Ahmedabad University
ECE501: Digital Image Processing
Final Project Report
Project: 8. Digital Image Watermarking and Extraction
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***Abstract*—Digital watermarking has become an important technology in the multimedia industry as the means of protecting copyrights, authentication of the content,digital rights management. As the digital content sharing and distribution grows exponentially, the need to protect intellectual property has grown. The present project displays a strong watermarking system of digital images (blind) on the frequency domain with the help of Discrete Cosine Transform (DCT). The main aim of this research is to come up with a watermarking method that inserts color watermark messages to cover images by adjusting mid-frequency DCT coefficients at a high level of invisibility and robustness. While in space domain approaches, frequency domain watermarking is much more robust to frequently used image processing tasks and compression. The lack of original cover image to extract the watermark which makes the system blind in extraction makes it especially practical in real world applications.**

***Index Terms*—Digital watermarking,DCT,blind extraction,frequency domain, imperceptibility,robustness**

I. Introduction

Digital watermarking has been an important technology to protect copyright, authentication of content and management of digital rights in the multimedia field. As the volume of digitally shared and distributed content grows exponentially, the importance of protecting intellectual property has also risen. The present project applies a strong blind digital image watermarking technique with Discrete Cosine Transform (DCT) in frequency domain. The ultimate goal of the given work is to create the watermarking method where the watermark data in the form of color watermarks are embedded into the cover images by changing mid-frequency DCT coefficients, reaching the optimal compromise between invisibility and resistance. Frequency-domain watermarking provides much better resistance to image processing and compression, as opposed to spatial domain methods. The blind extraction mode of the system that does not need the original cover image to retrieve the watermark makes it especially viable in the real world use.

II. Methodology

A. System Architecture

The watermarking system proposed has two principal modules which are embedding and extraction. Embedding process introduces watermark information into the cover image where the extraction process is used to extract the watermark without the original cover image.

B. Embedding Algorithm

Preprocessing Phase:

- Images of inputs cover and watermark are loaded and verified.
- The dimensions of the cover images are multiplied by 8x8 blocks.
- Image of watermark is adjusted to the size of block grid (height/BLOCK x width/BLOCK).

DCT Transformation:

- BGR is changed into YCbCr color space as cover image.
- Every 8x 8 block is subjected to Discrete Cosine Transform.
- The transformation transforms spatially defined information into frequency defined coefficients.

Coefficient Modification: Selected the mid frequency coefficients are modified based on watermark bits:

- Per chosen mid frequency coefficients are altered depending on watermark bits.
- In the case of every bit value 1: DCT coefficient = += STRENGTH repeat: 0 0: DCT coefficient = -= STRENGTH.
- In this change, 8 coefficients are employed per color channel (24 in total).

Reconstruction:

- Each modified block is then processed to inverse the DCT.
- Image is transformed back to BGR color space.
- Watermarked image is eventually saved.

C. Extraction Algorithm

The algorithm of the blind extraction works as follows:

Block Processing:

- Image with a watermark is broken down into 8x8 blocks.
- Each block is subjected to DCT.

Bit Extraction:

- Same coefficient positions in a used embedding are investigated.
- In case coefficient value is greater than 0: extracted bit = 1.
- In case coefficient value is less than 0: extracted bit = 0.

Watermark Reconstruction:

- Bits that are extracted are compiled to create RGB pixel values.
- The watermark image is rebuilt with low resolution.
- Last extraction is amplified to improve visualization.

D. Technical Parameters

- **BLOCK_SIZE:** 8×8 pixels(DCT block size)
- **STRENGTH:** 30 - 40(empirically determined for quality robustness balance)
- **Coefficient Positions:**

Red Channel: [(1,2),(1,3),(2,1),(2,2),(2,3),(3,1),(3,2),(3,3)]
Green Channel: [(1,4),(1,5),(2,4),(2,5),(3,4),(3,5),(4,3),(4,4)]
Blue Channel: [(4,2),(4,3),(4,5),(5,2),(5,3),(5,4),(5,5),(6,3)]

E. Batch Processing System

To be tested in detail and generate datasets, the system contains:

- Automated the cover watermark combination processing.
- Organized output naming convention like : `coverXX_wmYY.png`
- Simultaneous requests of generated sets of data. ion. The extraction feature of the system that does not need the original cover image to recover the watermark is blind and thus especially handy in real-life scenarios.

