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A TRANSFORMATION BASED STATISTICAL APPROACH FOR COPY DETECTION

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Abstract

Image hashing is one of the latest concepts of multimedia processing and is alternative to many applications previously implemented with watermarking. Image hashing is basically used to identify copy detection and content authentication of images. One of the major problems with the existing image hashing technologies is their limited resistance to a particular image hashing attack i.e. rotation. In this paper, we have proposed image hashing approach based on radon transform and statistical features, which is robust to many of image processing attacks including rotation. In the proposed technique, the input image is firstly normalized by using resizing, Gaussian filtering and color space conversion from RGB to YCbCr. The processed image is then divided into 64 equal size sub-matrix where Radon transform is then applied to each of the sub-matrix to produce the Radon coefficients. Averaging of the radon coefficients of each sub-matrix is done and combined to form the final matrix. Average values are once again computed row-wise from the final matrix to produce a column vector. The vector thus produced is used to calculate four statistical features, Mean, Standard Deviation, Kurtosis and Skewness which is used as a feature vector for image identification. Many experiments have conducted to compare the proposed technique with other state-of-the-art techniques and the result shows that the proposed technique is not only robust to various digital operations but also gives excellent result against rotation.

1. Introduction

Due to the wide spread use of digital technology, good number of images are being created and stored every day. In other words, initiation of Internet and multimedia technology has a significant impact on the creation,

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duplication and sharing of digital images [1]. Creation of duplicate copies will affect the existing system in multiple ways. Firstly, one cannot determine if an image already exists in database without examining all the stored copies. Secondly, duplication copies give rise to the concept of copy detection. The illegal duplication and counterfeit techniques for image have always been ahead of image forensic techniques [2]. Protecting the copyright of an image is a matter of great concern and thus finding the illicit copies have become an important focus for digital rights management [3]. To prove that image is an original one and is not a customized copy, image authentication techniques are in place [4].

Digital watermarking is one of the first techniques used to validate the authenticity of image, in which a signature is generated and appended within an image for identification [5]. The substitute to watermarking is Copy detection technique which does not depend on any signatures but the content itself is used as a signature to verify its originality [6]. New studies of copy detection are focusing towards a shorter version of copy detection termed as image hashing. In image hashing, unique features are extracted from the image which will be used for image identification [7, 8]. Hypothetically, image hashes should be able to discriminate between the robustness and discrimination for image identification apart from its robustness towards different image processing attacks. The rest of the paper is arranged is as follows: Section 2 gives an overview of literature related to image hashing. Section 3 elaborates proposed image hashing technique and Section 4 presents the experimental results. Section 5 concludes the paper.

2. Review of Literature

Many researchers worked on different algorithms related to various aspects of image hashing. Few of the prominent algorithms are given as follows:

Tang et al. [7] proposed image hashing technique based on dominant DCT coefficients which have been proven to perform well in classification and in detecting image copies. The proposed technique exhibits low collision probability which directly means that slightly different images will generate different hashes. Longjiang et al. [9] proposed a robust method based on sign bit of DCT. Tang et al. [10] used a concept based on a dictionary, which

represents the uniqueness of various image blocks. Tang et al. [11] proposed image hashing based on ring partition and invariant vector distance. Tang et al. [12] proposed another hashing method based on ring based entropies. The authors claim that their mechanism outperforms similar techniques in terms of time complexity.

Wu et al. [13] proposed a hash algorithm based on radon and wavelet transform. The proposed mechanism is discriminable to content changes. Xudong et al. [14] is similar to [15] where Harris detector is used to select the most stable keypoints which are less vulnerable to image processing attacks after applying SIFT. Venkatesan et al. [16] proposed novel image indexing technique in which after wavelet decomposition of the image, each sub-band is randomly tiled into small rectangles. The resulting hash is statistically independent on a key K which is variable in nature. Lefebvre et al. [17] presents a high compression and collision resistant algorithm named as RASH based on Radon transform.

