Signal Processing: *Image Communication* 29 (2014) 556–571

Contents lists available at ScienceDirect

Signal Processing: *Image Communication*

journal homepage: www.elsevier.com/locate/image

Curve normalization for shape retrieval

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A R T I C L E I N F O

Article history:
Received 28 March 2013
Received in revised form
15 January 2014
Accepted 22 January 2014
Available online 15 February 2014

Keywords:
Curvature points
Polygon approximation
Least squares model
Shape matching
Shape retrieval

A B S T R A C T

In this paper, we propose a novel part-based approach for two dimensional (2-D) shape description and recognition. According to this method, first the polygonal approximation is employed to represent the outline shape by an ordered sequence of parts. Then using the Least squares model, each part is associated with a cubic polynomial curve. The obtained curves are normalized that are invariant to scaling, rotation and translation. Finally, based on shape similarity of resulting curves, a shape similarity between an input shape and its reference model is defined. A two-step matching algorithm is proposed. Experiments using several benchmark databases are performed and the obtained retrieval results demonstrate that the proposed approach is effective as compared to other matching techniques.

1. Introduction

Shape recognition is a very important application area in computer vision and in multimedia processing particularly. But building a shape retrieval process requires two important components: a shape representation and a matching algorithm. A good shape matching should be invariant to affine transformations such as translation, scaling and rotation. Based on the silhouette of objects, various descriptors and matching algorithms have been proposed during the past decades [1]. The proposed methods are based on statistical approaches which use global features extracted from the shape like moments [2,3] and Fourier descriptors [4,5], local structural features such as segments and arcs [6,7] and part decomposition [8]. There are also hybrid approaches that combine both local and global shape features such as rolling penetrate descriptor [9,10].

Since the global shape features have some limitations in shape representation and poor performance in matching shapes partially occluded, we propose in this paper two new approaches: these are part-based representation and matching method. The part-based silhouette representation we use is built only on curves. Boundary shape is decomposed into different parts with associated least squares curves. The shape matching task is divided into two steps: the first step consists in reducing the search space by using global features such as invariant moments of order two. The second one is based on the similarity between normalized curves.

The rest of this paper is organized as follows. In Section 2, a brief review of shape representation and matching methods is presented. In Section 3, details on the proposed approach of shape representation are described. The associated shape matching process based on the defined similarity measure is presented in Section 4. Section 5 presents the evaluation of the approach and a comparative study with some existing methods of the state of the art. Finally, Section 6 gives some conclusions and concludes the paper.

2. Related work

Numerous techniques and algorithms have been proposed in the literature to represent objects based on their

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http://dx.doi.org/10.1016/j.image.2014.01.009
0923-5965

silhouettes. There are mainly two-kinds of methods: surface-based and contour-based methods. In general, surface-based methods extract features from the whole shape region. Some methods in this kind are Zernike moments [11,12] and Legendre moments [13,14] which have demonstrated to achieve excellent performance but these methods are not suitable for object recognition in the presence of occlusion. Generic Fourier descriptor [15] is another well known shape descriptor which uses the property of Fourier transform and allows multi-resolution analysis. The authors in [16] proposed another way to describe shapes using the PCA- based methods. On the other hand, the contour-based methods explore boundary shape information. They are more complicated and requiring sophisticated implementations but they are more suitable than global methods for recognizing partially visible objects. In this category we find chain codes which consist of line segments that must lie on a fixed grid with a fixed set of possible orientations [17], polygonal approximation [18,19] and skeleton approach. In polygonal approximation approach, a shape is decomposed into line segments. The polygon vertices are used as primitives and then some features are extracted for each primitive. The median axis transformation or skeleton is introduced by Blum in [20]. It consists to reduce regions to curves that follow the global shape of an object. Later Sebastian et al. [21] used this descriptor for shape recognition. Petrakis and Milios [22] propose to represent shapes as a collection of segments between two consecutive inflexion points. The obtained segments are considered at different levels of shape resolution.

