Logo Recognition System Using Angular Radial Transform Descriptors

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Abstract: Problem statement: The shape-based logo recognition systems have been developed to automate the logo registration process. The logo recognition operation faces many challenges such as having to recognize logos that might be scaled, rotated, translated and added with noises. Different types of logo's shapes further add to the complex nature of this problem. **Approach:** We developed a logo recognition system that comprises of three phases: Preprocessing, feature extraction and features matching. For feature extraction, we adopted a region-based Angular Radial Transform (ART) to extract the features from logo's shapes. We used the Euclidian Distance (ED) as a similarity measure parameter for the features matching. **Results:** We tested the system that used the ART as feature extraction method on a large logo database of 2730 images to investigate the effect of several deformations and noise on recognition performance. The experimental results showed the system that use the ART features was robust against the size changing, had an excellent discrimination power against different types of noises and good immunity to rotations. The performance evaluation results showed that ART technique perform better than Zernike moments and Invariant moment's techniques. **Conclusion:** The proposed ART descriptor was very effective to describe all types of logo's shapes independent on different types of deformations and noise. It also represented the logo's shapes in concise manner without information redundancy.

Key words: Angular Radial Transform (ART), Region-based, Euclidian Distance (ED), Affine Moment Invariant (AMI), Zernike Moments (ZM), Invariant Moment (IM), logo recognition system, contour-based techniques, rotation angle, device-mark, complex-mark

INTRODUCTION

With the growth in the business world and the vast increasing of the provided products and services, the logos are specially designed to serve as identification to the brands name. A logo represents the goodwill of the business, particular manufacturer or producer and used to prevent the consumer from becoming confused or misled about the origins or sources. For that, the logo of each brand should be unique. To handle this aim, the logo registration office perform infringement test to ensure that the new logo symbol is not identical to each registered logo. The previous practice to carry out this process was performed manually by human operator, but with the rapid increasing in the number of registered logos, the development of automatic logo recognition system becomes crucial. The traditional recognition process of logo images is based on their shape features, since the shape of objects within the logo provides a powerful visual clue to image identity (Hwang and Kim, 2006).

In the logo recognition system the adopted shape description method has the most important effect on the recognition performance. It is convenient that the shape descriptor have invariant properties against different types of deformations such as scaling, noise, translation and rotation. It is also should have enough description power to the different complex shapes of logos: Word-in-mark (logo that contains only characters or words in the mark), Device-mark (contains graphical or figurative elements only), Composed-mark (consist of characters or words and graphical elements) and Complex-mark (contains a complex image).

The shape description techniques are broadly divided into two categories: Contour-based and region-based. The contour-based techniques are not suitable for complex shapes consisting of multiple disconnected regions such as clipart, trademarks or logos and

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emblem, since the techniques of this category describe each region separately (Yadav *et al.*, 2008). The region-based techniques, on the other hand consider the whole area of the object by describing all the pixels constituting the shapes (Yadav *et al.*, 2007). For that, in the recent years many region-based techniques are utilized in several remarkable logo recognition systems. The state-of-the-art in logo recognition is the methods based on Zernike Moments (ZM) and Invariant Moments (IM). Those methods have been used Lam *et al.* (1996), (Kim and Kim 1998), (Amayeh *et al.*, 2003) and (Wei *et al.*, 2009). However, the Invariant moments are usually used to describe the simplest type of logos that is the device marks and that is interpret the insufficient in the description performance to cope the other complex types of logos, on the other hand the authors in (Amayeh *et al.*, 2003) have been reported that the ZM descriptor is variant under translation and scaling.

Therefore, in this study we apply the Angular Radial Transform (ART) descriptor to the problem of logo recognition. In fact, ART had been proposed as region based shape descriptor for the MPEG-7 standard (Kim and Kim, 1999; Bober, 2001). The ART features are invariant under rotation, scaling, translation and noise (Hwang and Kim, 2006; Kotoulas and Andreadis, 2008; Nasrudin *et al.*, 2010), furthermore they are have the ability to describe the complex objects effectively (Ricard *et al.*, 2004; Ricard *et al.*, 2005). The ZM and IM descriptors are used as benchmarks methods.

MATERIALS AND METHODS

The proposed logo recognition system can be used to recognize and retrieve the most relevant logos from the database when query image presents to the system. To do so, the proposed system comprises three phases: preprocessing, feature extraction and features matching. Figure 1 shows the framework of the proposed system, while each phase will be described in the following.

