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# A NEW WATERMARKING SCHEME, ROBUST AGAINST JPEG COMPRESSION AND SOME ASYNCHRONEOUS ATTACKS BASED ON HOUGH TRANSFORM

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*ABSTRACT:* Because of the unavoidable need to Internet in data exchange and multimedia use, in addition to the expand of electronic commerce, digital watermarking has been presented as solution to the copy protection of multimedia against properties stealing. In the diffusion process, informations are subject to different malicious or unintended attacks. In the other hand, because of the need to reduce the amount of manipulated data, the jpeg lossy compression remains the more involuntary attack used with data manipulating. This paper proposes a novel method for image watermarking based on the parametric space of the mathematical Hough transform. This space is used as a transform domain to process the image and embed the watermark. Different attacks permitting to test the robustness of the proposed watermarking scheme are simulated by the STIRMARK tool. After different applied attacks, experimental results show that the proposed method is very robust against lossy compression, and some geometrical attacks without any need to use the transformed DCT or multi-resolution domains.

*Keywords: Watermarking, Hough transform, JPEG robustness, Stirmark attack, Parametric space, New watermarking domain.*

## 1 Introduction

The increased commercial activity on Internet and media industries, demand protection of media such as images, video and audio against illicit processing and use. This data can be copied or redistributed, without any consideration to the proprietor rights [3,10,17 and 20]. To this end, there has been growing interest in developing effective techniques to discourage the unauthorized duplication of digital data with providing copyright protection [8] and proving owner rights [4,11]. Since it makes possible to identify the author, owner; or allowed consumer, watermarking is found to be an efficient way to prove ownership and defeat intellectual properties theft [19]. In the other hand, different constraints are required in a watermarking method, such imperceptibility and robustness [1, 9, 13 and 14]. In the other hand, lossy jpeg compression remains the most unintended used attacks with data exchange in Internet, for size reduction. It can seriously affect the embedded watermark if the compression rate is high and the used scheme presents a weakness against this attack. In this case, the best solution resides in exploiting the transformed DCT domain used in the jpeg algorithm [12] in order to dispose of robustness against this compression or the multi-resolution domain as in [6,12 and 22]. But acting to be robust against this attack reveals automatically the domains of watermark embedding and than increase the possibility of its detection. In this paper a novel watermarking method is proposed. It consists in using the parametric space of the mathematical Hough transform as a watermarking domain. The technique consists in selecting specific maximums in the Hough matrix with respect to a secret key. The peaks are found to be invariant points in the proposed Hough domain especially against lossy JPEG compression. Two signatures are considered; the first is hold in the Hough domain by the transformed space and consists in the locations of the specific chosen invariant points. Whereas, the second is represented by the use of end points of the correspondent detected lines. These end points are used as centres to embed similarities blocks in. Watermarking in this domain is found to be extremely robust against JPEG compression and some geometrical transforms. All these attacks are generated by the STIRMARK tools [15, 16]. This paper is organized as the following: In section 2, an overview of the Hough transform is presented. Section 3 details the proposed method in the Hough domains: the carried study and the proposed solutions. In section 4, we introduce the robustness of this technique against different STIRMARK attacks, and test the capacity to detect the embedded watermark. The privileges that this approach offer and the simulation results are also detailed and finally we conclude our paper.

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## 2 Hough Transform Overview

The Hough transform is a mathematical algorithm used in images processing to detect the presence of parametric forms as ellipses or lines in the image [5]. This technique uses the principle of evidences accumulating to prove the existence of a particular form in the image. For this aim this transform uses a parametric domain or space to characterize those forms. Each form is represented by its proper parameters in this space. In our work this transform is coded to be used as lines detector where its parametric space is exploited. Its important to note that the Hough transform is found to have the capacity to detect the same segments or broken lines in the image, before and after being compressed. This detection invariance, is due to the fact of the invariance properties of its parametric space in the case where the image is subjected to JPEG compression and some asynchronous transforms. In the case of lines the Hough transform is presented as follows:

Each line can be described in the orthonormal space by the equation (1) or (2)

$$y = a \cdot x + b \qquad (1)$$

$$\rho = x \cdot \sin\theta + y \cdot \cos\theta \qquad (2)$$

The parametric space is than composed by two parameters: ρ and θ forming a space matrix as shown in figure 1.