III. Results

A. Visual Quality Assessment

The system put in place was effective in imprinting watermarks in different cover images with less perceptual effects. Visual inspection revealed:

- Watermarked Images: No apparent quality degradation was noticed.
- Extracted Watermarks: Met was very easy to identify and fidelity to color.
- Imperceptibility: Watermarks can not be detected by the human eye system in normal conditions.

B. Functional Performance

The system performed remarkably well in some of the main aspects as follows:

- Embedding and Extraction successful.
- A hundred percent success rate in watermark embedding.r
- The Blind extraction without original cover.s
- Overall watermark extraction in watermark color preservation efficiency Color preservation in extracted watermarks
- Live processing of normal image sizes(up to 1024x1024)
- Block-based processing in efficient memory use.
- Batch processing that is scalable.

C. Capacity Performance

Watermark capacity 1 per 64 cover image pixels.
Figure 1024x1024 cover: 16,384 pixels watermark bandwidth (128x128).
Effective frequency domain space exploitation.

D. Robustness indicators

Preliminary testing showed:
Opposition to small-scale image compression.
Resistance to the color space transformations.
Regular operation in various types of images.

E. Visual Results (Uploaded Images)

The following images : original watermark, extracted watermark, original cover image, and watermarked image.

(a) Original Watermark (b) Extracted Watermark (c) Original Cover (d) Watermarked Image

Fig. 1: Visual results: (a) original watermark, (b) extracted watermark, (c) original cover image, (d) watermarked image.

IV. Discussions

A. Technical Advantages

The applied DCT-watermarking system has the following major benefits:

- Blind Extraction Capability: This is by far the most significant characteristic since it becomes possible to extract watermarks without the original cover image making it very useful in the real-world context.
- Frequency Domain Robustness: The system is robust to the common image processing operations and a slight compression by working in the DCT domain.
- Color Protection: So Separate sets of coefficients in use by each color channel make color watermark embedding and recovery to be effective.
- Controlled Imperceptibility: The selection of mid-frequency coefficients is controlled to make sure that watermarks are not visible and yet are extractable.

B. Limitations and Challenges

Even though this was successfully implemented, a number of limitations were realized:

- Fixed capacity constraint:The watermark capacity is directly related to cover image size and does not have the flexibility to be applied to a variety of application scenarios.
- Compression Vulnerability: Although the system can handle mild compression but high JPEG compression can affect the system and distort the DCT coefficients greatly.
- Sensitivity to parameters: The Strength parameter must be manually adjusted according to the type of image being processed so as to balance the visibility and strength.
- Geometric Attack Vulnerability: The system does not in itself deal with rotation, scaling, or cropping attacks.

C. Comparative Analysis

The DCT-based method has several advantages over the spatial domain watermarking methods:

- Increased the noise addition and filtering resistance.
- Better performance when we compressed.
- Frequency domain manipulation to improve security.
- Between the visibility and the robustness more controlled trade-offs.

D. Practical Implications

The functionality of the system gives it a number of applications in practice:

- Copyright Protection Reliable ownership verification of digital assets.
- Content Authentication: Sensitive image tampering.
- DRM: Control and monitoring of usage.
- Covert Communication: Protection of hidden data communications.

V. Conclusion

This project was able to design and implement a blind digital image watermarking system with the help of Discrete Cosine Transform. The system can serve as a good representation of the frequency domain watermarking techniques and offers a working functionality to the real-world application. Key achievements include:

- Creation of a strong embedding algorithm that does not compromise visual quality.
- Blind extraction which does not need original cover images.
- Effective management of color watermarks with high level of reproduction.
- Development of a scaleable batch processing system to generate data sets.

The system is well balanced in terms of imperceptibility and robustness and can be applied to different digital rights management applications. The compromise between the visual quality and extraction reliability was best achieved with the use of the mid-frequency coefficients.

A. Future Work

The following directions of future improvement are identified:

- Adaptive strength adjustment: Introduced content based strength estimation depending on the local image features.
- Error correction enhancements: We cab reduce the error by the Reed Solomon or Convolutional coding.
- Optimized Coefficient Selection: machine learning Coefficient selection optimization.
- Real time Implementation: GPU watermarking of video applications.

- This implementation is a good baseline to the future developments and shows the feasibility of the proposed method of DCT-based blind watermarking to protect digital images.

VI. Results

All results are uploaded in Github. GitHub Repository — Results

References

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