QUANTIFYING MEAN SHAPE AND VARIABILITY OF FOOTPRINTS USING MEAN SETS

J. Domingo[1], B. Nacher[2], E. de Ves[3], E. Alcantara[2], E. Diaz[3], G. Ayala[4] and A. Page[2]

[1]*Instituto de Robotica, Universidad de Valencia.*
Poligono de la Coma, s/n. Aptdo. 2085, 46071 Valencia (SPAIN)
Juan.Domingo@uv.es

[2]*Instituto de Biomecanica, Universidad Politécnica de Valencia.*
Edificio 9C. Camino de Vera s/n, 46022 Valencia (SPAIN)
beanacfe@ibv.upv.es,ealcanta@ibv.upv.es,afpage@ibv.upv.es

[3]*Departamento de Informatica, Universidad de Valencia.*
Avda. Vte. Andres Estelles,s/n, 46100 Burjasot (SPAIN)
Esther.deVes@informat.uv.es,Elena.Diaz@informat.uv.es

[4]*Departamento de Estadistica e IO, Universidad de Valencia.*
Avda. Vte. Andres Estelles,s/n, 46100 Burjasot (SPAIN)
Guillermo.Ayala@uv.es

Abstract This paper[1] presents an application of several definitions of a mean set for use in footwear design. For a given size, footprint pressure images corresponding to different individuals constitute our raw data. Appropriate footwear design needs to have knowledge of some kind of typical footprint. Former methods based on contour relevant points are highly sensitive to contour noise; moreover, they lack repeatability because of the need for the intervention of human designers. The method proposed in this paper is based on using mean sets on the thresholded images of the pressure footprints. Three definitions are used, two of them from Vorob'ev and Baddeley-Molchanov and one morphological mean proposed by the authors. Results show that the use of mean sets improves previous methodologies in terms of robustness and repeatability.

Keywords: Mean set, morphological mean, footprint, footwear design

Introduction

Footprints have been used as a source of data for many different applications such as medical diagnosis, anthropometric studies and footwear design.

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Although foot printing techniques may be inadequate to determine the maximum values for many length and breadth foot dimensions [21], they allow the calculation of a variety of parameters of interest for orthotic applications such as the footprint angle, the foot contact area and the arch index [3]. On the other hand, footprint and foot outline shape analysis has been used in anthropometric studies to establish foot-type classifications [2], to obtain average plantar curves [7] and to detect sex or ethnic morphological differences [8]. Finally, a systematic analysis of plantar foot-shape variation is necessary to identify the critical parameters of the insole design, in order to ensure an adequate fitting between insole and plantar foot shapes [20].

Detailed knowledge of footprint shape and dimensions implies the analysis of averaged values and forms as well as the quantification of size and shape variability. Both aspects of the quantitative description of footprint form, mean values and variability, are crucial in design applications. Two main approaches have been used for this purpose.

The easiest and most-used method is based on the measurement of metric distances, areas, angles or ratios and the calculation of descriptive statistical parameters such as mean, standard deviation or coefficient of variation. This approach provides good information about the distribution of the univariate anthropometric but it has several limitations. Firstly, it needs the selection of a set of landmarks and the use of a particular measurement protocol. The unsuitability of landmark set selection or differences between measurement protocols can generate results which are not comparable ([12], [13]). Moreover, this approach does not reflect the multivariate nature of strongly correlated variables such as foot length, foot width and contact area, for instance [20]. An adequate description of the whole footprint shape variability cannot be made by quantifying the variability of a discrete set of variables, because distorted percentiles are obtained when they are estimated from each individual component ([4], [15]). In short, traditional methods originating from classical descriptive statistics neither allow an efficient way to make shape analysis nor provide a comprehensible description of human foot variability.

An alternative strategy is based on the mathematical analysis and quantification of the whole footprint shape, although these methods are insufficient for extracting and quantifying shape characteristics.

A first approach is based on dimensions or foot outline coordinates using multivariate analysis techniques. The use of multivariate analysis techniques in anthropometric foot description includes factor analysis and principal component analysis [9],[5], multivariate discriminant analysis [16] or clustering techniques [2]. A completely different approach uses Fourier descriptors to represent outlines [10]. This technique allows a quantitative description of footprint shape and its classification independently of size [17]. Finally, some attempts to define averaged plantagram curves or foot outlines have been de-