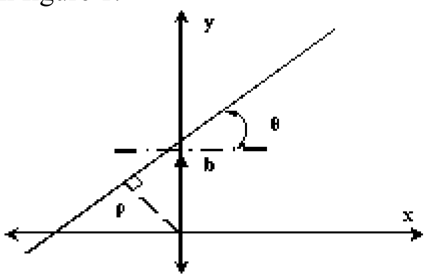


Fig.1: parametric space (ρ, θ).

An infinity of lines can pass through a fixed point called P having (x,y) as coordonates. But if we consider a second point $P_1$ having (x1, y1) as coordinates, one line only can pass through P and $P_1$satisfying the same couple of (ρ and θ) [18]. If this principle is applied to the image, the Hough transform of an image generates a parametric space matrix as presented in (3):

$$H(M) = A(\rho, \theta) \qquad (3)$$

Where H is the Hough transform, M is the image matrix and A is the space parametric matrix resulting. Since this matrix contains a limited number of elements, the number of possible detected line is with respect to the quantization step of the (ρ and θ) in their respective variation domains.

Peaks contained in this space represent an accumulation of evidences indication the possibility of lines presence with respect to a specific position and orientation.

## 3 The Proposed Method

In this work we propose to apply the philosophy of the Hough transform on the image in order to process and manipulate it in the parametric Hough space, and use it as a watermark-embedding domain. If we consider an N × M image; in order to accumulate evidences and define the parametric space, the information source is gathered from the pixels composing the image. More the evidences are accumulated and put in the parametric space matrix; more the chance to identify a real line in the image is high.

In the following, we will define the parametric space matrix generated by the Hough transform as the Hough space or Hough domain.

The first step consists in applying a high pass filter in order to extract the image edges. In each point belonging to this edge, infinity of lines can pass through it. Accumulating evidences in the parametric space provides the unique position and orientation (ρ and θ) for witch one line can pass through this point. In our case the positions and the orientations are quantified by a step computed with respect to the required precision. The Hough space is than a two-dimensional matrix or map, the size of this map depends on the quantification step as shown in figure 2.

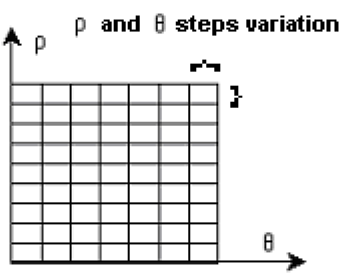


Fig.2: parametric space map.

The quantification steps are computed as follow:

Consider an image with size N × M, θ can vary in the interval range of [0, 2π], the value of ρ is maximum when it's computed in the image diagonal. The steps and variation domains are than described by the equations (4, 5, 6 and 7):

$$\rho_{MAX}^2 = \left(\frac{N}{2}\right)^2 + \left(\frac{M}{2}\right)^2 \qquad (4)$$

$$\rho_{MAX} = \sqrt{\left(\frac{N}{2}\right)^2 + \left(\frac{M}{2}\right)^2} \quad (5)$$

$$\rho_{MAX} = \sqrt{N^2 + M^2}/2 \quad (6)$$

$$\rho_{MAX} \in \left[0, \sqrt{N^2 + M^2}/2\right] \quad (7)$$

More the quantification steps are decreased, better the resolution is, but the Hough matrix size increase. In order to attend equilibrium between resolution, computing time and parametric space dimension for an N×M image, we will fix the orientation step depending on the image size. If θ varies as $\theta \in [0, 2\pi]$:

$$\theta \in \left[0, \frac{2\pi}{\sqrt{N \cdot M}}\right] \quad (8)$$

If the image is square the resolution will be as:

$$\theta \in \left[0, \frac{2\pi}{N}\right]; \text{and } \rho_{MAX} = \frac{\sqrt{2}}{2} \cdot N; \text{ with } \Delta\rho = \sqrt{2} \quad (9)$$

In the following work we will consider the ρ step as:

$$\Delta\rho = \frac{\rho_{MAX}}{100} \quad (10)$$

$$\Delta\rho = \frac{\sqrt{N^2 + M^2}}{200} \quad (11)$$

These steps provide an acceptable precision to browse the entire image as shown in figure 3.