Preprocessing: Two steps of preprocessing are performed to each query image, i.e. binarization and size normalization (into 200*200 pixels). The preprocessing phase usually used to pave the way to the next stages. Furthermore, it has a direct effect on the reliability and efficiency of the feature extraction process. In order to make an equal comparison, for the ZM descriptor we added a preprocessing step as suggested in (Kan and Srinath, 2002) to make it invariant under scaling and translation.

Feature extraction: In this study, in order to extract a set of features from the logo images, The ART feature extraction method have been proposed. This method describes the 2-D objects in a unite desk, that means all pixels falling inside the image are used in the computation, where the dimensions of the unit desk are the dimensions of the image. The ART coefficient F_{nm} of order n and m, are defined by:

$$F_{nm} = \int_0^{2\pi} \int_0^1 V_{nm}(p,\theta)f(p,\theta)pdpd\theta \tag{1}$$

Where:
P = Radial component
θ = Azimuthal component
f(p,θ) = Image intensity function in polar coordinates

$V_{nm}(p,\theta)$ = ART basis function of order n and m that are separable along the angular and radial directions, that is:

$$V_{nm}(p,\theta) = A_m(\theta)R_n(p) \tag{2}$$

To achieve rotation invariance, an exponential function is used for the angular basis function. The radial basis function is defined by a cosine function:

$$A_m(\theta) = \frac{1}{2\pi}e^{jm,\theta}, \text{Where } j = \sqrt{-1} \tag{3}$$

$$R_n(p) = \begin{cases} 1, & n = 0 \\ 2\cos(\pi np), & n \neq 0 \end{cases} \tag{4}$$

In order to utilize the optimal invariant performance of the ART descriptor, the radial n and the angular m in the ART coefficient F_{nm} is set into n=3 and m=12, i.e. $(0 \leq n < 3, 0 \leq m < 12)$. That means 36-entry features will extracted from the query logo and each logo in the database.

Feature matching: The feature matching phase will serve to detect the relevant shapes to the submitted query image. The Euclidian Distance (ED) is utilized to measure the similarity distance between the query image features and the features extracted from the images in the database. ED is defined as:

$$d(F^I, F^Q) = \sqrt{\sum_{j=1}^{n}(F_J^Q - F_J^I)^2} \tag{5}$$

where, $F^I = F_1^I, F_2^I, ..., F_n^I$, $F^Q = F_1^Q, F_2^Q, ..., F_n^Q$ are the feature sets extracted from the images that need to calculate the similarity distance between them and n is the number of these features. The obtained distances are sorted in ascending order to simplify the retrieval operation.
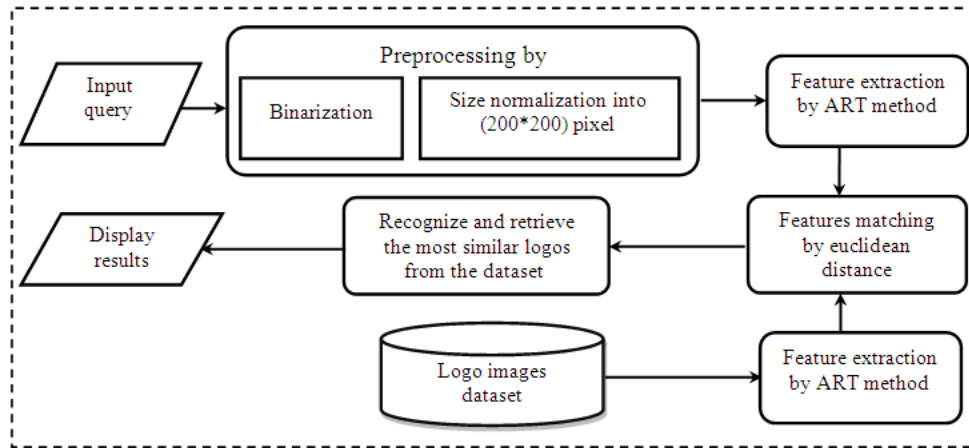
Fig. 1: The architecture of the proposed logo recognition system

Table 1: Number of logos

Type of logos	Quantity
Origin logos	105
Scaling logos	315
Logos with additive noise	840
Logos with multiplicative noise	840
Rotation logos	540
Translation logos	105
Total	2730

Performance evaluation: The performance of the proposed system that used ART as a shape descriptor is evaluated by comparing it with systems based on Zernike Moment (ZM) and Invariant Moment (IM). To describe the logos shapes by ZM, three orders and three repetitions are calculated as suggested Khotanzad and Hong (1990) that means six features are extracted from each image.