The goal of the above references is to approximate a shape as a polygon and then the shape is represented by a set of line segments. This description work well for man-made objects but it is not suitable for natural objects [1].

Mokhtarian et al. [23] proposed the Curvature Scale Space (CSS) descriptor, which is based on the maxima of the curvature zero-crossing boundaries to represent shapes. CSS representation is invariant under the affine transformations but it is sensitive to occlusion and convex shapes [24]. Recently Fotopoulou and Economou [25] proposed a multi-scale descriptor, which is based on the sequence of angles formed by the boundary points and then computed at different scales. Triangle area representation (TAR) [26] is another type of multi-scale descriptors based on the signed areas of triangles formed by boundary points at different scales. Other techniques consist of approximate the shape contour by differential-Turning Angle Scale Space function (d-TASS) [27,28], B-splines [29,30] and height functions [31,32]. The height function for one sample point is defined by distances of all the other sample points to its tangent line. The obtained height functions are then smoothed to represent and recognize 2D objects silhouettes.

Shape context (SC) [33] is a method for finding corresponding between point sets. Based on the inner distance, SC is extended to Inner-Distance Shape Context (IDSC) [34]. SC and IDSC have the ability to extract very discriminative features for a shape and to deal with the inexact correspondence problem in shape matching. However, they are sensitive to different shape poses and deformations. Recently, the authors in [35] presented a novel shape representation based on the local phase quantization. It transforms the descriptors obtained by the inner distance shape context, shape context and height functions into a matrix descriptor using the local phase quantization descriptor. The extracted matrix descriptors are then compared with the Jeffry distance. Later Hu et al. [36] proposed a novel contour-based hand shape recognition method called Coherent Distance Shape Contexts (CDSC), which is based on shape context and Inner-distance shape context. This descriptor is robust to hand poses and can be used in both hand shape and palmprint recognitions. Another interesting technique for two-dimensional shape matching, called contour flexibility is developed by Xu et al. [37] in which the deformable potential at each point of boundary is represented.

Shapes can also be modeled using part-based representation which has played an important role in object recognition. Organizing shape representations in terms of parts allows one to separate the representation of the shape of each individual part from the representation of the spatial relationships between the parts. This, in turn, leads to a more robust representation of shape. In [38] shapes are decomposed into different rectangles. The locations of the rectangles and their dimensions are selected by using a dynamic programming. The authors in [39] propose the use of the curvature zero-crossing points from a smoothed contour to get the parts, called tokens. The orientations and the maximum curvatures of the obtained parts are taken into account to represent shapes and matching. The method is not invariant to rotation because of the token orientation [40]. Using a dynamic programming, Latecki et al. [41] propose a method for partial shape matching, where local tangents to silhouettes are used for shape description. In [42] Cui et al. propose the use of the integral of absolute curvature as shape descriptor. For matching parts of occurring curves, they use the normalized cross correlation. The method is invariant to rotation, scale and translation. Daliri and Torre [46] proposed a representation for shape-based recognition based on the extraction of the perceptually relevant fragments. According to this approach, each shape is transformed into a symbolic representation, using a predefined dictionary for the contour fragments, which is mapped to an invariant high-dimensional space that is used for recognition.

In this paper, we explore a different approach to object recognition which is based on the analysis of the boundary of the shape using normalized curves. The proposed approach combines the advantages of polygonal approximation that are suitable for shape partitioning as its vertices correspond to high curvature points of the shape boundary and the least squares model that is particularly suitable for minimizing quadratic errors. The representation of the two-dimensional curve normalization for shape-based retrieval is proposed instead of line segments because segments are useful for man-made objects but they are not suitable if a shape consists of a curved boundary. The proposed approach involves three major steps: first, the extraction of the meaningful parts constituting the boundary shape, secondly, the modeling of the extracted part using the