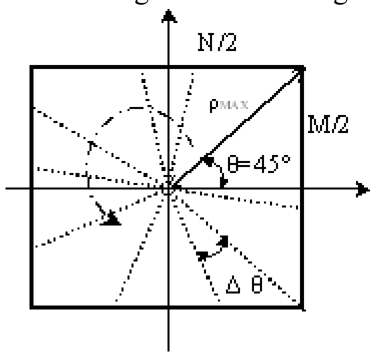


Fig.3: Image browsed by ρ and θ variation.

The operation of accumulating evidences in the Hough matrix for potential presence of lines in the image is characterized by the appearance of maximums in the matrix. A threshold is previously chosen to characterize since witch values we can consider maximums in the space parametric matrix as peaks. The number of picks and their position in the Hough map is used as secret key. By finding and fixing the peaks number, we extract the correspondent lines and respectively their end points. These end points are used as centres of blocks similarities embedding.

In fact in each end point we extract a block with size equal to $(2 \cdot n+1) \times (2 \cdot n+1)$. All these blocks are substituted with similarities as shown by the equations (12) and (13). If we consider $B_i$ as the chosen block, $W_i$ the watermark and $B_{wi}$ the watermarked block:

$$W_i = dyn(B_i) = \frac{B_i - \ddot{B}_i}{\max(B_i - \ddot{B}_i)} \quad (12)$$

$$B_{wi} = B_i \cdot (1 + \alpha \cdot W_i) \quad (13)$$

Where $\ddot{B}_i$ is the indexed block mean and α is the watermark embedding strength [2]. In the experimental results as will be shown in the next section, the selected peaks (maximums) in the Hough space matrix corresponds to the embedded watermark location in the image. The peaks position in the Hough space and their respective end points in the spatial representation, are completely invariant when the image is attacked by jpeg lossy compression or some geometrical transforms.

## 4 Experimental Configuration

In our experiments, the cameraman image is used to simulate the applied method and the chosen attacks. This image is chosen because of its content variation. In fact it contains lines in addition to homogeneous, and textured zones. On this image a binarizing method is applied to convert it into a binary image. An edge extractor filter is then applied to extract the image edges. Once theses edges are taken out, the Hough transform is coded and then applied on the resultant image to browse it and then accumulates evidences in the transformed parametric matrix to decide witch maximums corresponds real lines in the image. In this matrix, the number of chosen peaks and their respective position represents the secret key used to select the ends of the correspondent lines where the similarities blocks are embedded. The position of the peaks are returned and saved to be compared with the same peaks position after the attacks are applied on the image and view if they can be considered as unvaried points with respect to the applied attack [2]. The peaks are defined as the entire matrix maximum that exceeds a fixed threshold. In this work, in order to obtain a better precision the threshold is fixed as $T_h = 0.7$ and then:

$$P_K = T_h \cdot \max(H) \quad (14)$$

Where $P_k$ represents the returned peaks, H is the Hough matrix. Different peaks can be selected and then view theirs corresponding lines and end points in the image as shown in figures 4,5,6 and 7.

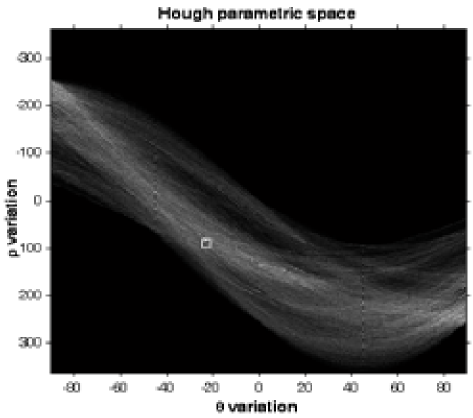


Fig.4: The first pick in the parametric Hough space.

