Abstract

Watermarking helps in ensuring originality, ownership and copyrights of a digital image. This paper aims at embedding a Watermark in an image using Wave Atom Transform. Preference of Wave Atoms on other transformations has been due to its sparser expansion, adaptability to the direction of local pattern, and sharp frequency localization. In this scheme, we had tried to spread the watermark in an image so that the information at one place is very small and undetectable. In order to extract the watermark and verify ownership of an image, one would have the advantage of prior knowledge of embedded locations. A noise of high amplitude will be needed to be added to the image for watermark distortion. Furthermore, the information spread will ensure the robustness of the watermark data. The proposed scheme has the ability to withstand malicious operations and attacks.

Keywords: Wave Atom Transform, Pseudo Number Generators, Watermark Embedding, Watermark Extraction, Image Regeneration

Introduction

The digital watermarking is a relatively young field, about 15 to 20 years old. It protects author's copyrights. The watermarking techniques deal effectively with imperceptibility (visibility), robustness and capacity [1]. The watermark supplies some additional information about the image for identification, verification of image integrity, and protection of owner copyrights [2]. The digital watermarking of multimedia data [3] includes copyright protection, copy protection in watermarked environment, fingerprinting, and image authentication and integrity verification.

Spread Spectrum (SS) watermarking is more robust as compared to other Spatial and Transformed Domain techniques. In this technique, watermark data is embedded over wide spectrum of the cover image and the information stored at one bin is very small and hard to be detected. During recent times SS watermarking has attracted many non-conventional applications such as broadcast monitoring, security in communication, authentication and blind assessment of quality of services (QoS) in mobile radio network. It can be categorized in terms of security as additive SS watermarking, attenuated SS watermarking [4], and improved SS (ISS) watermarking [5].

In SS, data stream is coded such that total information rate is higher than data rate [6]. SS is based on frequency hopping that concept was first presented by Nikola Tesla in July 1900. Earlier in 1898, Tesla demonstrated the concept through world's first
radio-controlled submersible boat through wireless signals. The signal (an electrical, electromagnetic, or acoustic) is generated in a particular bandwidth and spread in a frequency domain to have wider bandwidth signals. Frequency hopping also provides the flexibility to a signal to hop out of frequency channel with interference or slow frequency selective fading [7]. SS provides secure communications, resistance to natural interference, noise and jamming [8], and is commonly used in Wi-Fi and cellular networks.

In SS, watermark data is embedded in the host (image, audio, or video) by defining a reference sequence. The popular approach is initialization of the Pseudo Random Numbers Generators by using a Seed and this sequence is communicated to the recipient for watermark extraction. The addition of the reference sequence to the host image is at very low amplitude and without introducing too much distortion. The correlation between the referenced and non-referenced patterns is used to extract the watermark bits using a threshold. Embedding of watermark in the host image has definite changes in image pattern and results in some degree of artifacts. The offset between robustness and image distortion is overcome by appropriately adjusting the watermark strength.

This scheme has proposed to use Wave Atom Transform (WAT). Demanet and Ying introduced WAT as a variant of two dimensional wavelet packets [9]. WAT obey the parabolic scaling law (wavelength \(\sim (\text{diameter})^3\)), adapt to arbitrary local directions of a pattern, and have sparser expansion and multi-scale nature [10]. Many existing applications of WAT show its great potential for image de-noising [11, 12]. WAT also takes advantage of HVS characteristics i.e. sensitivity of human eye to noise which is less in textured area and is more near the edges [13]. WAT also provide three types of frames; orthobasis, directional and complex-valued frames. WAT is a new transform and has vast potential of research. H.Y Leung, and L.M Cheng have used WAT to modify the transformed coefficients with a simplified quantization approach for watermarking [14]. Fang Liu, and Lee-Ming Cheng have used WAT, hashing (RC4 algorithm using the secret key) and mutual sum-energy relationships of the extracted features for watermarking [15]. Their scheme is robust as well as more secure as compared to previous schemes.

**Proposed Scheme**

In this scheme, WAT and SS are used to implement the proposed algorithm. WAT transforms the cover image into a two dimensional array and SS ensures spread of watermark data all over the host image. WAT has five scale bands and proposed scheme uses Fourth Scale Band for embedding the watermark data. Pseudo Random
Number Generator is initialized to form an embedded sequence of block numbers and watermark is converted to binary bits. The watermark bits are embedded by modifying the selected coefficients. These selected coefficients are a block of coefficients which are selected on the basis of embedded sequence. The Inverse Wave Atom Transform is applied to regenerate the watermarked image. This scheme has the advantage over other schemes that watermark bits are spread all over the image and any malicious attack will not be able to destroy the watermark completely. The embedding is unpredictable, as a random sequence is generated for selection of sub-blocks in the fourth scale band. The extraction is blind and each bit is extracted on the basis of a threshold.

