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Shape representation based on mathematical morphology

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Abstract

This paper presents a novel shape representation algorithm based on mathematical morphology. It consists of two steps. Firstly, an input shape is decomposed into a union of meaningful convex subparts by a recursive scheme. Each subpart is obtained by repeatedly applying condition expansion to a seed, which is selected by utilizing the skeleton information. Secondly, the shape of each subpart is approximated by a morphological dilation of basic structuring elements. The location and direction of the subpart are represented respectively by two parameters. Thus the given shape is represented by a union set of a number of three-dimensional vectors. Experiments show that the new algorithm is immune to noise and occlusion, and invariant under rotation, translation and scaling. Compared to other algorithms, it achieves more natural looking shape components and more concise representation at lower computation costs and coding costs.

Keywords: Mathematical morphology; Shape decomposition; Shape representation

1. Introduction

Shape description is a very important issue in computer vision and pattern recognition (Loncaric, 1998; Wang, 1995). A number of different shape description schemes have been developed over the years. Following Pavlidis (1978), those methods can be classified according to several criteria. The first classification is based on the use of shape boundary points as opposed to the interior of the shape. These two approaches are known as external and internal, respectively. Another classification can be made according to whether the result is numeric or non-numeric. The scalar transform techniques map the image into an attribute vector description, while the space-domain techniques transform the input image into an alternative spatial domain representation. The third classification can be made on the basis of whether a transformation is information preserving or information losing.

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Mathematical morphology is a topological and geometrical based approach for image analysis (Serra, 1982). It provides a potential tool for extracting geometrical structures and representing shapes in many applications. Therefore, morphological shape representation algorithms have been receiving increasing attention in recent years. Those algorithms can be classified into three categories: scalar morphological descriptor, skeleton and morphological shape decomposition.

A number of scalar morphological descriptors have been investigated. Maragos (1989) proposed the concept of pattern spectrum, which is related to the notion of granulometries first studied by Matheron (1975) and more recently by Dougherty and Pelz (1991). Granulometries are a result of a sieving operation applied to binary images. It is a sieving operation because the structure in the image is filtered according to component size. The result of sieving is a size distribution obtained by opening the shape by a sequence of structuring elements. The sequence of openings is called a granulometry. Shih and Pu (1992) proposed another "spectrum" transformation called the G-spectrum, which is less redundant than granulometries or pattern spectrum. Another set of techniques were derived from the concept of morphological covariance, for example, the geometrical correlation function (GCF) (Loui et al., 1990). Moreover, an approach called morphological signature transform is developed by Loncaric and Dhawan (1993). The morphological signature transform utilizes multi-resolution morphological image processing by multiple structuring elements (SEs). Although those descriptors can distinguish certain different shapes, they are not information conservative descriptors, i.e., they do not yield unique shape representations of the given objects.

Another type of shape representation scheme is the morphological skeleton transform (MST) (Maragos and Schafer, 1986; Sanniti di Baja, 1994). In this scheme, a given shape X is represented as a union of all the maximal disks contained in X:

$$X = \bigcup_{i=0}^{N} S_i \oplus iB \tag{1}$$

where $S_i = (X \ominus iB)\backslash((X \ominus iB) \circ B)$, and N is the largest integer such that $X \ominus NB \neq \phi$, and $iB = B \oplus B \oplus \cdots \oplus B$ (i time) is a disk of size i. It is a convenient and compact form for representing an object and preserves the topological structure of the shape. However, those maximal disks in general overlap with each other. Also, it is mainly suitable for elongated objects and the skeletons are very sensitive to noise.

Morphological shape decomposition (MSD) is a different approach for binary shape representation, first proposed by Pitas and Venetsanopoulos (1990). They decomposed a shape into a union of certain disks contained in the shape.

$$X = \bigcup_{i=0}^{N} L_i \oplus iB \tag{2}$$

where $L_N = X \ominus NB$, and

$$L_i = \left(X \Bigg\backslash \left(\bigcup_{j=i+1}^{N} L_j \oplus jB\right)\right) \ominus iB, \quad 0 \leqslant i \leqslant N \tag{3}$$

Reinhardt and Higgins (1996a,b) proved that the MSD often represents objects more efficiently than the MST. One reason is that the overlapping between disks of different sizes is eliminated. To reduce the number of components, algorithms allowing the use of multiple structuring elements were proposed (Pitas and Venetsanopoulos, 1992; Reinhardt and Higgins, 1996a,b). But the selection of structuring elements is difficult and time consuming. Recently, partially optimal MSD schemes (Xu, 2001a,b; Sanniti di Baja and Svensson, 2002) have also been proposed for efficient morphological shape representation. However, the decomposition of their outputs is not always suitable for human perception. Also, some of them are very sensitive to noise.

In this paper, a new morphological shape decomposition scheme is proposed. We first decompose a binary shape into a union of convex subparts, and then approximate each subpart by a sequence of 3×3 morphological structuring elements. Therefore, a shape using our representation can be reconstructed fast by a set of simple structuring elements. Such a representation is immune