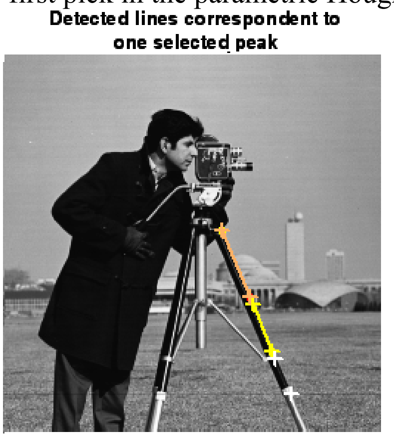


Fig.5: Three detected segments corresponding to the first selected peak presented in fig.4.

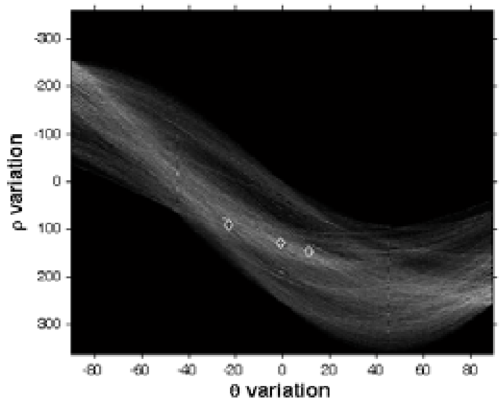


Fig.6: The three first selected picks

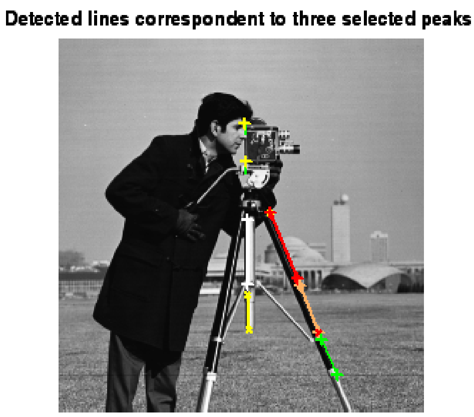


Fig.7: Three detected segments corresponding to the three first selected peak presented in fig.6.

# 5 Simulation Results

In the following simulations the number of peaks is chosen equal to one. The location of the peaks in the Hough parametric space is represented by the respective position in the matrix lines and columns as (L, C). The first peak is selected and its position is returned as (-23, 89.2472) in the Hough matrix space. That means that $\theta = -23°$ and $\rho = 89.2472$. Figures from 8 to 11 presents the detected peaks in the Hough space and their respective positions shown in table1. The correspondent detected lines and respectively their end points where the similarities blocks are embedded are shown in these figures. Table1 presents the attacks applied on the cameraman image; the JPEG compression and the rot-scale transform. The extracted peaks after the attacks have been applied presented. A total invariance is remarked concerning the peaks positions against lossy jpeg compression.

| APPLIED ATTACK | PEAK POSITION IN THE HOUGH SPACE |
|---|---|
| JPEG 100 | (-23, 89.2472) |
| JPEG 90 | (-23, 89.2472) |
| JPEG 80 | (-23, 89.2472) |
| JPEG 70 | (-23, 89.2472) |
| JPEG 60 | (-23, 89.2472) |
| JPEG 40 | (-23, 89.2472) |
| JPEG 30 | (-23, 89.2472) |
| JPEG 20 | (-23, 89.2472) |
| JPEG 10 | (-23, 89.2472) |
| ROTSCALE –0.25 | (-23, 89.2472) |
| ROTSCALE –0.5 | (-23, 89.2472) |
| PSNR 100 | (-23, 89.2472) |

Table1: Invariance of the selected peak position against applied attacks.

## 5.1 Experiment 1: JPEG compression

The figures from 8 to 11 show respectively the cameraman image attacked by the JPEG 10, 20 and 40 compression and the obtained result of the detected peaks position leading to the watermark detection. The proposed method by processing in the Hough parametric space is found to be highly robust against lossy compression. A series of different JPEG compression rates from JPEG 100 to JPEG 10 are applied as shown in table 1. The distortion caused to the watermarked image by all these attacks hasn't changed the position of the selected peaks in the Hough space.

