An Innovative Vortex based Complex Potential Signature for Shape based Object Recognition

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Abstract: - An Innovative approach for representation and description of shape components for object recognition based on complex potential is proposed. In the complex plane, the flow of velocity is a crucial factor to discriminate different shapes. Hence, the present paper computes the potential flow by transforming the shape of the input object into complex plane. The present paper computes the Vortex based Complex Potential signature (VCP) by considering the radial lines as Equipotential lines and the circles as streamlines. The proposed VCP signature is described with the Fourier transformation for the generation of feature vector. The Chebyshev distance measure is used in the shape toning stage. The efficiency of the proposed descriptor is evaluated with the MPEG-CE-1 Set B database. The results prove the competency of the proposed descriptor than the benchmark descriptors.

Key-Words: - Complex Plane, Fourier Transformation, Distance, Feature Vector, Shape Toning and Performance Measures.

I. INTRODUCTION

Currently, object recognition plays an important role [1] in various real time applications. The object recognition methods ([2][3][4][5][6][7][8][9][10]) can be classified in to two categories such as top-down, bottom-up. The top-down methods ([11][12]) consists of a training stage for defining the configuration of the object. Hypotheses are found by matching models to the image features. Bottom-up approaches start from low-level or mid-level image features, i.e. edges or segments ([8][5][9][10]). These methods build up hypotheses from such features, extend them by construction rules and then evaluate by certain cost functions.

Shape based object recognition is an efficient approach [13]. Various shape based object recognition methods includes generic Fourier transform [14], convex hull [14], shock graph [15] and shape matrix [16] etc. The shape of the object can be efficiently represented by the invariant signature [17] [18] and the further described by the Fourier transformation [17].

The complex plane of the shape can be prominent for shape representation and description [19]. In the complex plane, the flow of velocity can be efficiently represented with the complex potential [20]. Through the complex potential, various preliminary solutions for the flow detection with the sinks, sources and vortex can be computed. The combination of these can yield to the conformal transformations of the shape of the object. Hence, the present paper computes the Vortex based Complex Potential (VCP) signature for the representation of the shape of the object in the complex plane.

The paper is organized in 3-sections. Introduction to complex potential based shape representation and description methods are reported in Section-1. The details of methodology implemented presently and the relevance are detailed in section-2. Results of implementing the novel algorithm designed by the proposed approach over the standard database and their analysis with relevant discussion are presented in Section-3.

II. METHODOLOGY

A novel vortex based complex potential signature is proposed for shape based object recognition. The step by step details of proposed descriptor are presented in section 2.1, while the section 2.2 discusses regarding the measures of performance.

A. Design of System

The proposed method consists of four stages given as follows

i. Contour based shape representation

ii. Evaluation of Vortex based Complex Potential Signature feature vector

iii. Description with the Fourier transformation

iv. Shape toning and ranking respectively.

It is observed that the Contour is efficient than the region for shape representation. Thus, in the initial stage, the contour based shape representation is extracted for the input object. The Equivalent Arc Length [17] sampling procedure is used for optimizing the representation points.

During the second stage, an input shape is transformed in to complex plane. The two dimensional potential flows can proficiently analyze the flow with in the shape. For this, the complex potential which consists of stream function and velocity potential should be computed. The preliminary complex potential computation includes the source, sinks and vortices. Among them, the present paper computes the complex potential based on vortices. In the log polar transformation, the vortex flow consists of radial lines are equipotential and concentric circles are stream lines.

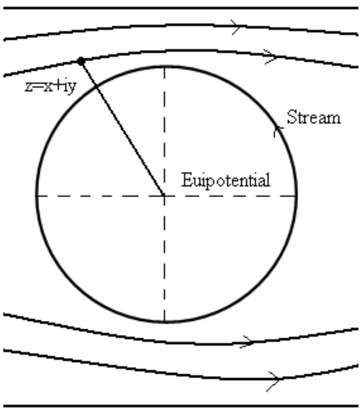

Fig.1 Vortex based Flow outside the circular cylinder.

Fig. 1 represents the positive vortex flow outer a circular cylinder. The vortex based complex potential (VCP) for outside the cylinder is given by

$$VCP = \frac{-i\Gamma}{2\Pi}\log(z - z_0) + \log\left(z + \frac{a^2}{z}\right) \quad (1)$$

where,

Γ represents the circularity strength of the vortex,
z is the representation point in the complex plane,
z_0 represents the singularity of the vortex and
a represents the radius of the cylinder.

