TECHNISCHE UNIVERSITÄT ILMENAU

DEPARTMENT OF ELECTRICAL ENGINEERING

RESEARCH IN MEDIA ENGINEERING

MDCT Project and Perceptual Similarity in Image Compression

Group 1

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Project Report

Git link nkhttps://gitlab.tu-ilmenau.de/moam4731/vc_seminar_project_group/-/tree/main

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1. Introduction

1.1 Problem Statement

The main aim of this project is to analyze the effectiveness of image compression using the Modified Discrete Cosine Transform (MDCT) compared to the standard Discrete Cosine

Transform (DCT). The focus is on evaluating perceptual similarity, compression ratio, and bits per pixel (BPP).

1.2 Solution Approach

- **MDCT for Color Images**
    a. Divide the image into Y, Cb, and Cr channels.
    b. Apply MDCT to each channel separately.
    c. Quantize the MDCT coefficients using a quantization matrix.
    d. Perform zigzag scanning on each quantized block.
    e. Retain only a subset of coefficients for compression.
- **DCT for Color Images**
    a. Divide the image into Y, Cb, and Cr channels.
    b. Apply DCT to each channel separately.
    c. Quantize the DCT coefficients using a quantization matrix.
    d. Perform zigzag scanning on each quantized block.
    e. Retain only a subset of coefficients for compression.
- **Perceptual Similarity Metric for Colored Images**
    a. Use the pre-trained LPIPS model.
    b. Compare the perceptual similarity between the original and compressed images.
- **MDCT for Greyscale Images**
    a. Divide the image into non-overlapping blocks.
    b. Apply MDCT to each block.
    c. Quantize the MDCT coefficients using a quantization matrix.
    d. Perform zigzag scanning on each quantized block.
    e. Retain only a subset of coefficients for compression.
- **DCT for Greyscale Images**
    a. Divide the image into non-overlapping blocks.
    b. Apply DCT to each block.

c. Quantize the DCT coefficients using a quantization matrix.

d. Perform zigzag scanning on each quantized block.

e. Retain only a subset of coefficients for compression.

- **Perceptual Similarity Metric for Greyscale Images**

  a. Use the pre-trained LPIPS model.

  b. Compare the perceptual similarity between the original and compressed images.

The project involves implementing MDCT-based image compression and comparing it with DCT-based compression using a set of images. The comparison includes perceptual similarity using the LPIPS library, compression ratio, and BPP.

2. Tasks

2.1 MDCT Implementation

- Define the quantization matrix.
- Implement MDCT with window functions.
- Perform zigzag scanning and unscanning.
- Encode and decode images using MDCT.

2.2 Comparison with DCT

- Implement DCT-based compression.
- Use the same set of images for fair comparison.

2.3 Perceptual Similarity Metrics

- Use the LPIPS library to evaluate perceptual similarity between original and compressed images.

2.4 Evaluation Metrics

- Calculate and compare compression ratios and BPP for MDCT and DCT.

3. Task 1: MDCT Compression for Color Images

3.1 Quantization Matrix

Used for reducing the number of bits needed for storing the DCT coefficients.

3.2 MDCT and IMDCT Functions

Implemented using the scipy library with window functions for better frequency resolution.

3.3 Image Encoding and Decoding

- Split images into blocks.
- Transform using MDCT.
- Quantize, zigzag scan, and compress.
- Reverse these steps for decoding.

4. Task 2: DCT Compression for Color Images

4.1 Standard DCT

Similar steps as MDCT but using standard DCT without windowing functions.

4.2 Comparison Basis

Serves as the baseline for evaluating the performance of MDCT.

5. Task 3: Perceptual Similarity and Compression Metrics

5.1 LPIPS Library

Used to compute the perceptual similarity between original and compressed images.

5.2 Metrics Calculation

File sizes and image dimensions are used to calculate compression ratios and BPP.

