Digital Watermarked Anaglyph 3D Images Using FrFT

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***Abstract*— *In recent times, the movement of 3D movies and 3D projection took enormous attention. Anaglyph images are elementarily obtained by overlapping left and right eye images in different color planes of a single image for successive viewing through colored glasses. Digital watermarking is a desirable tool for copyright protection, secret communication, detection of illegal duplication and alteration and content authentication. Here Fractional Fourier transform (FrFT) watermarking algorithm is used for implanting a sequence or an image as digital watermark on one of the stereo pair images and then superimpose on the other image to build a 3D anaglyph watermarked image. In the counter process, De-anaglyph is used to detach the two stereoscopic images from which watermark is derived. Inserting watermark either in the right image or left image fetches more protection compared to embedding watermark straight into an anaglyph image.*

Keywords— *Watermarking; Anaglyph 3D; FrFT; Secret Communication; Stereoscopy*

I. INTRODUCTION

The call for 3D technology has shot up in recent years due to tremendous enhancement in electronics media. These days most of the movies are being produced in 3D format. This 3D technology is not only useful in the entertainment industry, but also in various fields such as secret communication. Sooner or later because of the improvements in the 3D watermarking system will be considered as the most reliable means of security for the data. Humans will discern the depth illusion in a 3D image from two non-identical perspectives. The two viewpoints are from both the eyes provides an excellent immersive vision. The two different images are collectively called as a stereoscopic image and the whole process is called stereo image method.

An anaglyph image is devised by superimposing the stereo pair of images. Watermark can be planted directly to an anaglyph image but in this paper, the watermarks are inserted into the right image of the stereo pair and then combined with left image to create an anaglyph image for a higher degree of security. We can embed the watermark in either right image or left image using Fractional Fourier Transform.

To detect the watermark, a reverse procedure is implemented to the anaglyph image i.e., De-anaglyph, where we detach the left image and the right image and by using fractional Fourier transform and Inverse fractional Fourier transform, a watermark is discovered from the watermarked-right image.

Rest of the paper is arranged in the following pattern. Section II probes a brief study of anaglyph 3D images and its different methods. Section III constitutes fractional Fourier Transform method in 3D images. Section IV comprises of proposed method of watermarking, section V projects proposed method results. Ultimately a resolution will be presented in section VI.

II. ANAGLYPH 3D IMAGE

Stereoscopic 3D illusion accomplished by concealing each eye's image using filters of dissimilar colors, usually red and cyan. The two differently filtered colored images in anaglyph 3D image maps one for each eye. Having two photos capturing at an instant is the vital part in creating an anaglyph image. Both photos must be focused on the same object, sliding the camera horizontally between 3 and 5 cm for the next picture.

Fig. 1. Stereoscopic images taken from a stereoscopic camera.

Anaglyph delivers a marginally distinct perspective to individual eyes. From the variance between the two viewpoints and other visual indications, the human optical system can provoke the stereoscopic depiction of spatial correlation in the scene. To generate an anaglyph image, the left and right images of a stereo image pair are superimposed in discrete color planes. The two images will be isolated from the amalgamated picture by color filtering and fed to each eye. The red channel of the left image and the blue and green channel of the right image are fused to produce a red-cyan color anaglyph image. It is essential to have a colored glass which is devised by two unlike colors red and cyan. These glasses act as filters and permit each eye to see only what it deserves, thus, creating an illusion.

III. FRACTIONAL FOURIER TRANSFORM

The Fractional Fourier transform (FrFT) is an imprecise form of the conventional Fourier transform (FT). The FrFT is a substantial and dynamic tool for non-stationary and time-varying signal processing.

The rotation in the time-frequency plane about an angle α = π/2 accords to Fourier Transform.But, the FrFT correlates to a turn over some discretionary angle i.e. α = pπ/2, where p is the order of Fractional Fourier Transform. The p^{th} order FrFT of a signal f (x) is defined as

$$F^p[f(x)] = \int_{-\infty}^{\infty} K_p(x,u)\, f(x)\, dx, 0 \leq |p| \leq 2$$

The kernel function of the FrFT K_p *(x, u)* is given as:

$$k_p(x,u) = \begin{cases} \sqrt{\frac{i - j\cot\alpha}{2\pi}} \exp\left(j\frac{x^2+u^2}{2}\cot\alpha - j\frac{xu}{\sin\alpha}\right), if\ \alpha \neq n\pi \\ \delta(u-x),\ if\ \alpha = 2n\pi \\ \delta(u+x),\ if \alpha = (2n+1)\pi \end{cases}$$