Tang et al. [18] proposed a robust hashing method in which after preprocessing Non negative matrix factorization (NMF) is applied to the secondary image to produce a coefficient matrix, which is coarsely quantized and randomly scrambled to produce the final hash. The algorithm exhibits a low collision probability. Qin et al. [19] proposed a hash algorithm in which the pre-processed image is converted to a secondary image by rotation projection. The proposed mechanism is claimed to be robust against basic image processing operations. The advantage of DFT-based techniques is that they are resilient to content-preserving modifications such as moderate geometric and filtering distortions [20].

Most of the given techniques performed well under many of the image processing attacks. However, majority of them failed against a particular image processing attack i.e. rotation. Rotation is one of the simple and powerful image processing attack which can be applied very easily by using any of the image editing software. The paper proposes image hashing technique based on Radon transform and statistical features to address the problem related to image rotation. Many experiments are conducted to evaluate the proposed hashing technique on different performance parameters. Results proved that the proposed technique outperforms many of the similar image hashing algorithms.

3. Proposed Image Hashing

Major steps of the proposed image hashing algorithm are shown in figure 1. Initially, preprocessing is done which converts input image to normalized image. In the next step, Radon transformation is then applied to generate a row vector which is used to generate final image hash. Lastly, four statistical features are calculated for hash generation.

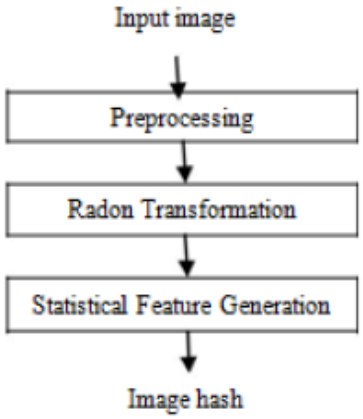

Figure 1. Steps of proposed approach.

3.1. Preprocessing

The input image is firstly normalized by means of resizing, Gaussian filtering and color space conversion. Image resizing is used to resize the image to a standard size of 512x512; 3x3 Gaussian filtering is done to filter out the effects of minor image processing operations. RGB image is then converted to YCbCr image where only the Y component is taken for final hash generation.

3.2. Radon Transformation

Radon transform is the projection of the image intensity along a radial line oriented at a specific angle. In medical image processing, when a bundle of X-rays goes through an organ, its reduction depends on composition of organ, distance and direction or angle of projection [21]. This set of projections is called Radon transform. Radon transform is widely used in areas ranging from seismic analysis to medical images processing. The radon transform of an image $f(x, y)$ denoted as $g(r, \theta)$ is defined as its line

integral along a line inclined at an angle θ from the y-axis and at a distance r from the origin [22] is given in figure 2.

Mathematically, it can be written as:

$$g(r, \theta) = R[f(x, y)] = \int\int_{-\infty}^{\infty} f(x, y)\delta(r - x\cos\theta - y\sin\theta)dxdy. \tag{3.1}$$

The radon transform performs well with respect to translation, rotation and scaling. The properties related to these are given as follows: Translation: If the image is shifted by (x_0, y_0) in the spatial domain, then RT will be translated along r as follows:

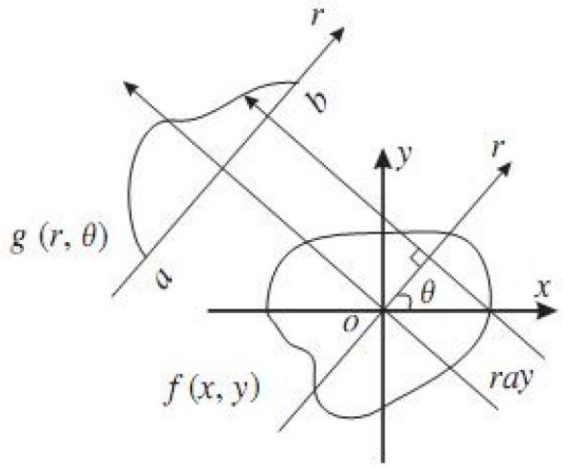

Figure 2. Radon Transform: Projection of an image at angle.