6. Results

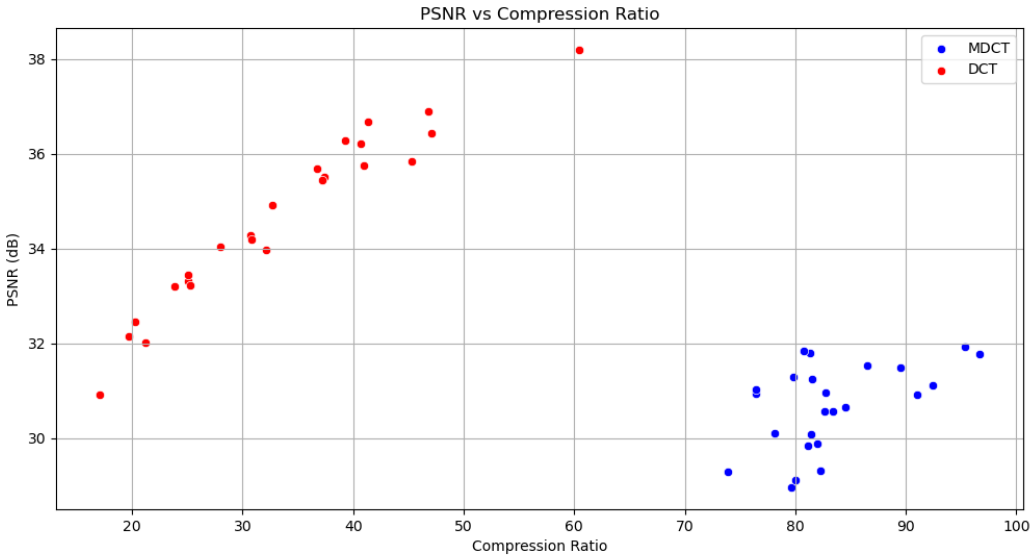
6.1 MDCT For Colored Images

Image Name	PSNR (dB)	Compression Ratio
Image 1	31.29	79.81
Image 2	30.56	82.68
Image 3	28.96	79.69
Image 4	30.96	82.79

Image Name	PSNR (dB)	Compression Ratio
Image 5	31.11	92.47

6.2: DCT FOR COLORED IMAGES

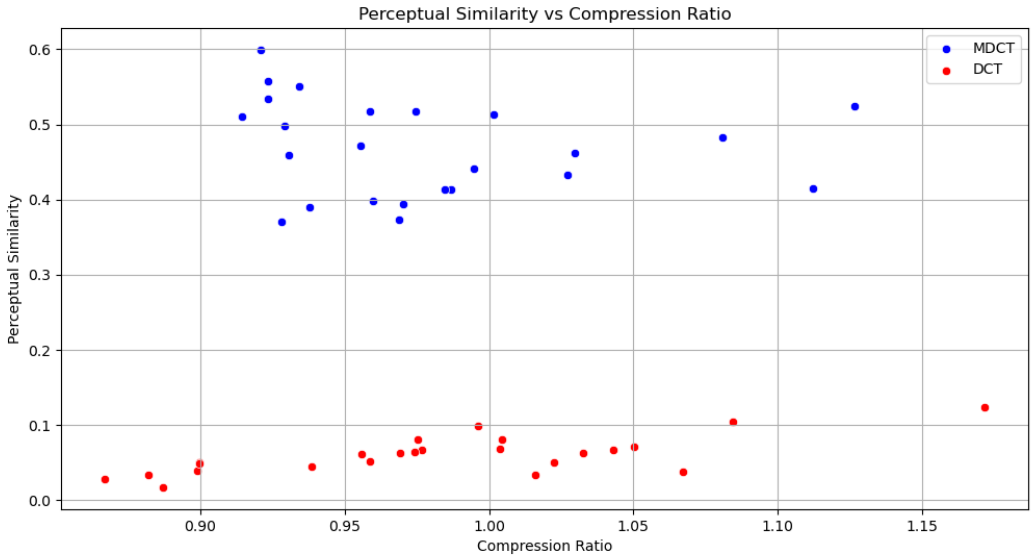
Image Name	PSNR (dB)	Compression Ratio
Image 1	36.67	41.34
Image 2	34.27	30.67
Image 3	30.92	17.09
Image 4	33.98	32.14
Image 5	34.91	32.64