The Imaginary values of the VCP are in harmonic function and thus this can be used for designing the VCP signature.

In the third step, the description of the VCP signature is computed with the 1-D Fourier transformation [17]. The described feature vector is found to be invariant to translation, rotation and scaling. In the wake of the fact, that the VCP signature is obtained wrt the centroid, the obtained features proved to be invariant to the translation operation. Further, the resulting finite and stipulated magnitude values of the features would be validated for the rotation invariance. The scaling invariance is achieved by dividing the feature vector with the first feature value. In the third step, the feature vector is constructed, which describes the entire shape aspect of the object. To further improve the quality of VCP signature, three global descriptors (GD) are included to the VCP feature vector. The GD feature vector, viz., {S,C,A} contains the measures of solidity, circularity and aspect ratio.

During the fourth step, the shape toning process [21] is performed with the Chebyshev Distance (CD). The specified data of distance measurement i.e. the so computed distances are further rearranged in ascending order and are assigned with specific ranks. In turn, the system is enabled to recognize top ranked images.

B. Performance Indicators

The performance of the proposed method is estimated by the computation of the confusion matrix, which contains [21] four elements viz., (i) False Negatives (FN) (ii) False Positives (FP) (iii) True Positives (TP) (iv) True Negatives (TN). From the confusion matrix, the performance measures viz., True Positive Recognition (TPR), Specificity (SPC), Positive Predicted Value (PPV), False Discovery Rate (FDR) and Accuracy (ACC) are computed by

$$TPR = \frac{TP}{(TP + FN)} \quad (2)$$

$$SPC = \frac{TN}{(FP + TN)} \quad (3)$$

$$PPV = \frac{TP}{(TP + FP)} \quad (4)$$

$$FDR = \frac{FP}{(FP + TP)} \quad (5)$$

$$ACC = \frac{(TP + TN)}{(TP + TN + FN + FP)} \quad (6)$$

III. PROBLEM SOLUTION

Due to the diversified shapes of objects, the Set B database is used for evaluating the proposed Vortex based Complex Potential descriptor as discussed in section 2-1. The results of proposed method and various other standard methods are presented in the following subsection-3.1. The proposed VCP+GD descriptor is validated with the relative performance measures and are given in the sub section 2-2 in the wake of the other reported descriptors.

A. Processing of Proposed Descriptor

The present paper computes the proposed VCP signature given in Equation (1) with the circulation strength as 1 and the radius of the concentric circle as 1. The only imaginary values of the complex potential are considered as t he proposed VCP signature. The proposed signature is constructed for various objects of Set B database and the VCP of three Butterfly images (Butterfly5, Butterfly11 and Butterfly17) are illustrated in Fig. 2. It is observed that the VCP of different objects of the same group are found to be similar.

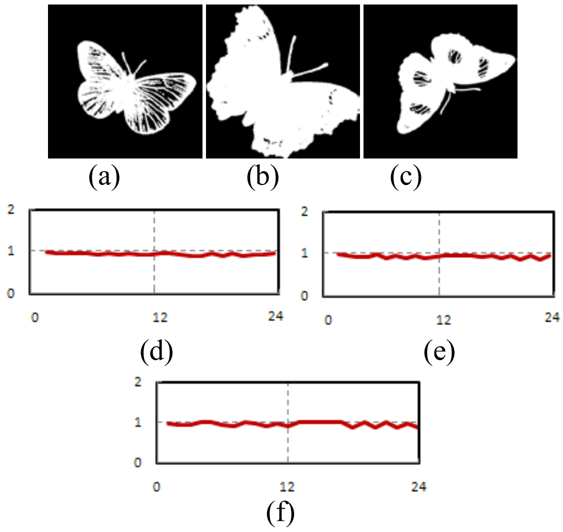

Fig. 2 (i) Butterfly5 (ii) Butterfly11 (iii) Butterfly17 (iv) VCP Signature of Butterfly5 (v) VCP Signature of Butterfly11 (vi) VCP Signature of Butterfly17.

Next, the Chebyshev Distance (CD) is used for the shape toning process. This will compute the distance between test and target feature vectors and are allocated with the rank according to the distance. The performance of the proposed descriptor is estimated by the top twenty (groupsize) retrieved objects. Fig. 3 illustrates the recognition results of Bell6 object from Set B database. The Fig. 3(i) represents the input object, 3(ii) represents the ZMD recognition result and 3(iii) represents the VCP+GD recognition result. From this, it is observed that the proposed VCP+GD descriptor reduces the dissimilar recognition result than the ZMD.