![Figure 1. Embedding of Watermark](image1)

![Figure 2. Extraction of Watermark](image2)
The steps of the algorithm are as following:

- **Embedding**
  - Select an Image
  - Apply Wave Atom Transform to convert the image into Cell Array
  - Select Fourth Scale Band for watermark embedding
  - Initialize the Pseudo Random Number Generator
  - Convert Watermark (Message) into binary bits
  - Modify the Wave Atom Coefficients for embedding of Watermark bits (Spread Spectrum)
  - Apply Inverse Wave Atom Transform
  - Regeneration of the Watermarked Image

- **Retrieval**
  - Select the watermarked image
  - Apply Wave Atom Transform
  - Select Fourth Scale Band
  - Regenerate Embedded Sequence for watermark extraction
  - Extract the Watermarked bits (0 or 1) basing on the Threshold Value using Correlation
  - 0, if value is less than Threshold Value
  - 1, if value is greater than Threshold Value
  - Regenerate the Watermark

**Experimental Results**

In order to test the performance of the proposed algorithm with respect to robustness and fragility, a random sample of 512 x 512 grey scale images are used. The proposed Spread Spectrum approach is implemented in MATLAB by using Wave Atom Transform on an Intel(R) T2400 (1.83GHz) CPU (2 G RAM).

Embedding of watermark does not leave any HVS. However, increased Watermark Strength, alpha indicates some changes in the histogram.
Original Image

Watermarked Image ($\alpha = 1.5$)

Watermarked Image ($\alpha = 2$)

Watermarked Image ($\alpha = 2.5$)

Watermarked Image ($\alpha = 3$)

Watermarked Image ($\alpha = 5$)

Histogram - Original Image

Histogram Watermarked Image ($\alpha = 1.5$)
Watermarked Image ($\alpha = 2$)                  Watermarked Image ($\alpha = 2.5$)

Watermarked Image ($\alpha = 3$)                   Watermarked Image ($\alpha = 5$)

Histogram - Original Image    Histogram Watermarked Image ($\alpha = 1.5$)
The proposed scheme has shown efficient watermark extraction. The algorithm was applied to a randomly selected sample of forty eight standard 512 x 512 grey scale images with different Watermarks’ strengths (1.5, 2, 3.5, 3 and 5). The correct watermark extraction ranges from 80.14% to 100%. The results of Watermark extraction are at Annexure A. We can assert that better extraction results can be obtained by increasing the Watermark strength. However, the histogram of increased Watermark strength embedded images will have few indications. The graph of the Mean Bit Error Rates (BER) % for different Watermarks’ strengths is as following:-

Figure 1 –Watermarked Images and Histogram
Figure 2 – Graph between Watermark Strength and BER

The graph of the Mean Square Error (MSE) % for different Watermarks’ strengths is:-

| Watermark Strength | 1.5  | 2   | 3.5 | 5   |
|--------------------|------|-----|-----|-----|
| MSE %              | 1.14308 | 1.249065 | 1.83482 | 2.651305 |

Figure 3 – Graph between Watermarked Images and MSE

The graph of the Peak Signal to Noise Ratio (PSNR) for different Watermarks’ strengths is as following:-
JPEG standard image compression is used to adjudge the robustness of the watermarked images. In order to test the robustness, the watermarked image was compressed to 100%, 90%, 80% and 70%. The compressed images are shown as following (the compression has not affected watermark extraction significantly):-

| Watermark Strength | 1.5 | 2   | 3.5 | 5    |
|--------------------|-----|-----|-----|------|
| PSNR               | 46.92848 | 46.47505 | 44.72831 | 43.20299 |

Figure 4 – Graph between Watermarked Images and PSNR
The graph of BER % in extracting the Watermark from the images which have been compressed at 100%, 90%, 80% and 70% is as following:

| Compressed Image Size | 70%  | 80%  | 90%  | 100% |
|-----------------------|------|------|------|------|
| BER %                 | 14.29| 12.86| 11.43| 11.04|

The robustness of the watermark was tested by adding White Gaussian Noise to the images at different scales. The results show a small decrease in mean correct extraction % of these images. The images at different scales are shown below:
Figure 7 – Graph between Compressed Image Size and BER%
Comparison of the proposed scheme with other by using standard gray image Lena 512 x 512 scale is as following [14]:

| Ser | Researchers | PNSR Value (dB) | NC Value at Scale 10 | Transform   |
|-----|-------------|----------------|----------------------|-------------|
| 1.  | Zhu et al   | 54.329         | 0.7912               | DCT         |
| 2.  | Xiao et al  | 44.5323        | 0.9738               | Curvelet    |
| 3.  | Leung et al | 42.8072        | 0.9889               | FDCT        |
| 4.  | Tao et al   | 35.8           | 0.7974               | DWT         |
| 5.  | H.Y Leung, and L.M Cheng | 40.379 | 0.9591               | Wave Atoms  |
| 6.  | **Proposed Scheme** | **46.1168** | **0.9655**           | Wave Atoms  |

NC - Normal Cross Correlation

**Conclusion**

The scheme presented in this paper is motivated by frequency domain manipulation and has been found robust against a number of well know attacks. Spread Spectrum has added a more secure way for embedding the data. The proposed method, compared with latest techniques of watermarking in different domains, has proven better robustness against the watermarks attacks. The system can be further enhanced to coloured images of different dimensions, audio and video media. Encryption along with Spread Spectrum techniques can be used to enhance embedded data security. Further improvements in the algorithm can be worked out to allow a large amount of data to be stored in the image.

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