STUDY OF CHILDREN FOOTPRINTS GROWTH USING GEOMETRIC MORPHOMETRIC TECHNIQUES

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INTRODUCTION

The growing and maturing process of the foot structure, bones, ligaments, soft tissue and as a consequence of its outer shape, continues approximately until the age of eighteen. A detailed knowledge of shape changes in children feet during growing is an important issue to design footwear with comfort and healthy attributes for this population.

The objective of this paper is to present a methodology to study, with horizontal data, the morphological changes of children feet shape with age, using as an example the evolution of the footprint outline. From this information and in a second stage, a model to predict the average footprint shape at different ages has been developed.

The information obtained and the methodology applied could be used in diverse industrial applications as anatomical insoles design or shoe last grading.

REVIEW AND THEORY

The study of the changes on human shape during growing or aging has been mainly centered in the anthropology field (Slice and Stitzel J., 2004) or in medical applications, as the work performed by Hutton et al. (2003), who studied shape changes of the face with age to obtain an average growth trajectory. However, these techniques have not been applied in the development of human products.

In the study of foot morphometrics, we can found some works that analyzed adult's shape variability using diverse techniques. Haber (1997) and Gheng (1999) used linear anthropometrical measurements to define footwear grading systems. Morphological characteristics of two dimensional foot shapes have been used with different purposes as clustering to assess insole design (Bataller et al., 2001). Finally, three dimensional morphological analysis has been done using FFD technique for last design (Mochimaru et al. 2000).

However, although there are some works that used anthropometric linear dimensions to assess children feet growing (Hlavacek, 1995) and there are many qualitative approaches, there is a lack of information about the morphological and shape changes of children foot during the growth period.

MATERIALS AND METHODS

A Spanish database with 2000 footprints of a horizontal study with children from 9 months to 16 years old with a distribution of 54.5% boys and 45.5% girls was used for the study. The footprints are represented by the coordinates of 24 hand-placed anatomical landmarks with high reproducibility and anatomically representative. Each set of landmarks has been jointly translated to the centroid, rotated and scaled to a common size using the Generalized Procustes Analisys (GPA), which fits one landmark configuration over another by minimizing the sum of squares distance between homologous landmarks (Rohlf and Slizce, 1990).

The first stage of the study had the objective to obtain the deformation modes of the footprint shape. A Principal Components Analysis (PCA) with Varimax rotation was carried out with the x and y coordinates of the footprints database.

In the second part, a prediction model of the foot shape growth has been obtained. Regression techniques were used to predict the scores of the principal components with the age. Gender shape differences were observed, thus this analysis was performed separately for boys and girls.

In order to validate the model, 17 children were measured in two different time instants. The time space was large enough to observe shape differences due to growing. The validation method consisted in comparing the predicted and the actual footprint of these children and obtaining the average error.

RESULTS AND DISCUSSION

Seven factors were identified in the PCA, explaining the 85% of the total variance. Correlations between each factor and age were calculated in order to separate those components which explained the growth effect from the ones which defined other morphological characteristics. The first component had a high correlation with age ($r=0.85$; $p<0.01$), representing the size increase due to foot growth. Significant correlations ($p<0.05$) with age have been also fount with the remainder factors, although the coefficients were lower than 0.2. From these components, the higher correlation coefficient ($r=0.2$) corresponded with the sixth factor, which represented the longitudinal displacement of the landmark that defines the end of the arch support.

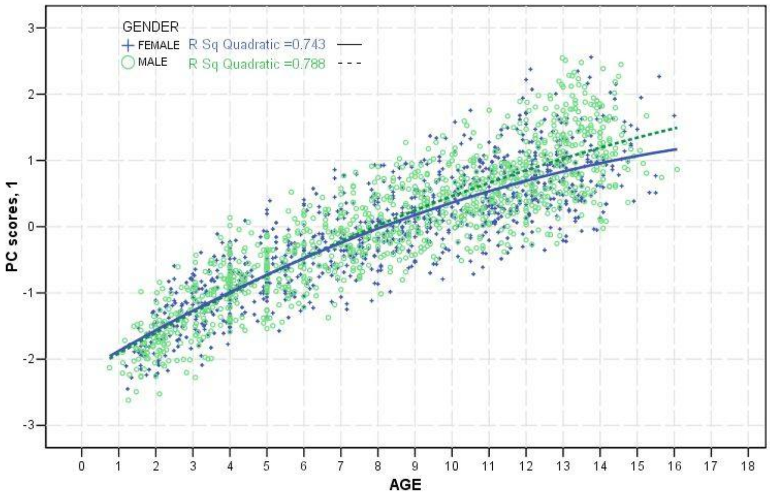

Figure 1. The first principal component plotted against the age.

The validation of the prediction model showed differences between the actual and the predicted footprints. Improvements of the growth prediction model could be achieved introducing individual information about parents' foot shape, height and weight curves (Hlavacek, 1995), medical records or usual activities.

The study of the foot shape is a fundamental issue in the development of products for the shoe industry. The information obtained form this work and the methodology proposed could be applied for product design: anatomic insoles, last design, shoe last scaling or footwear customization. In the same way, this methodology could be applied in other cases as the aging effect on the foot shape of elderly people. The model proposed could be also a valuable tool for medical or orthopedic applications to detect or predict foot pathologies in the childhood and prevent them in early stages.

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