The FrFT order and rotation angle is
Here *p* is the FrFT order or power, α is the FrFT rotation angle and they can be related as α = pπ/2. The inverse of an FRFT with an order *p* is the FrFT with order –p.

$$f(x) = F^{-p}[F^p(f(x))]$$

IV. PROPOSED METHOD

We have applied the projected method in MATLAB R2010a using a PC with Intel ® Core™ i5 2430M CPU @ 2.40GHz 2.40GHz with 8GByte RAM and 64-bit Windows-10 operating system. The suggested method contains two steps. They are:

1. Watermark Embedding
2. Watermark Detection

Embedding is a process of adding or inserting the required information into the original image. After embedding the watermark in the right image using FrFT, create an anaglyph 3D image from the stereoscopic image.

A. Watermark Embedding

The embedding process is divided into three steps.
Step 1: A 2-D FrFT is implemented on the right image to obtain the complex FrFT coefficients.
Step 2: Embed the watermark sequence into the right image and apply inverse Fractional Fourier Transform to obtain the watermarked-right image.
Step 3: Homogenize the watermarked-right image and left image to get the watermarked-anaglyph 3D image.

The schematic diagram of projected watermark embedding process is shown in **Fig.2.**

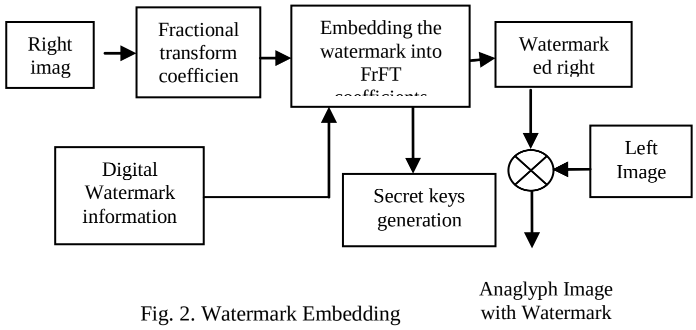

Fig. 2. Watermark Embedding

B. Watermark Detection

Detection of watermark means to check whether the given image or received image contains watermark information. As any number of watermarks can be present in the image, the presence of all or some watermarks is to be detected. The Detection process is done in three steps.
Step 1: Using de-anaglyph obtain the watermarked-right image from the watermarked 3D anaglyph image.
Step 2: Apply 2-D FrFT to the watermarked-right image to get complex coefficients and compute the detection value.
Step 3: Detect watermark by calculating the threshold and comparing it with the detection value.

The schematic diagram of projected watermark embedding process is shown in **Fig.3.**

FrFT

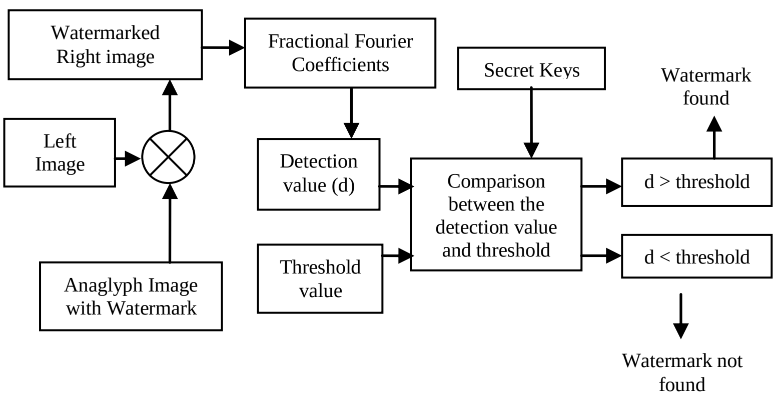

Fig. 3. Watermark Detection

The computation of detection value can be represented as below

$$d = \sum_{i=L+1}^{L+M} [u_i - jv_i]\, Z_i^w$$

The computed detection value is to be compared with some reference value called threshold value. The threshold value is calculated as below

$$E[d] = \frac{\sigma^2}{2} \sum_{i=L+1}^{L+M} (|X_i| + |Y_i|)$$

The presence or absence of the watermark is decided based on the decision whether the computed value of *d* is greater or smaller than threshold, which is set to half of the mean of detected value i.e., *E*[*d*]/2. This seems reasonable since an image without a watermark has E [d]=0. The value d for the correct watermark should stand out above this average.

C. PSNR parameters and related discussion

PSNR is used to measure the objective quality of watermarked images. It is defined as

$$PSNR = 10\log_{10}\left(\frac{255^2}{MSE}\right)$$

Here MSE is the mean square error of watermarked image with host image. MSE is defined as

$$MSE = \frac{1}{512 \times 512}\sum_{x=1}^{x=512}\sum_{y=1}^{y=512}[p(x,y) - p'(x,y)]$$

V. EXPERIMENTAL RESULTS

In our proposed technique, a watermark is inserted in right image (see Fig.4) to form the watermarked-right image (see Fig.5).

