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Review of Geometric Distortions in Digital Image Watermarking

Sukhwinder Kaur Bhatia, Assistant Professor JSPM's Imperial College of Engg. & Research Wagholi,Pune.
Dr.Rajneesh Talwar, Principal Swift Technical Campus Rajpura,Punjab

Abstract— Digital Image Watermarking has become a need of the hour in case of multimedia. But along with that comes the problem of dealing with the geometric distortions. This paper presents an overview of the various techniques used for eliminating geometric distortions. It summarises the advantages and disadvantages of one method over the other. As we are more dependent on multimedia for passing of the information so dealing with the various types of distortion is of utmost necessity nowadays.

Index Terms— Digital Image Watermarking, Geometrical Distortions.

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1 Introduction

Image Watermarking has been evolved as an effective tool for the protection of multimedia contents. But, multimedia documents which are digital in nature can be duplicated, modified, transformed, and diffused very easily. So , it is very important to develop a system for copyright protection, protection against duplication, and authentication of contents. For this, a watermark can be embedded into the digital data in such a way that it is tied to the data itself. Later on, such watermark can be extracted to prove ownership to trace the dissemination of the marked work through the network, or simply to inform users about the identity of the rights-holder or about the allowed use of data. Simple distortions like rotation, scaling or translation of an image can prevent detection of a public watermark so it is desired that the image watermarking scheme must resist a wide variety of possible attacks.

2 Attacks on Watermarking Systems

2.1

Generally, attacks on a watermarking scheme can be classified into two categories as
1) Common image processing operations and
2) Geometric distortions.

The common image processing operations include median filtering, noise contaminating, and compression. Many techniques have been tried and proved to be effective against common image processing operations. But dealing with geometric distortions is an important part because they produce synchronization errors and thus disable detectors to detect watermarks preserved in distorted image. Because of such attacks, many of the watermarking algorithms turn out to be ineffective so it is a current area of research .

Geometric transformations modify the spatial relationship between pixels of an image as it is having no reference except the coordinates of each pixel. So if the image is undergoing any transformation of any kind the watermark detection becomes very problematic and the whole purpose of adding the watermark is defeated. It basically consists of two basic operations: 1) A spatial transformation of coordinates and 2) intensity interpolation that assigns intensity values to the spatially transformed pixels. The transformation of coordinates may be expressed as

$(x, y)= T \{(v, w)\}$

Where (v ,w) = pixel coordinates in the original image
(x, y)= pixel coordinates in the transformed image.

Geometrical distortions can be divided into two classes

a) Global transformations &

b) Local transformations.

Global transformations include rotations, translations cropping, and affine transformations & local transformations include piecewise linear & local weighted mean transformation. Global transformations are easily represented with the help of mathematical equations. So method of exhaustive search is possible, in which all possible transformations are considered and tested.

Adding redundancy during insertion of the watermark helps in solving geometrical desynchronisation & improves detection. Second class is based on template insertion i.e. artificial embedded reference. It can be done by increasing the magnitude of some selected coefficients thus creating a local peak. At the decoder side matching of initial location and detected location is performed .Watermark can also be embedded in an invariant domain and for this Fourier transform along with log-polar mapping may be used. Finally original image may also be used to embed the watermark.[3]

2.2 Literature Review

In the first category the watermark is embedded in the geometric invariant domain. Pun et. al [1] proposed that the watermark is embedded in the magnitude of Fourier–Mellin transformations such as Stir Mark attack to achieve robustness to affine transforms. But watermarking techniques which use invariant domain are prone to cropping and local geometric distortions, and are usually difficult to implement**.** In the second category a template is embedded along with the watermark. In [2], Pereira proposed that a template is embedded in the discrete Fourier transform (DFT) domain to generate the shape of local peaks, and they are used to recover geometric parameters in the detection end. The major limitation of such a system is that the template based methods are vulnerable to template estimation attacks and incompetent to estimate the attack parameters of some complicated geometric distortions. The third category is feature-based watermarking techniques. In this the watermark is binded with the geometrically invariant features; the watermark synchronization error can be avoided. By using such method the watermark is embedded in a number of local regions formed by feature points, such watermarking methods can resist cropping**.**

Bas *et al*. [3] proposed a watermarking scheme where the mark was binded with the content of the image, so the problem of geometrical synchronization is solved. Feature point detector is used in this case that embeds a predefined triangular pattern inside triangles in a tessellation of the image. They basically used and compared three feature point detectors and evaluated their robustness i.e. Harris Detector The Achard Rouquet Detector and the SUSAN Detector. Finally a detector benchmark has been designed that preserves the selected points, when the image undergoes a geometric transformation. The detector has been tested using a number of geometrical distortions like Stir Mark Distortion, shearing transformation, scaling, rotation, print and scan, JPEG compression. The main focus is on self synchronizing schemes, for tackling the problem of geometric distortions i.e. techniques using periodical sequences, template insertion, invariant transforms and using the original image.

