

CONTENT-BASED SHAPE RETRIEVAL USING DIFFERENT AFFINE SHAPE DESCRIPTORS

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Abstract: Shape representation is a fundamental issue in the newly emerging multimedia applications. In the Content Based Image Retrieval (CBIR), shape is an important low level image feature. Many shape representations have been proposed. However, for CBIR, a shape representation should satisfy several properties such as affine invariance, robustness, compactness, low computation complexity and perceptual similarity measurement. Against these properties, in this paper we attempt to study and compare three shape descriptors: two issued from Fourier method and the Affine Curvature Scale Space Descriptor (ACSSD). We build a retrieval framework to compare shape retrieval performance in terms of robustness and retrieval performance. The retrieval performance of the different descriptors is compared using two standard shape databases. Retrieval results are given to show the comparison.

1 INTRODUCTION

In the newly emerging multimedia applications such as MPEG-4 and MPEG-7, shape plays an important role in supporting the so called content based functionalities. Many shape representations have been proposed for various purposes. These methods can generally be grouped into contour-based and region-based.

For CBIR purpose, a shape representation should be affine invariant, robust, compact, easy to derive and perceptually meaningful. In terms of these properties, Fourier Descriptors (FD) and Curvature Scale Space Descriptors (CSSD) have been recognized as suitable for CBIR. CSSD has been adopted in MPEG-7 as shape descriptors.

In a previous work (Chaker and al., 2003a,b) we have proposed a new complete and stable set of Affine Invariant Fourier Descriptors (AIFD). Experiments have shown that these descriptors have good retrieval accuracy and if applied to the shape of a curve it can deal with affine transformed curves (Chaker and al., 2007). In this paper, we will test the performance of AIFD in the context of shape

retrieval and we will compare it to two well known affine descriptors such as the Affine Fourier Descriptors (AFD) proposed by Arbter (Arbter, 1990) and the Affine Curvature Scale Space Descriptor (ACSSD) (Mokhtarian and al., 2002). We will show that the AIFD outperforms the AFD and the ACSSD in terms of retrieval accuracy and efficiency and are very robust against affine transformations and much more for strong distortions such perspective distortions.

The rest of the paper is organized as follows:

In Section 2, we remind in detail the formulation of each descriptor. Section 3 gives the experimental results and discussion follows. Section 4 concludes the paper.

2 AFFINE INVARIANT SHAPE DESCRIPTORS

A number of shape representations have been proposed to recognise shapes under affine transformation (Arbter, 1990; Chaker and al. 2003a,b) (Mokhtarian and al., 2002). In these

methods, the basic idea is to use a parameterisation which is robust with respect to affine transformation, i.e. *affine length* (Arbter, 1990). The shortcomings of the affine length include the need for higher order derivatives which results in inaccuracy, and inefficiency as a result of computation complexity. We propose here to use B-spline. Indeed, it's well known that these functions have good smoothing quality and are robust relatively to multiple derivatives and rounding errors.

In the rest of the paper we assume that all of the contours are re-parameterized by affine arclength.

For a parametric contour γ , given by its Cartesian coordinates x and y (formally, $\gamma(t) = (x(t), y(t))$ where t represent the associated parameter). We re-parameterized the contour using the affine-length parameter:

$$s(t) = \frac{1}{L} \int_0^t \|\gamma'(t) \wedge \gamma''(t)\|^{2/3} dt \quad (1)$$

where L denotes the total equi-affine length of the considered contour.

2.1 Affine Invariant Fourier Descriptors (AIFD)

Let α and β be positive real numbers, k_0, k_1, k_2 and k_3 four positives integers. Let c_n^x and c_n^y be the complex Fourier coefficients of the coordinates x and y , Δ denotes the determinant and

$$\Delta_n^m = \Delta \begin{pmatrix} c_n^x & c_m^x \\ c_n^y & c_m^y \end{pmatrix},$$

The both families of descriptors I and J are respectively given by Eq.2 and Eq.3. For more details, derivations, proofs, the reader is referred to (Ghorbel, 1998).

$$I : \begin{cases} I_{k_1}(C) = |\Delta_{k_1}^{k_0}| \\ I_{k_2}(C) = |\Delta_{k_2}^{k_0}| \\ I_k(C) = (\Delta_{k_k}^{k_0})^{k_1-k_2} (\Delta_{k_1}^{k_0})^{k_2-k} (\Delta_{k_2}^{k_0})^{k-k_1} \\ \quad |\Delta_{k_1}^{k_0}|^{k-k_2+\alpha} |\Delta_{k_2}^{k_0}|^{k_1-k+\beta} \end{cases} \quad (2)$$

for all $k \in \mathbb{N}^* - \{k_0, k_1, k_2\}$.

$$J : \begin{cases} J_{k_1}(C) = |\Delta_{k_1}^{k_3}| \\ J_{k_2}(C) = |\Delta_{k_2}^{k_3}| \\ J_k(C) = (\Delta_{k_k}^{k_3})^{k_1-k_2} (\Delta_{k_1}^{k_3})^{k_2-k} (\Delta_{k_2}^{k_3})^{k-k_1} \\ \quad |\Delta_{k_1}^{k_3}|^{k-k_2+\alpha} |\Delta_{k_2}^{k_3}|^{k_1-k+\beta} \end{cases} \quad (3)$$

for all $k \in \mathbb{N}^* - \{k_1, k_2, k_3\}$.