For IM, the Affine Moment Invariant (AMI) that proposed by Flusser and Suk (1993; 1994;1994) is utilized. The proposers of the AMI have suggested utilizing either four or six invariant moments. However, in this study we will use six moments to describe the logos shapes since the last two invariant moments have additional desirable properties such as the invariant against mirror reflection (Suk and Flusser, 2006).

Retrieval performance: The retrieval performance of each descriptor is measured in term of precision. Precision P is defined as the ratio of the number of retrieve relevant shapes 'r' to the total number of retrieved shapes 'n', i.e. P=r/n. The physical significance of precision is the measurement of accuracy (Yadav *et al*., 2007; Yadav *et al*., 2008).

Logo database: To perform a considerable performance evaluation experiment, we used the logo database that has been developed by the University of Maryland and called UMD. The UMD contains 105 logo images with all types of logos (word-in-mark, device-mark, composite-mark and complex-mark). To use these images, we preprocessed the origin logos by binarization and size normalization into 200*200 pixels. The preprocessing was followed by differ the origin logos by different rotation angles, scaling factors, noise and perspective translations. This is to investigate the effect of those deformations on the logo recognition. In total, we developed 2730 distinct logo images that were divided into 105 classes. Each class contains 26 relevant logos. Table 1 presents the number of logos with rotation, scaling, noise and translation over the whole database.

Performance evaluation criteria: The performance estimation process is measured based on how well the relevant logos can be retrieved in present of different types of deformations and noise. Then, the robustness measurement is used to evaluate the performance of the proposed system based on the effect of scaling, effect of noise, effect of translation and effect of rotation. To handle those criteria on the real ground, four testing sets obtained from the developed database were used in the evaluation experiments:

- The first set of test includes all the scaled logos in the dataset
- The second set of test includes all the noised logos in the database
- The third set of test includes all the translated logos in the dataset
- The fourth set of test includes all the rotated logos in the dataset

Table 2: Examples from the testing sets
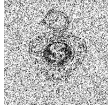
Test type	Model logo	Test example		
Scaling testing set				
Noise testing set				
Translation testing set				
Rotation testing set				

Table 3: Number of logos in each testing set

Exp. type	Data		
	Testing data (logos)	Reference data (logos)	Objective of the experiment
Effect of scaling	315 (scaled)	2415	To test the scale invariant
Effect of noise	1680 (noised)	1050	To test the tolerance to the noise
Effect of translation	105 (translated)	2625	To test the robustness to perspective translation
Effect of rotation	525 (rotated)	2205	To test the rotation invariant

Table 2 gives examples from each testing set.

Experiment: Table 3 shows the experiments details that include the number of logo images in each testing set and the objective of the experiment.

RESULTS

The obtained results by implementing the proposed system and the other two systems in mathlab programming language on a duo core 2.0 GHZ computer have been organized and presented in four major steps based on the type of the experiment as follows.

Effect of scaling: After submit the 315 logos of the first testing set as query images, the accuracy results that shown in Table 4 have been obtained.

Effect of noise: In the second experiment, the effect of different types with various variance magnitudes of noise was studied. The objective was to test the tolerance of the proposed system against the noise and to investigate until which variance value the retrieval of the relevant shapes is still possible. The experiment was started by submit queries undergo by Gaussian noise with variance value $\sigma^2 = 0.01$, the experiment was repeated by using varied values of σ^2 (0.05, 0.1, 0.2, 0.25, 0.3, 0.4, 0.5). Similarly, queries undergo by Speckle noise with starting variance values $\sigma^2 = 0.04$ were submitted; also the experiment was repeated by using varied values of σ^2 (0.05, 0.3, 0.4, 0.5, 3, 4, 5). The obtained results in Table 5 shows that the retrieval of similar shapes was possible when the variance values less than: $\sigma^2 = 0.2$ for IM system, $\sigma^2 = 0.25$ for ZM system and $\sigma^2 = 0.5$ for ART system when queries with Gaussian noise were submitted. For the queries with Speckle noise, the retrieval of similar shapes was possible when the variance values less than: $\sigma^2 = 0.3$ for IM system, $\sigma^2 = 4$ for ZM system and $\sigma^2 = 5$ for ART system as shown in Table 6.