In 2005 Dong & Brankon[4] presented two watermarking schemes ,robust to geometric distortion ,based on image normalization and watermark resynchronization scheme Basically the normalized image is obtained from a geometric transformation procedure ,that is invariant to any affine distortions of the image ,so it is able to survive many affine geometric attacks.

The second scheme proposed by them was able to tackle more complex geometric distortion in watermarked image. Such attacks cannot be defined by RST or more general affine transforms.

Tang et.al. [5] adopted Mexican Hat wavelet filtering for feature points extraction, and watermark was embedded in the normalized local regions centered at the feature points to achieve robustness to affine transforms. However, watermarking techniques involving invariant domain are inherently vulnerable to cropping and local geometric distortions, and are usually difficult to implement. However, the size of local regions remains fixed, so that this scheme is vulnerable to rotation and scaling. To further enhance the robustness of the feature based image watermarking, scale-space theory is applied for feature points extraction. Feature points were extracted by Harris–Laplace detector, and several copies of the watermarks were thereafter embedded in the circular disk centered at the feature points. However, the drawback of this scheme is that the circular embedding region is highly sensitive to nonisotropic scaling and projective transformations.

To this end, Seo and Yoo [6] exploited the affine invariant point detector to extract feature points. Then an elliptical feature region is formed and used for embedding in spatial domain. Before embedding, the watermark is geometrically transformed into an elliptical pattern according to the shape of the region. This approach possesses a certain degree of robustness and provides a potential idea for resistance against complicated geometric distortions. However, the overlapping between feature regions has not been resolved in this approach.

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- *s is currently pursuing masters degree program in electric power engineering in University, Country, PH-01123456789. E-mail: author_name@mail.com*
- *Co-Author name is currently pursuing masters degree program in electric power engineering in University, Country, PH-01123456789. E-mail: author_name@mail.com*
  (Th*is information is optional; change it according to your need.)*

Solachdis & Pitas [7] proposed another method for digital image watermarking, that is resistant to geometric transformations. In this case a private key, which allows a very large number of watermarks, determines the watermark, and is embedded on a ring in the DFT domain. However applying Fourier Mellin Transform has been avoided to decrease computational complexity and to avoid problems involved in log polar coordinate system transformation errors. This watermark possesses circular symmetry in order to solve rotation invariance. Correlation is used for watermark detection.

Pereria & Pun [8] proposed another approach in which an additional template, known as a pilot signal in traditional communication systems is embedded, besides the watermark embedded in DFT domain of the image. This embedded template was used to estimate the affine geometric attacks in the image. The image is first corrected with estimated distortion & the detection of watermark performed afterwards .Theoretical analysis was provided on bit error rate for this plot based approach, under a number of geometric attacks.

Kutter et.al [9] provided another solution to counter geometric distortions that were content based watermarking schemes. He proposed a scheme based on point features in images using a scale interaction technique based on continuous wavelets. In this way the location of the mark is not linked with image coordinates but with image semantics. The problem of geometrical synchronization is solved because the image content represents an invariant reference to geometrical transformations. Content based techniques belong to send generation watermarking schemes because the image's content is exploited for embedding of the mark.

Duriac et al. [10] proposed a method for restoring the original appearances of images & it is used to recover the embedded watermarks. Authors developed another watermarking method based on finding unique points in each image at multiple resolutions to identify the geometrical transformation. Local geometric distortions are countered calculating normal displacement fields between two images.

Sun et al. [11] developed another watermarking method based on image feature to identify the geometrical transformation. First feature points are extracted from the original & the marked image. Then the synchronizing scheme performs a matching between the two set of points and identify the transformation.

So we say that Ruanaidh & Pun work was a great work in invariant domain, as they used FMT on the watermark only to achieve robustness to affine transformations but still it is prone to cropping & local geometric distortions. Then the second method by Pereira focused on inserting a template in DFT ,but these methods are vulnerable to template estimation attacks. Dong & Brankov worked on two watermarking schemes, based on image normalization & watermark resynhronisation. Tang et al proposed to embed the watermark in a circular disk centered at feature points but it is highly sensitive to nonisotropic scaling. So Seo & Loo used an elliptical feature region for embedding in spatial domain. It provides resistance against complicated geometric distortions but overlapping between feature regions has not been resolved. Scholadis & Pitas embedding a private key on a ring in DFT domain .Its advantage being that it posseses circular symmetry . Pereira & Pun also proposed an approach in which a pilot signal is embedded in DFT domain of the image and it was analysed based on calculation of bit error rate.Kutter et al work was based on content based watermarking schemes where the location of the mark is linked with the image semantics and it solves the problem of geometric synchronization.

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