$$R[f(x - x_0, y - y_0)] = g(r - x_0\cos\theta - y_0\sin\theta, \theta). \tag{3.2}$$

Rotation: If the image is rotated by angle, then the corresponding RT will be shifted by the same angle.

$$R[f(x\cos\psi - y\sin\psi, x\sin\psi + y\cos\psi)] = g(r, \theta + \psi). \tag{3.3}$$

Scaling: If the input image $f(x, y)$ is scaled by a factor then it will cause the RT to be scaled as follows:

$$R\left[f\left(\frac{x}{\psi}, \frac{y}{\psi}\right)\right] = \psi g\left(\frac{r}{\psi}, \theta\right). \tag{3.4}$$

The radon transform is resistant to almost all types of geometric transform except shifting, shearing etc. In the proposed approach, it returns better results against rotation and also giving acceptable values for other kind of attacks.

After applying the Radon transform, Radon matrix is produced where each column of the matrix corresponds to Radon transform for one of the angles of different radial co-ordinates. In this paper, Radon transform is applied to the input image by varying degrees from 0 to 179 i.e. with an increment of 1. After applying the radon transformation, we get a two-dimensional matrix which is minimized by removing the zero rows.

3.3. Statistical feature generation

To efficiently capture the content of the entire image, four statistical features mean, variance, skewness and kurtosis are chosen. These statistical features are calculated for every image by using the row generated after applying Radon transformation.

$$f = [f(1), f(2), f(3), f(4)], \tag{3.5}$$

where $f(1)$ is mean, $f(2)$ is standard deviation, $f(3)$ is skewness and $f(4)$ is kurtosis.

3.4. Similarity metric

In this paper, hash distance is used as a similarity measures between a pair of hashes. Let H_1 and H_2 be the two image hashes, then hash distance is defined as follows:

$$\text{Hash distance } (D) = \sum_{i=1}^{4} | H_1(i) - H_2(i) |. \tag{3.6}$$

If HD is not bigger than a predefined threshold, the images of the corresponding hashes are identical, otherwise they are different

4. Experimental Results

Number of experiments is conducted to validate the effectiveness of the proposed mechanism by using MATLAB R2013. The parameters used for

experimentation are as follows: 512x512 input image is normalized by a sequence of image processing operations to obtain processed image of same size. Image thus produced is then divided into a 64 sub-matrix of size 64x64. Radon transform is applied to each of the sub-matrix to produce a 64 radon matrix of size of 95x180. Columnwise average value is computed for each of the radon matrix to produce a row vector of size 1x180. The row vectors of the entire image are combined to form a matrix of size 64x180. Finally, row-wise averaging of 64x180 matrix is done to produce a column vector of size 64x1. Lastly, four statistical features are calculated on the basis of the generated column vector to produce an image hash of size 1x4 which is used for image analysis and identification.

4.1. Performance evaluation

Standard images that were used in our experiments are Baboon, House, Lena, Girl etc. as shown in Figure 3.

Figure 3. Standard benchmark images used.

Each of the original image is used to create 34 different copies by modifying the original image with the number of image processing attacks like brightness adjustment, contrast adjustment, gamma correction, Gaussian low-pass filtering, rescaling and rotation. MATLAB are used for the creation of duplicate copies by using attack parameters as shown in Table 1.

After producing the duplicate copies hashes are extracted from all the images including the original image and hash distance is calculated between the original image and its duplicate copies. Table 2 presents the maximum, minimum, mean and standard deviation of hash distance under different

operations. It is observed that all the mean values are under 6 and maximum distances of all the attacks are less than 11. To exhibit the discrimination, 40 different images of varying sizes from 225x225 to 2144x1424 are accumulated from different databases. Here hash differences are calculated by comparing each of the image with the remaining images in the dataset. Finally, moving in that way 780 hash differences are calculated for 40 different images. The maximum, minimum, mean and standard deviation of hash difference for discrimination is 28.61, 0.75, 9.81, 5.06 respectively.

