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Shape classification using line segment statistics

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ABSTRACT

Contour shape description is an important field in computer vision. This is due to the fact that shape is an important low level image feature. In light of this, many approaches have been proposed in order to analyze it. Therefore, this paper introduces a very simple, yet efficient, shape descriptor based on straight-line segment statistics. For each contour point, we consider a continuous portion of the contour with length equal to a pre-defined percentage of the contour size. Then, we compute the length of the straight-line segment between its extreme points. For the set of straight-line segments, we compute statistical moments (average and standard deviation). Lastly, we perform this calculation for different lengths of contour portions. The proposed shape descriptor is a powerful tool for shape discrimination: it is robust (it can characterize a huge set of different classes of shapes) and is tolerant to variations in the shapes' scale and orientation. Classification results of the proposed method overcome traditional methods found in literature, proving that it is an efficient tool for shape analysis.

1. Introduction

The shape of an object is one of the frequently used visual features for performing object characterization. It is a feature stable in terms of illumination and variations in object color and texture [28], thus, playing an important role in image analysis and representation. It is also an important feature in human communication, as the human visual system recognizes it by using only its higher curvature points [25].

Shape characterization is a classic problem in computer vision. Over the years, many shape analysis methods have been proposed. These methods aim at obtaining a signature that characterizes the relevant features of the shape [17,26]. Shape analysis methods are commonly classified into three groups: contour-based, region-based and skeleton-based methods. Basically, the distinction among methods is based on where the shape features are extracted from [28,31]. Contour-based methods use the contour information to describe the shape objects [20]. This group considers the shape as being an ordered set of points connected to a piecewise defined curve [6]. Thus, the lack of points, missing parts or occlusion could affect the results. Some instances of this group are Fourier descriptors [19,27,21], Curvature Scale Space (CSS) [20,29], Inner Distance [18] and Learning Graph Transduction [30].

The region-based methods use the image of an object to compute the features which characterize its shape [32,16]. Even though these methods are useful for generic shapes, they fail to distinguish similar classes of objects. An example of a method in this group is Zernike moments [32].

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Skeleton-based methods use only the media axis information during the calculation. These techniques are suitable for shapes which present occlusion and articulation. They usually present better results for this sort of images when compared to contour and region based methods. Some approaches from this group include Path Similarity [5,4] and Graphs with Fractal Dimension [3].

Shape descriptors are also an important tool to describe three-dimensional models. Different shape methods, such as Zernike moments, are commonly used to describe two-dimensional views obtained from an original three-dimensional model in order to perform its retrieval or classification [2,14,13].

The presented paper proposes a novel shape descriptor based on straight-line segment statistics computed from the shape contour. Our motivation is to provide a high discriminative method with a very low computational complexity. Taking each contour point as a starting point, we select a continuous section of the contour with length equal to a pre-established percentage of its size. In the sequence, we measure the length of the straight-line segment between the extreme points. Then, we compute the statistical moments "average" and "standard deviation" from the set of straight-line segments. We perform this procedure for different lengths of contour sections.

The remainder of the paper is organized as follows: Section 2 describes the straight-line segment statistics approach and how we obtained a feature vector that describes a shape. In Section 3, we described an experiment to evaluate our proposed approach. For this, we considered two shape datasets: (i) generic shapes and (ii) fish shapes. We also compared our descriptors to traditional shape analysis methods. Results and discussion are presented in Section 4. Section 5 presents some final remarks on this paper.

2. Proposed approach

2.1. Line segment approach

Curvature is a very important feature concerning shape analysis, which in itself has inspired a great number of studies [29,20,10,7]. This is a local feature which describes how much the contour curve bends at each point of the shape. Nevertheless, curvature calculation requires the computation of second derivatives, a problematic issue for discrete curves. Moreover, differentiation methods have a tendency to emphasize high frequencies of a signal, including undesired noise [8]. Such effects can be easily avoided by using a smoothing function during the derivative calculation.

Instead of computing the curvature, one may be interested in analyzing the line segment that connects the extremes of a curve due to its simplicity of computation. Given two portions of a shape contour with the same number of points and different curvatures, it is likely that their line segments present different lengths, as shown in Fig. 1.

In consideration of this characteristic, we propose using the length of the line segment as a feasible shape characteristic. Let $C = \{c_0, c_1, \ldots, c_{N-1}\}$ be the contour of a shape of size N points, where $c_i = \{x_i, y_i\}$ is the Cartesian coordinate of a contour point. Each point c_n has exactly two neighbors and the Chebyshev distance between two neighboring points $(c_n,\ c_{n+1})$ is equal to 1. We then calculate the length of the line segment between two points using the Euclidean distance:

$$d(i,j) = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2}. \tag{1}$$

Given that each $\{c_0, c_1, \ldots, c_{N-1}\}$ is a starting point in the contour, we are able to compute a line segment to any other point. However, not all line segments are relevant. For example, line segments computed between two nearby points are likely to present similar length, regardless of the contour shape. Thus, to avoid the presence of an excessive number of non-significant line segments, we opted to compute segments of line situated between two reference points and between these there are a fixed number of intermediate points. Considering that we may be describing the same shape at different scales, we established that between the starting point and the end point of the line segment we must have a continuous portion of contour of size t, where t is given in terms of percentage (e.g., $t = 15\%$). So, given a starting point i, the end point j of a line segment $\overline{ij}$ is defined as

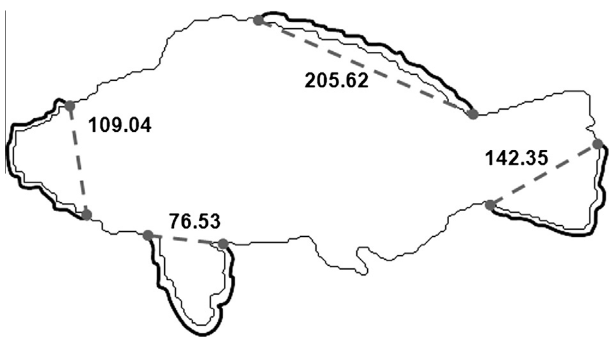

Fig. 1. Examples of different contour portions and respective lines segments. Notice that the curvature of the contour affects the length of the line segments even though all portions have the same number of points ($t = 15\%$).