Fig. 4. Right Image   Fig. 5. Watermarked Image

This watermarked-right image (see Fig.5) is combined with the left image (see Fig.6) to form the watermarked-anaglyph 3D image (see Fig.7).

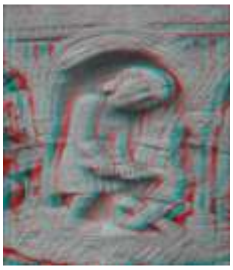

Fig. 6. Left Image   Fig. 7. Watermarked Anaglyph Image

During the process of extraction, left image and watermarked-anaglyph 3D image must be given as input to De-anaglyph which gives watermarked-right image (see Fig.8) as output.

Fig. 8. Extracted Right Image   Fig. 9. Noisy Watermarked Image

Different Output Values obtained for Different Watermark Specifications:

TABLE I. WATERMARK 1 FOR L=96000, M=800, VAR=50

	PSNR dB	***Mean***	***Std. Dev***	***Threshold***	***Detection Value***
Watermarked image	27.79	2615.15	1386.01	8159.20	66150.84
Noisy Watermarked image	14.13	7043.90	3654.85	21663.28	65906.05

	PSNR dB	*Mean*	*Std. Dev*	*Threshold*	*Detection Value*
Watermarked image	27.79	4913.50	2629.67	15432.20	127836.27
Noisy Watermarked image	14.13	10010.94	5230.40	30932.53	128958.66

TABLE II. WATERMARK 2 FOR L=90000, M=800, VAR=100

	PSNR dB	*Mean*	*Std. Dev*	*Threshold*	*Detection Value*
Watermarked image	27.79	1249.00	698.22	4041.86	23217.28
Noisy Watermarked image	14.13	3535.73	1913.43	11189.45	29339.46

TABLE III. WATERMARK 3 FOR L=100000, M=400, VAR=30

Graphs representing the PSNR Vs. various parameters

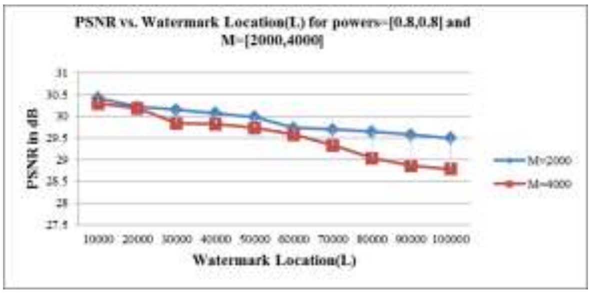

Fig. 10. PSNR vs. Watermark Location (L) for various watermark lengths.

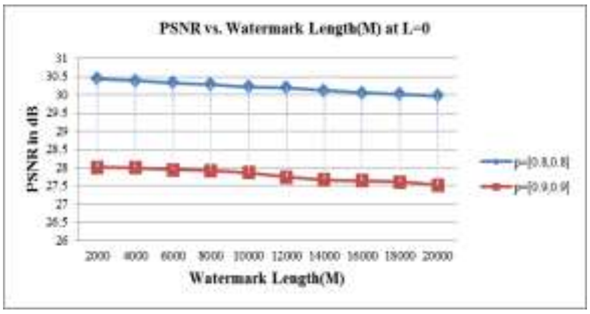

Fig. 11. PSNR vs. Watermark Length (M) for various powers.

VI. CONCLUSION

The FrFT offers two additional degrees of freedom to the digital image watermarking scheme. They are FrFT powers and watermark location which can be used as secret keys to enhance the security of watermarked information. This results in the possibility to embed increased number of watermark bits than FT and Discrete Cosine Transform domains. It is shown that the variety of parameters like FrFT powers, random watermark length and watermark location can be used to provide additional security for watermark detection. As we are embedding the watermark preferably in a single image rather going for both the images, yields more security to the data. Someone who does not have all the key parameters cannot detect watermark easily. Though they have it they have to use it on the right image to retrieve the data. A proposal is made for a threshold for the detection value. It should neither be too large so that the correct watermark is recognized and nor be too small so that false alarms are avoided in most cases. Yet it adapts itself to the modifications that the watermarked images have suffered. Almost all the watermarked images satisfy the imperceptibility criterion i.e., the difference between original host image and watermarked image is not perceivable which makes the attacker difficult to find the image with the watermark from the stereoscopic image.

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