2.2 The Affine Fourier Descriptors (AFD)

Let X_k, Y_k the Fourier coefficients of $x(t), y(t)$ respectively, the following normalized coefficients are affine-invariants when the parameter t is linear under affine transformation.

$$Q_k = \frac{\Delta_k}{\Delta_p} = \frac{\det \begin{bmatrix} U_k & U_p^* \\ U_p & U_k^* \end{bmatrix}}{\det \begin{bmatrix} U_p & U_p^* \\ U_p & U_p^* \end{bmatrix}} = \frac{X_k Y_p^* - Y_k Y_p^*}{X_p Y_p^* - Y_p Y_p^*}, \quad (4)$$

$\Delta_p \neq 0, k = \pm 1, \pm 2, \dots$

p is a constant and $p \neq 0$. In his experiments, Arbter (Arbter, 1990) utilize the area parameterization instead of the affine arclength. The Euclidean distance between two feature vectors was used as the similarity measurement.

2.3 Affine Curvature Scale Space Descriptor (ACSSD)

Consider a parametric vector equation for a curve $\gamma(s) = (x(s), y(s))$. The formula for computing the curvature function can be expressed as:

$$\kappa(s) = \frac{\dot{x}(s)\ddot{y}(s) - \ddot{x}(s)\dot{y}(s)}{(\dot{x}^2(s) + \dot{y}^2(s))^{3/2}} \quad (5)$$

where \dot{x}, \dot{y} and \ddot{x}, \ddot{y} are the first and second derivatives at location s respectively (s is the affine normalised arc length). If $g(s, \sigma)$, a 1-D Gaussian kernel of width σ , is convolved with each component of the curve, then $X(s, \sigma)$ and $Y(s, \sigma)$ represent the components of the resulting curve, γ_σ :

$$\begin{aligned} X(s, \sigma) &= x(s) * g(s, \sigma) \\ Y(s, \sigma) &= y(s) * g(s, \sigma) \end{aligned} \quad (6)$$

the curvature of γ_σ is given by:

$$\kappa(s, \sigma) = \frac{X_s(s, \sigma)Y_{ss}(s, \sigma) - Y_{ss}(s, \sigma)Y_s(s, \sigma)}{(X_s(s, \sigma)^2 + Y_s(s, \sigma)^2)^{3/2}} \quad (7)$$

The CSS descriptor extraction algorithm is described in (Abassi and al., 2000; Mokhtarian and al., 2002). The CSS descriptor vector represents a multiscale organization of the curvature zero-crossing points of a planar curve. In this sense, the descriptor dimension varies for different shapes, thus a special matching algorithm is necessary to compare two CSS descriptors. We implemented the Matlab prototype presented in (Ming, 1999).

3 A COMPARATIVE STUDY FOR SHAPE-BASED RETRIEVAL

3.1 Test Setup

- Multiview Curve Dataset (MCD) (Zuliani, 2004): This dataset comprises 40 shape categories, each corresponding to a shape drawn from an MPEG-7 shape category. Each category in the new dataset contains 7 curve samples that correspond to different perspective distortions of the original shape. The original MPEG-7 shapes were printed on white paper and 7 samples were taken using a digital camera from various angles (Figure 1). The contours were extracted from the iso-intensity level set decomposition of the images (Lisani, 2001).

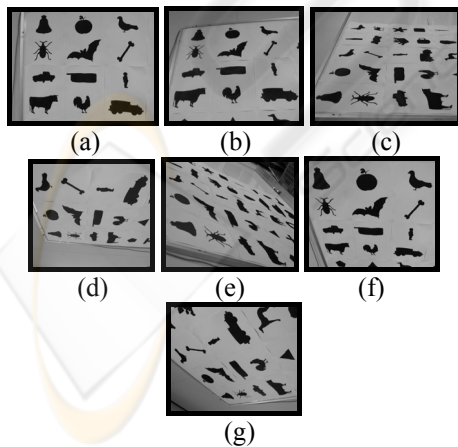


Figure 1: Some Examples of Images from the MCD database acquired from different viewpoints; (a) : Central (b) Bottom (c) Left (d) Right, (e) Top (f) Top-left, (g) Bottom- Right.