Effect of translation: By submit the 105 translated logo images of the third testing set, the effect of perspective translation on the performance of the proposed system was investigated. The segmentation algorithm Kan and Srinath (2002) that was used for the ZM system also been tested to the proposed and IM systems. The obtained results by these experiments are shown in Table 7.

Effect of rotation: The last evaluation experiment was carried out to test the robustness against rotation. In a similar manner to the previous experiments, the images of the fourth testing set were submitted to the three systems and the accuracies of these systems were compute. The obtained results are presented in Table 8.

Table 4: The accuracy of the three systems in present of different scaling factors

Scaling factor	The proposed system (%)	IM system (%)	ZM system (%)	ZM system + preprocessing (%)
0.9	95.2381	72.3810	10.4762	61.6667
0.7	78.0952	16.1905	7.6190	61.1905
0.5	53.3333	12.3810	2.8571	59.2857
Average	75.5555	33.6503	6.9841	60.7143

Table 5: The accuracy of the three systems against queries undergo by different variance magnitude of gaussian noise

σ^2	The proposed system (%)	ZM system (%)	IM system (%)
0.01	99.0476	68.5714	12.3810
0.05	71.4300	61.9048	4.7619
0.1	39.0476	16.1905	1.9048
0.2	14.2857	1.9048	0.0000
0.25	11.4286	0.0000	0.0000
0.3	3.8095	0.0000	0.0000
0.4	3.8095	0.0000	0.0000
0.5	0.0000	0.0000	0.0000

Table 6: The accuracy of the three systems against queries undergo by different variance magnitude of speckle noise

σ^2	The proposed system (%)	ZM system (%)	IM system (%)
0.04	100.0000	86.6667	62.8571
0.05	100.0000	85.7143	46.6667
0.3	27.6190	14.7143	0.0000
0.4	24.7619	13.3333	0.0000
0.5	12.3810	9.5238	0.0000
3	2.8571	1.9048	0.0000
4	0.9524	0.0000	0.0000
5	0.0000	0.0000	0.0000

Table 7: The accuracy of the three systems against the perspective translation

Image condition	The proposed system (%)	IM system (%)	ZM system (%)
Translated images	27.619	8.5714	5.7143
Segmented images	100.00	73.7341	61.9048

Table 8: The accuracy of ART system in present of different rotation angles

Rotation angle	The proposed system (%)	IM system (%)	ZM system (%)
9°	99.0476	86.6667	0.9524
30°	73.3333	90.4762	10.9524
60°	61.9048	94.2857	18.0952
90°	66.6667	88.5714	1.9048
180°	92.3810	79.0476	15.2381
Average	78.6667	87.8095	9.4286

DISCUSSION

During the four performance evaluation experiments, the results that obtained by the proposed systems that used ART as a shape descriptor were compared to their corresponding from the other two systems of ZM and IM. In the first experiment, the ART descriptor shows robustness to different values of scaling factors and outperforms the other two descriptors. Figure 2(a) shows the precision performance of the three descriptors in this testing set. After analysis the obtained results by this experiment, it was noted that the accuracy of all the descriptors were decreased dramatically when the scaling factor is decrease. This phenomenon have been investigated and found that, when the queries have been scaled especially by high scaling factors such as 0.5 the most relevant information about the shape were changed and that certainly effects on the shape discrimination. However the ART descriptor showed the lest effect. The accuracy performance of the ZM descriptor had increased after we applied the suggested preprocessing step Kan and Srinath (2002), nevertheless the performance of the ART descriptor is still the best.

The results that obtained from the second experiment that involved test the ART descriptor against the noise, clearly shows that the proposed descriptor has much tolerance power against the noise compared to ZM and IM descriptors. It gave the highest accuracy and had the ability to recognize and retrieve the relevant shapes when the queries include noise with high values of variance. As shown in Figs. 2(b-c), ZM descriptor also shows reasonable retrieval performance in both types of noise compared with IM, while the poorest results were obtained by IM.

The obtained results from the third experiment by all the descriptors were poor due to the nature of the query logos. Translating the multi disconnected objects within the logo will yield a new shape that is difficult to discriminate. However, the accuracy had increased after the segmentation processes were added to the systems. Generally, the proposed descriptor performed better than the others.

