Review of Geometric Distortions in Digital Image Watermarking

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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.

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 pa-
parameters of some complicated geometric distortions. The third category
is feature-based watermarking techniques. In this the watermark is bind-
ed with the geometrically invariant features; the watermark synchroniza-
tion error can be avoided. By using such method the watermark is em-
bedded in a number of local regions formed by feature points, such wa-
tmarking methods can resist cropping.

Bas et al. [3] proposed a watermarking scheme where the mark was
binned with the content of the image, so the problem of geometrical synchr
chronization 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 detec-
tors and evaluated their robustness i.e. Harris Detector, The Achodzą Rou-
quet 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 us-
ing a number of geometrical distortions like Stir Mark Distortion, shear-
ing transformation, scaling, rotation, print and scan, JPEG compression.
The main focus is on self synchronizing schemes, for tackling the prob-
lem 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 wa-
termark 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 de-
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 in-
herently vulnerable to cropping and local geometric distortions, and are
usually difficult to implement. However, the size of local regions re-
mains 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 robust-
ness and provides a potential idea for resistance against complicated
distortions. However, the overlapping between feature regions has not been resolved in this approach.

Solachdis & Pitas [7] proposed another method for digital image water-
marking, that is resistant to geometric transformations. In this case a
private key, which allows a very large number of watermarks, deter-
mines the watermark, and is embedded on a ring in the DFT domain.
However applying Fourier Mellin Transform has been avoided to de-
crease 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 geom
metric attacks in the image. The image is first corrected with estimated dis-
tortion & the detection of watermark performed afterwards. Theoretical
analysis was provided on bit error rate for this plot based approach, un-
der a number of geometric attacks.

Kutter et.al [9] provided another solution to counter geometric distor-
tions that were content based watermarking schemes. He proposed a
scheme based on point features in images using a scale interaction tech-
nique based on continuous waves. 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 appear-
ances of images & it is used to recover the embedded watermarks. Au-
thors 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 do-
main, 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 estima-
tion attacks. Dong & Brankov worked on two watermarking schemes,
based on image normalization & watermark resynchronization. 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 pro-
vides resistance against complicated geometric distortions but overlap-
ning between feature regions has not been resolved. Scholadis & Pitas
embedding a private key on a ring in DFT domain. Its advantage being
that it possesses circular symmetry. Pereira & Pun also proposed an ap-
proach 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 loca-
tion of the mark is linked with the image semantics and it solves the
problem of geometric synchronization.

2.4

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