- MPEG-7 contour shape database CE-1 Part B: this set takes into consideration of common shape distortions in nature and the inaccuracy nature of shape boundaries from segmented shapes. Set B is for testing of similarity-based retrieval or for testing shape descriptors' robustness to various arbitrary shape distortions. In our experiments we have used a sample from the MPEG-7 database (216 shapes) (Figure 2). This dataset contains eighteen categories with twelve shapes in each category.



Figure 2: The 216 shapes from MPEG-7 contour shape database CE-1 Part B.

3.2 Retrieval Results

The performance of the retrieval is evaluated using precision and recall pair (PRP) which give the percentage of retrieved information that is relevant as a function of the percentage of relevant information retrieved (Bimbo, 1999). For each query, the precision of the retrieval at each level of the recall is obtained. The result precision of retrieval is the average precision of all the query retrievals. The average precision-recall of retrieval using the three shape descriptors on each dataset are shown in Fig. 3(a)-(b). Some screen shots of retrieval are shown in Fig. 4 and Fig. 5. In all the screen shots, the top left shape is the query shape. The retrieved shapes are ranked in descending order of similarity to the query shape.

It is clear from the precision-recall charts that the retrieval performance using AIFD is the best among the three. Although the affine FD is designed to particularly target affined shape description it is expected to work fine for polygonal shape under affine transformation. CSSD robustness to boundary variations is very limited. It is not robust to common boundary variations such as defections and arbitrary distortions. On average, FD is better than CSSD, while FD is much easier to derive, match, normalize and more compact compared with affine CSSD.

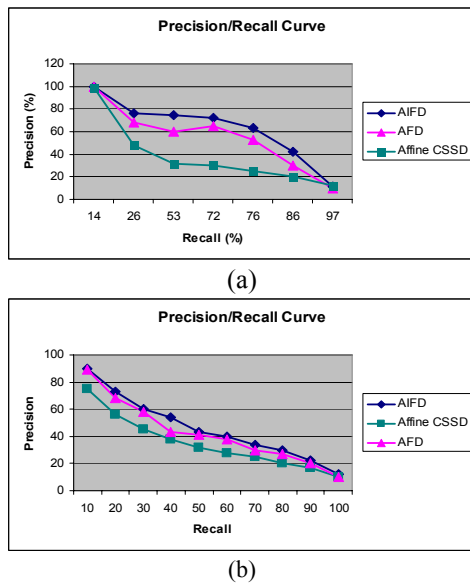


Figure 3: Retrieval effectiveness of AIFD, AFD and Affine CSSD on (a) Multiview Curve Database. And (b) MPEG-7 contour shape database.

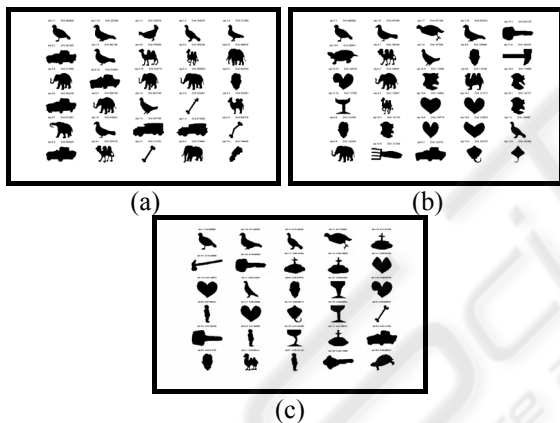


Figure 4: Retrieval of bird shapes from MPEG-7 Database using (a) AIFD; (b) AFD; (c) Affine CSSD.

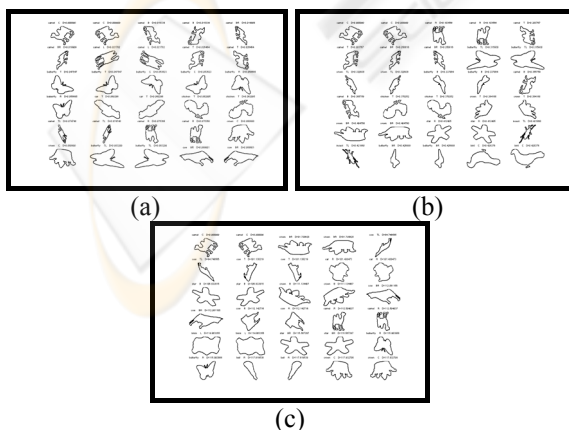


Figure 5: Retrieval of camel shapes from MCD Database using (a) AIFD; (b) AFD; (c) Affine CSSD.

4 CONCLUSIONS

In this paper we have made a comparative study on three affine shape descriptors used for shape retrieval. Results show that in terms of robustness and retrieval accuracy the AIFD outperforms the AFD and the affine CSSD. Although ACSSD capture strong perceptual shape features, many negative factors have affected its performance. Indeed, the retrieval effectiveness of ACSSD is severely affected by the complex matching method which is an intrinsic problem of CSS description.

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