The last experiment shows that the proposed ART method outperforms the other two methods when images were rotated by 180˚. This descriptor also outperforms the others when it was used with image rotated by small rotation angle such as 9˚. For the rest rotation angels the IM performed better than the other methods. Nevertheless, the proposed ART method shows reasonable retrieval accuracy to be considered as a robust feature extraction method against the rotation. Figure 2(d) shows the precision of the three descriptors against the fourth testing set.
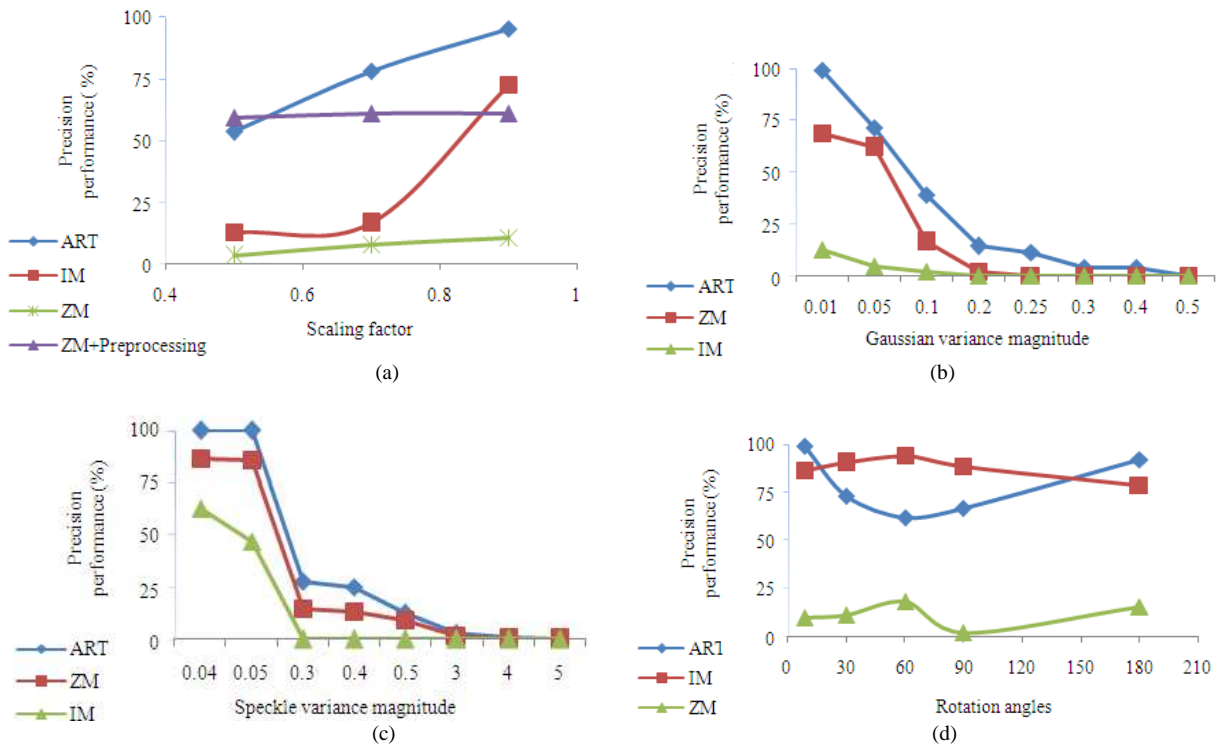
Fig. 2: Average precision performance of three descriptors when query images are deformed by (a) scaling
(b) Gaussian noise (c) Speckle noise (d) rotation

CONCLUSION

In this study, a new shape-based logo recognition system using Angular Radial Transform descriptor (ART) has been proposed. It has been tested on developed large logo database of 2730 logo images. The results that obtained by implement the proposed system on the developed database shows that the ART descriptor is robust against the scaling, has excellent tolerance power to different types of noise and performed well against the rotation. It is also describes simple and complex shapes effectively, where it is copes all types of logos: word-in-marks, device-marks, composite-marks and complex-marks.

The performance of the proposed ART descriptor was evaluated by compared it to other two state-of-the-art descriptors the ZM and IM. Based on the comparative experiments results, the ART descriptor performs better than the other techniques. For the ZM, defining the target image using a polar coordinate in a unit circle might be the reason of it is inferior results against some types of deformations. However, the preprocessing process helps the ZM descriptor to cope with the translated and scaled images. Where else, the IM method is particularly sensitive to distortions that affect the 'center of gravity' of the target image, like the effect of deformation which could represent clutter or local damage of the image.

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