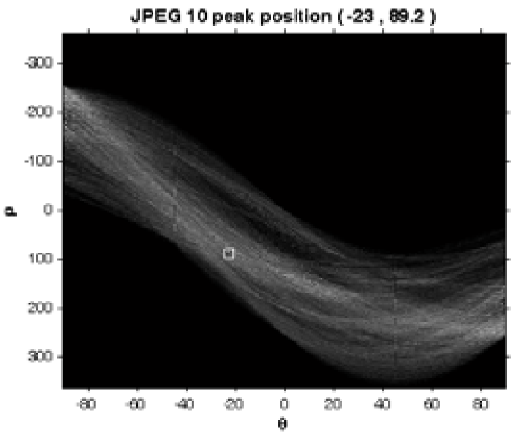


Fig.8: The position of the detected peak in the JPEG 10 compressed image.

Fig.9: End points of the detected lines correspondent to the peak in fig.8.

## 5.2 Experiment 2: asynchronous attacks

Figures 10 and 11 show the rotation and scale attack, and the correspondent detected peaks position in the Hough space. As shown in the table 1 and the figures below, using this space provides high robustness against these attacks and provides invariance properties to the selected peaks if the image is attacked. Specially when dealing with small distortions the invariance of the peaks position is kept unchanged.

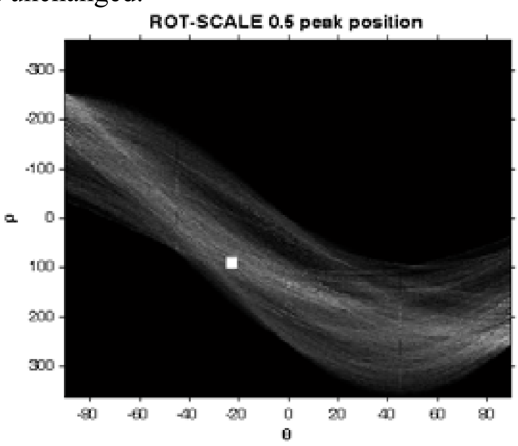


Fig.10: The position of the detected peak in the ROT-SCALE 0.5 attacked image

Fig.11: End points of the detected lines correspondent to the peak in fig.10.

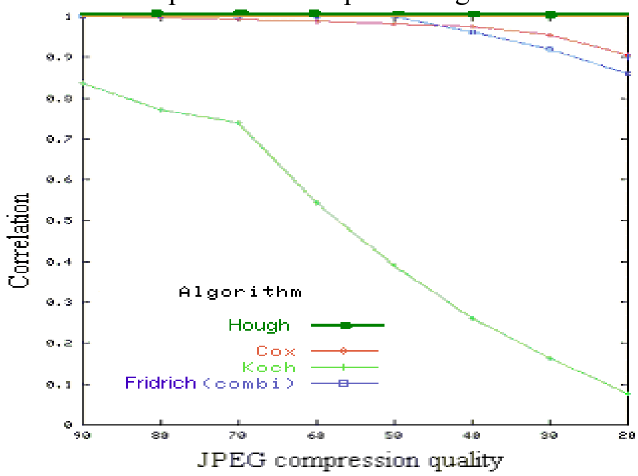


Fig.12: Robustness of the Hough algorithms.

Figure 12 shows the robustness of the proposed Hough algorithm when compared with the well known and most robust algorithms proposed in the DCT domain to defeat the JPEG compression attacks. It's evident that our algorithm is the most robust. This method is found to be better then those actually in use, due to the fact that the image is not processed or modified at all. The image is represented by the Hough parametric space as a new representation domain where the signature is characterized by the unvaried positions of the selected peaks. The robustness of this method is picked out from the robustness of this new Hough domain face to JPEG and other attacks.

# 6 Conclusion

In this work, a new watermarking method is presented. Based on the mathematical Hough transform, a parametric space matrix is obtained and used as a new space where the image is processed. A secret key characterized by the number of selected peaks in this space matrix is chosen. These peaks are found to be invariant and robust against jpeg compression and some asynchronous transforms.

They are also used to determine the correspondent lines end points where similarities blocks are embedded. The embedded watermark is carried in Hough space by the invariant peaks and their position that corresponds to the embedded similarities. This method proposes higher resistance against lossy compression than the previous algorithms based essentially in the DCT domain [7, 3 and 12].

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