Available online at www.sciencedirect.com
SCIENCE DIRECT®

Computer Vision and Image Understanding

Computer Vision and Image Understanding 99 (2005) 175–188

www.elsevier.com/locate/cviu

Measuring rectilinearity

Paul L. Rosin [a,*], Joviša Žunić [b,1]

[a] Cardiff School of Computer Science, Cardiff University, Cardiff, UK
[b] Computer Science Department, Exeter University, Harrison Building, Exeter EX4 4QF, UK

Received 8 August 2003; accepted 19 January 2005
Available online 19 February 2005

Abstract

Two new methods for computing the rectilinearity of polygons are presented. They provide shape measures and estimates of canonical orientations which can be used in applications such as shape retrieval, object classification, image segmentation, etc. Examples are presented demonstrating their use in skew correction of scanned documents, deprojection of aerial photographs of buildings, and scale selection for curve simplification. Furthermore, testing has been carried out on synthetic data and with human subjects to verify that the measures do indeed produce perceptually meaningful results.

Keywords: Shape descriptor; Polygon; Rectilinear

1. Introduction

Shape is used in many instances of data processing. Take for example, medical imaging of the brain: shape is used for segmentation of the cortical surface prior to functional brain mapping [10]; the shape of the cerebral cortex (its degree of folding) can distinguish normal and abnormal fetal brains [1]; and the shape of the

* Corresponding author. Fax: +44 29 2087 4598.
E-mail addresses: paul.rosin@cs.cf.ac.uk (P.L. Rosin), J.Zunic@exeter.ac.uk (J. Žunić).
[1] Also with the Mathematical Institute of the Serbian Academy of Sciences and Arts, Belgrade.

1077-3142/$ - see front matter
doi:10.1016/j.cviu.2005.01.003

corpus callosum was used to analyse deficits due to fetal alcohol exposure [3]. There are a myriad of other applications: characterising large and small submarine volcanoes [17], measuring cherry fruit shape [2], analysing the molecular structure of gold [24], and optimising aerodynamic design [6] to name but a few.

In computer vision, shape has been a long standing topic of research [19,14], and many schemes have been developed. However, for the particular aspect of shape covered in this paper, namely measures for *rectilinearity*,[2] there has been little previous research. Nevertheless, rectilinear shapes obviously occur frequently in manufactured environments, and moreover the human visual system is particularly tuned to right angles [7]. In a recent paper, Žunić and Rosin [25] gave two possible definitions of measures of rectilinearity of an arbitrary polygon P:

$$\mathcal{R}_1(P) = \frac{4}{4-\pi} \cdot \left(\max_{\theta \in [0,2\pi]} \frac{\mathcal{P}er_2(P)}{\mathcal{P}er_1(P,\theta)} - \frac{\pi}{4} \right),$$

$$\mathcal{R}_2(P) = \frac{\pi}{\pi - 2\cdot\sqrt{2}} \cdot \left(\max_{\theta \in [0,2\pi]} \frac{\mathcal{P}er_1(P,\theta)}{\sqrt{2}\cdot\mathcal{P}er_2(P)} - \frac{2\cdot\sqrt{2}}{\pi} \right),$$

where $\mathcal{P}er_2(P)$ denotes the Euclidean perimeter of P, and $\mathcal{P}er_1(P)$ denotes the perimeter of P in the sense of the L_1 norm. $\mathcal{P}er_1(P,\theta)$ is the L_1 perimeter of the polygon obtained by rotating P by the angle θ with the origin as the centre of rotation. The measures are such that they lie in the range $(0,1]$, return the peak value of 1 only for rectilinear polygons, and moreover they are invariant under similarity transformations of P.

Žunić and Rosin [25] demonstrated the integration of the rectilinearity measures into snakes to perform boundary refinement, increasing the rectilinearity of noisy regions extracted from images. They also used it as part of a feature vector in a trademark matching example. Further applications of rectilinearity measures are possible, the most obvious being classification. Also in certain situations, it can be used as an alternative to convexity in segmentation [18], shape partitioning [23], grouping [13], etc.

Hand-in-hand with computing rectilinearity values, the rectilinearity measures provide a means of determining canonical orientations for shapes. In many applications such an orientation is useful as a first step in the analysis of shapes, and this is often provided by the moments based principal axis. In contrast, the orientation maximising rectilinearity is based more on local shape properties, while the principal axis only reflects the gross spatial distribution. The difference between the two is demonstrated in Fig. 1, where the the rectilinearity based orientation appears more appropriate than that computed using moments. Further related examples will be shown in the experimental results described in Section 4.

[2] Many dictionary definitions of rectilinearity are vague, e.g., "Composed by straight lines." In this paper, the more precise sense of a rectilinear polygon such that it is composed of horizontal or vertical segments is used.