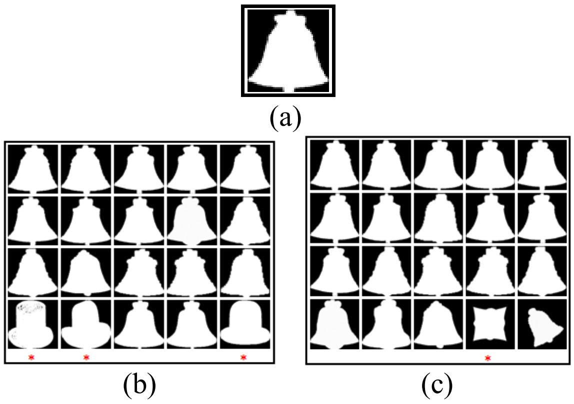

Fig. 3 (i) Bell6 Image (ii) ZMD Recognition Result of Bell6 (iii) VCP+GD Recognition Result of Bell6.

B. Design of System

With the computation of confusion matrix, the present paper performs the validation of the proposed VCP+GD descriptor. The confusion matrix consists of False Negatives, False Positives, True Positives and True Negatives measures of the proposed descriptor. The Table 1 shows the confusion matrix of the proposed VCP+GD descriptor. The present paper compares the confusion matrix of the proposed and four other standard descriptors viz., Zernike Moment Descriptor (ZMD), Angular Radial Transform Descriptor (ARTD), Moment Invariant Descriptor (MID) and Curvature Scale Space Descriptor (CSSD). The Table 1 g ives the comparison of confusion matrix of proposed and standard descriptors. From the Table 1, the five performance measures are computed and shown in Table 2. In the Table 2, the TPR, SPC, PPV, FDR and ACC performance measures are computed for the VCP+GD, ZMD, ARTD, MID and CSSD descriptors. From the Table 2, it is found that the proposed VCP+GD yields improved performance and is validated.

Table 1 Confusion Matrix of Various descriptors.

Descriptor	FN	FP	TP	TN
CSSD	0.309	0.205	0.691	0.814
MID	0.256	0.184	0.744	0.888
ARTD	0.252	0.175	0.748	0.891
ZMD	0.248	0.153	0.752	0.895
VCP+GD	0.155	0.092	0.845	0.908

Table 2 Performance Measure of various descriptors.

Descriptor	PPV	TPR	SPC	FDR	ACC
CSSD	0.771	0.691	0.799	0.229	0.745
MID	0.802	0.744	0.828	0.198	0.788
ARTD	0.810	0.748	0.836	0.190	0.793
ZMD	0.831	0.752	0.854	0.169	0.804
VCP+GD	0.902	0.845	0.908	0.098	0.877

The PR plot [18] of all the five descriptors is shown in Fig. 4. The VCP+GD descriptor clearly witnesses an improved precision prevalently at all recalls from 0 t o 100 than the other descriptors. Among them, the CSSD descriptor is having low precision than the other descriptors.

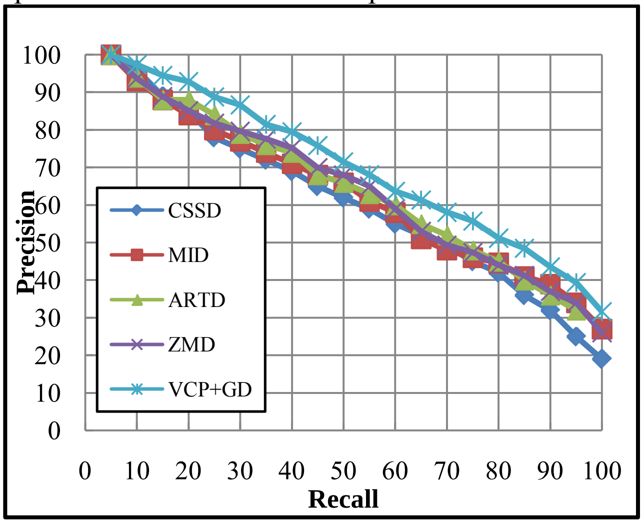

Fig. 4 C omparison PR plot of CPS+GD and other standard descriptors.

IV. CONCLUSION

- Representation and description of shape of the object is found to be efficient with the complex potential.
- The vortex based complex potential yields improved recognition results than the standard descriptors.
- The performance measures viz., TPR, SPC, PPV, FDR and ACC gives the detailed description of the efficiency of the proposed VCP+GD descriptor.

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