowing a better characterization of body shape.

INTRODUCTION

In spite of the wealth of traditional anthropometric information and its application to a large number of problems over the years, the fact remains that the type of information provided by traditional data is somewhat incomplete. Traditional anthropometric measurement methods provide lengths, breadths, heights and circumferences, but reveal very little about individual shape or posture, since the location of these measurements in 3D space is not known. New measurement technology is now available that can collect shape as well as size information. This additional information has the potential to improve various anthropometric applications, including clothing size selection.

Current methods of issuing clothing usually require the use of two or three key dimensions to determine a likely garment size for a given individual. Tests have shown that while these dimensions are good indicators of garment size, their prediction performance can be low. One of the reasons for this is that the small number of dimensions used can only provide a first order approximation of body shape and size, and this may be insufficient for certain difficult to fit garments. It is likely that to improve clothing size prediction performance, the predictors need to better capture the essence of body shape and size as it relates to a specific garment.

The aim of this study was to explore whether additional shape-related anthropometric information can be useful in predicting the best-fitting clothing size for a given individual.

METHOD

A total of 143 males participated in this fit testing study. Anthropometric size and shape information was collected using a computerized digital camera-based system with two Kodak DC120 digital cameras (1280 x 960 pixels). Front and side images, taken simultaneously on semi-nude subjects, were automatically processed to extract landmarks and anthropometric measurements. Traditional data, that is data collected using traditional definitions, were collected, as were the three-dimensional coordinates of their component landmarks. Figure 1 shows the position of some of the landmarks extracted by the measurement system.

The subjects were instructed to stand on the footprints located in the middle of the imaging platform and to adopt the prescribed posture, that is standing at ease, looking straight ahead with arms straight but slightly abducted. Anthropometric measurements, obtained from image processing, were used to determine the initial size of military dress uniform to try on. In this context, the dress uniform refers to the long sleeve shirt, the jacket, and the trousers. For males, the complete range of garment sizes included 40 sizes of shirt, 44 sizes of jackets, and 46 sizes of trousers. The subjects donned the selected clothing, and appraised the quality of the fit with the help of clothing and sizing technologists. Alternate sizes were supplied when necessary, until the best possible fit was obtained. The final choice of garment size was used in the analysis.

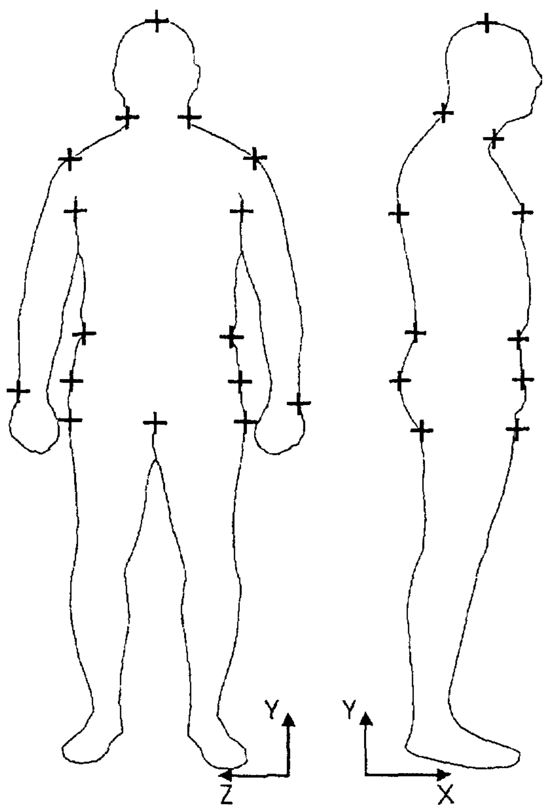


Figure 1. View of front and side landmarks.

The fit test results were analyzed using discriminant function analysis (Statsoft, 1999). Four sets of anthropometric input variables were used:

1) Conventional bivariate input. This was the baseline of the study (since the dress uniform sizing system is currently bivariately based). For example, neck circumference and sleeve length were used for shirt sizing.
2) 3D bivariate input. This dataset is composed of the x, y, z coordinates of the landmarks used to measure the two key variables of dataset 1) above. For instance, rather than using neck circumference as input for shirt sizing, the xyz coordinates of front, back, left and right neck landmarks would be used. Sleeve length was an exception to this rule as it was not broken down into its component 3D landmarks.
3) Conventional multivariate input. A larger set of traditional measurements was included than is usually the case. In all, 13 variables were used as input (chosen from a total of 38). These included lengths, breadths, depths, widths, and circumferences but not their 3D position.
4) 3D multivariate input. The xyz coordinates of all the landmarks shown in Figure 1 were used in this dataset.

Forward and backward stepwise analyses were performed to determine the variables to include in the multivariate cases. The variables used in the bivariate cases were, by design, predetermined. The discriminant functions were then used to classify the subjects into clothing categories.