Table 1. Generation of duplicate copies of original images.

Attack	Parameter	Parameter values	No.of images
BA	Intensity Values	0.05, 0.10, 0.15, 0.20	4
CA	Intensity Values	0.75, 0.80, 0.85, 0.90	4
GC	Gamma	1.25, 1.5, 1.75, 2.0	4
GLPF	Standard deviation	0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0	8
RE	Ratio	0.5, 0.75, 1.1, 1.5, 1.75, 2.0	6
RO	Angle	$-1, -0.75, -0.5, -0.25, 0.25, 0.5, 0.75, 1$	8
Total			34

BA: Brightness adjustment; CA: Contrast adjustment; GC: Gaussian correction; GLPF: Gaussian low-pass filtering; RE: Rescaling; RO:Rotation.

It is fairly obvious here that mean value of discrimination is 9.81 which is almost more than 1.5 times greater than the highest mean of robustness. Also the maximum value of discrimination is 28.61 which is almost 3 times larger than the maximum value of robustness. It is important here to explain that robustness corresponds to the study of duplicate copies of similar images whereas discrimination corresponds to the study of totally different images. Notionally, we are looking for small robustness value and larger discrimination value. The proposed hashing is giving good experimental results with respect to the concept of robustness and discrimination.

Table 2. Maximum, Minimum, Mean and Standard Deviation of hash distance of similar images under different attack.

Attack	Max	Min	Mean	S.D.
BA	6.61	0.51	3.027	1.52701
CA	7.25	0.86	3.252	1.67933
GC	10.8	0.87	5.221	2.19698
GLPF	0.95	0.02	0.258	0.23242
RE	1.43	0.01	0.34	0.28889
RO	2.46	.17	.79	.4809

BA: Brightness adjustment; CA: Contrast adjustment; GC: Gaussian correction; GLPF: Gaussian low-pass filtering; RE: Rescaling; RO: Rotation.

We have also calculated maximum, minimum, mean and standard deviation of difference of hash values between the original image and its duplicate copies, image-wise by considering all but one of the attacks i.e. the difference values are calculated by considering all the attacks except one of the attacks. Here we have used six different attacks, therefore such an analysis will give six different maximum, minimum, mean and standard deviation values for all the images. We also calculate maximum, minimum, mean and standard deviation values by considering all the attacks image-wise. It is essential to specify here that, we get a column based values calculated on the basis of all attacks and all but one of the attacks. Difference is then calculated between the column of mean value calculated on the basis of all the attacks and 6 other column mean values calculated on the basis of leaving one of the 6 attacks. Averaging of the column based difference values are done to produce row vector which reflects the values pertaining to different attacks.

Table 3 gives the averaged values for different attacks for the proposed technique along with two state-of-the-art techniques used for comparison. The acronym used in Table 3 like BA indicates that average values are calculated by considering all the attacks except brightness adjustment. Similarly CA indicates average values calculated on the basis of all the attacks except contrast adjustment and so on. The calculated values are

having different range of values for different techniques. In order to make reasonable comparison among the compared techniques, they are normalized in a range of 0 to 1. Normalized average values of the proposed technique along with few other implemented approaches [7,18] is given in Table 4. For rotation, the normalized values for proposed, [7] and [18] are 0.181, 1.0 and 1.0 respectively. It is quite apparent from these values that proposed technique gives outstanding results for rotation apart from giving satisfactory results for all other attacks.

Table 3. Average difference values for all but one of the attack.

Technique	BA	CA	GC	GLPF	RE	RO.
[7]	– 0.290	– 0.508	– 0.397	– 0.286	– 0.226	1.909
[18]	– 0.028	– 0.073	– 0.288	– 0.383	– 0.806	1.699
Proposed	0.182	0.212	0.475	– 0.431	– 0.283	– 0.267

BA: Brightness adjustment; CA: Contrast adjustment; GC: Gaussian correction; GLPF: Gaussian low-pass filtering; RE: Rescaling; RO: Rotation

Table 4. Normalized average difference values for all but one of the attack.

Technique	BA	CA	GC	GLPF	RE	RO.
[7]	0.090	0.000	0.046	0.092	0.117	1.000
[18]	0.310	0.293	0.207	0.169	0.000	1.000
Proposed	0.677	0.710	1.000	0.000	0.164	0.181

BA: Brightness adjustment; CA: Contrast adjustment; GC: Gaussian correction; GLPF: Gaussian low-pass filtering; RE: Rescaling; RO: Rotation

4.2. Performance with state-of-the-art techniques

Performance comparison of the proposed technique with the state-of-the-art in terms robustness and discriminability was also carried out. The techniques compared include DCT [7] and NMF [18]. To represent the performance, the receiver operating characteristics (ROC) curve is employed which is plotted between the true positive rate (TPR) and the false positive rate (FPR). These parameters are defined as follows:

$$TPR = \frac{n_1}{N_1}, \; FPR = \frac{n_2}{N_2}, \tag{4.1}$$

where n_1 is the number of visually identical images correctly identified as copies while N_1 is the total number of identical images. Similarly, n_2 is the number of different but visually similar images incorrectly identified as a copy while N_2 is the total number of different images. If two algorithms is having same TPR then the algorithm with the lower FPR is considered to be best. Similarly, if two algorithms exhibit the same FPR, then the algorithm with the higher TPR is considered to be best.

The ROC curve for different algorithms including the proposed is given in Figure 4. From Figure 4, it is evident that the ROC curve of the proposed technique is closer to zero as compared to the techniques reported in [7] and [18]. Taking into account the values of robustness and discriminability from the previous subsection along with the TPR and FPR values obtained in this subsection, it is evident that the proposed hashing technique outperforms similar hashing techniques.

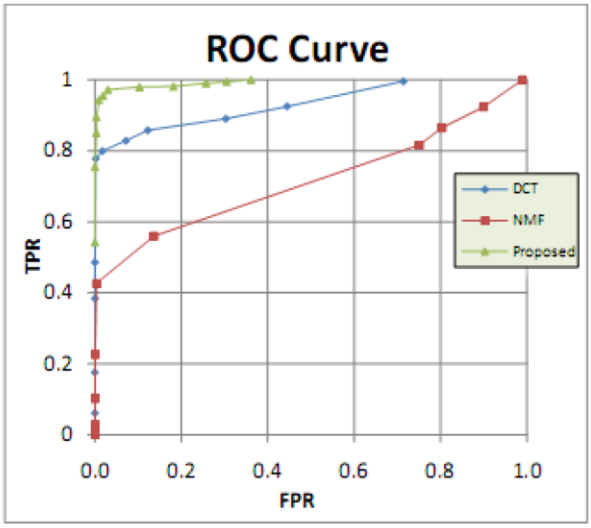

Figure 4. ROC Curve.

5. Conclusion

In this paper, a novel image hashing technique is proposed which is based on radon transform and statistical features. Proposed image hashing firstly calculates the Radon transform for the entire image along different directions

by using different sub-matrices, which are generated on the basis of preprocessed image. Twice averaging of the Radon coefficients is done to generate the final column vector which is used for unique feature generation. Lastly, four statistical features i.e. mean, standard deviation, skewness and kurtosis are calculated from the column vector to produce the image hash which is used for image identification. Different experiments validate the performances of the proposed hashing against number of image processing operations including rotation. Future work will move towards the development of techniques which addresses the limitation of Radon transform.

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