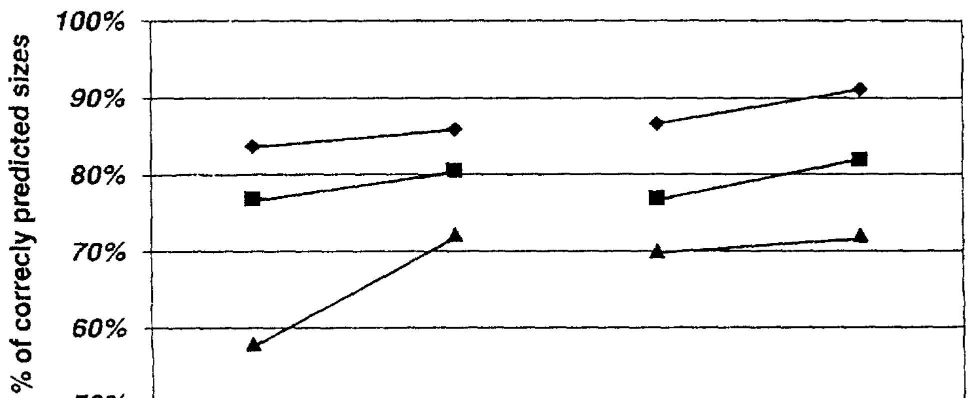
RESULTS

A list of the variables used in the discriminant functions for each of the garment types is shown in Table 1. The 3D bivariate and multivariate rows contain the landmark name along with the name of the coordinate axis. For example, the discriminant functions obtained for pants using 3D multivariate input included the y-coordinate of the stature landmark (designated "stature y"), the x-coordinates of the front and back waist landmarks, the z-coordinates of the right waist and hip landmarks, and the x-coordinate of the front and back hip landmarks.

Figure 2 provides a summary of the performance of the discriminant functions in terms of prediction rate for each garment type. The results are displayed in pairs of points, comparing the prediction rates of functions using conventional measurements (including circumferences) with that of functions using 3D landmark coordinates.

Table 1. Variables in the discriminant function models by garment type.

Variable type	Garment type		
	Pants	**Jacket**	**Shirt**
Bivariate (conventional)	Stature Waist circumference	Stature Chest circumference	Neck circumference Sleeve length
3D bivariate (landmark)	Stature y Waist x,y (front, back) Waist z (left, right)	Stature y Chest x,y (front, back) Chest z (left, right)	Neck x,y (front, back) Neck z (left, right) Sleeve length
Multivariate (conventional)	Stature Waist circumference Hip circumference	Stature Chest circumference	Stature Neck circumference Chest circumference
3D multivariate (conventional)	Stature y Waist x (front, back) Waist z (right) Hip x (front, back) Hip z (right)	Stature y Chest x (front, back) Chest z (left, right)	Neck x,y (front, back) Neck z (left, right) Sleeve length



	Bivariate (conventional measurements)	3D bivariate	Multivariate (conventional measurements)	3D multivariate
◆ Pants	84%	86%	87%	91%
■ Jacket	77%	81%	77%	82%
▲ Shirt	58%	72%	70%	72%

Type of input variable

Figure 2. Type of input variable versus the rate of successful size prediction for a military dress uniform.

DISCUSSION

Figure 2 shows higher prediction rates coming from discriminant functions based on three-dimensional landmark coordinates than those based on conventional measurements. Modest but consistent increases in prediction rate (2% to 5%) were noted for all garment types, and in particular with the bivariate shirt size prediction, where a substantial increase (14%) was observed.

The 14% improvement in shirt size prediction was obtained by using the x, y, z coordinates of the four neck landmarks (front, back, left and right landmarks) rather than the neck circumference measurement derived from them. This result is thought to be due to a better characterization of neck shape, leading to a better classification of cases. Landmark coordinates are richer in information in that not only can they provide a circumference measurement (through modelling), but they can also provide the height, breadth, depth, and orientation of a measurement. A circumference measurement does not distinguish between a circle and a thin ellipse or provide any indication of position or orientation in space.

Examination of the discriminant functions reveals that neck breadth and depth were used to predict shirt size, as evidenced by pairs of x and z values of opposite signs in the equations. The same was true of jacket and pants where the depths and breadths of chest, waist, and hip were retained. The 3D multivariate functions for pants included additional hip shape information by considering the z-coordinates of the right hip and waist landmarks. These examples indicate that the additional information contained in landmark coordinates that can be quite useful in predicting clothing size.

Conventional bivariate measurements have evolved over years of use and are, for the most part, reasonably good predictors of clothing size. It is clear, however, that they are not the only predictors, and that better size prediction results can be obtained by either using a larger number of variables or by providing more detailed information on the same number of variables. The pants were an example of the benefit an additional variable can bring whereas the shirt and jacket were examples of benefit coming from more detailed information.

Although clothing size prediction improved through the use additional variables and/or shape information, it was still not possible to achieve 100% prediction rate for any of the garments. This may be due to several factors. One of these factors may be related to the fact that perhaps not all of the variables relevant to fit were considered in the analysis or that they were incorrectly measured. To guard against this, it may be necessary to develop a new measurement strategy that would be more apt to capture those variables.

Another aspect that needs to be considered is the clothing itself, with its design and manufacturing flaws. The clothing size prediction accuracy may never quite reach 100% because of the variability induced by the manufacturing process. Even in this study, where precautions were taken to order clothing from the same manufacturing batch, significant inconsistencies in sleeve length were noted from size to size. Unless manufacturing methods improve to the point of making this factor negligible, this will remain a source of variability.

Another factor may simply have to do with personal preference. Although personal preference can, to some extent, be a matter of shape and size (depending on the interface between the clothing and the body), the fact remains that some individuals will prefer a looser fit than others. While the advent of new measurement technology is expected to improve clothing size prediction, the subjectivity of personal preference will probably prevent predictions from reaching 100%.

CONCLUSIONS

The results of this study show that the use of three-dimensional landmark coordinates, as input to a discriminant function analysis, is superior to the use of circumference measurements in predicting clothing sizes. The use of these landmarks is thought to improve the classification of cases by allowing a better characterization of body shape.

The fact that the garment prediction success rates were less than 100% indicates that other factors remain unaccounted for. Some of these may be due to an incomplete input dataset, inconsistent measurement locations, variability of clothing dimensions due to manufacturing fluctuations, and/or personal preference.

REFERENCES

Statsoft. (1999). Statistica for Windows (Version Kernel release 5.5A).