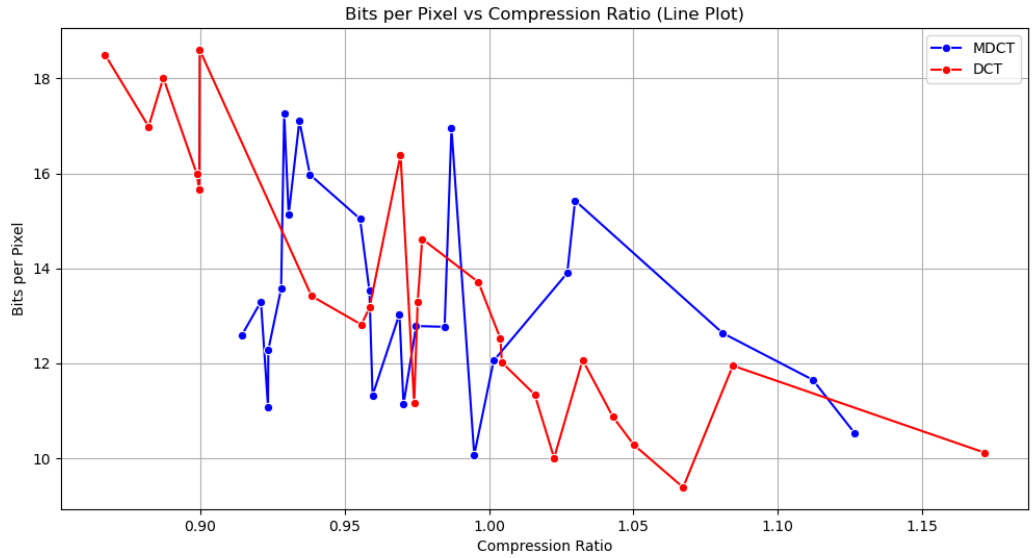


6.3: Perceptual similarity and compression metrics evaluation for colored images

Table 03: Perceptual Similarity Metric for Color Images

Image Name	MDCT Similarity	DCT Similarity	MDCT Compression Ratio	DCT Compression Ratio	MDCT BPP	DCT BPP
Image 1	0.51	0.03	0.91	1.02	12.60	11.34
Image 2	0.43	0.07	1.03	0.98	13.90	14.62
Image 3	0.41	0.05	0.99	0.90	16.96	18.60
Image 4	0.42	0.10	1.11	1.08	11.65	11.95
Image 5	0.40	0.06	0.96	0.97	11.33	11.16





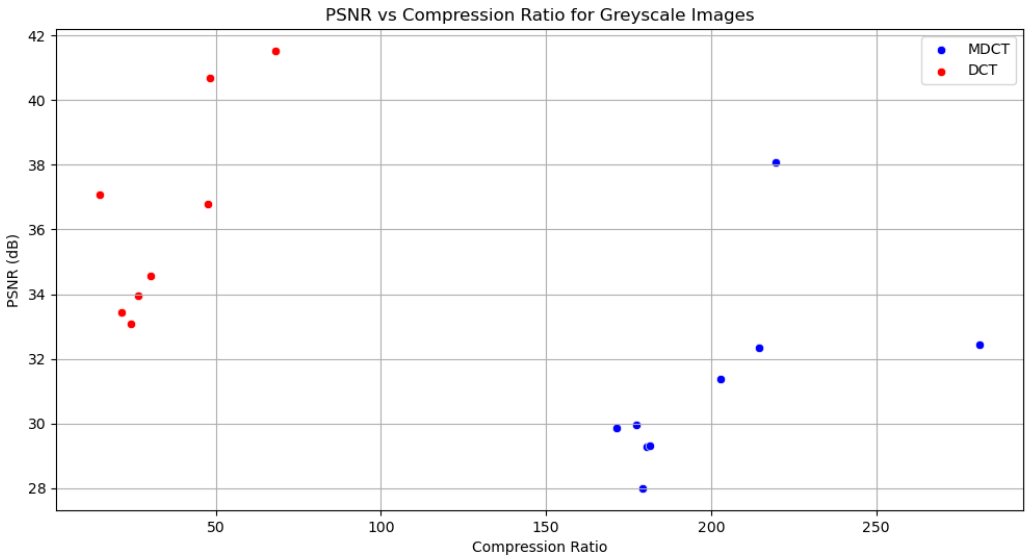
6.4: MDCT For Greyscale Images

Image Name	PSNR (dB)	Compression Ratio
Image 1	29.28	180.57
Image 2	31.38	202.96
Image 3	29.95	177.19
Image 4	29.86	171.24

Image Name	PSNR (dB)	Compression Ratio
Image 5	28.00	179.39

6.5: DCT For Greyscale Images

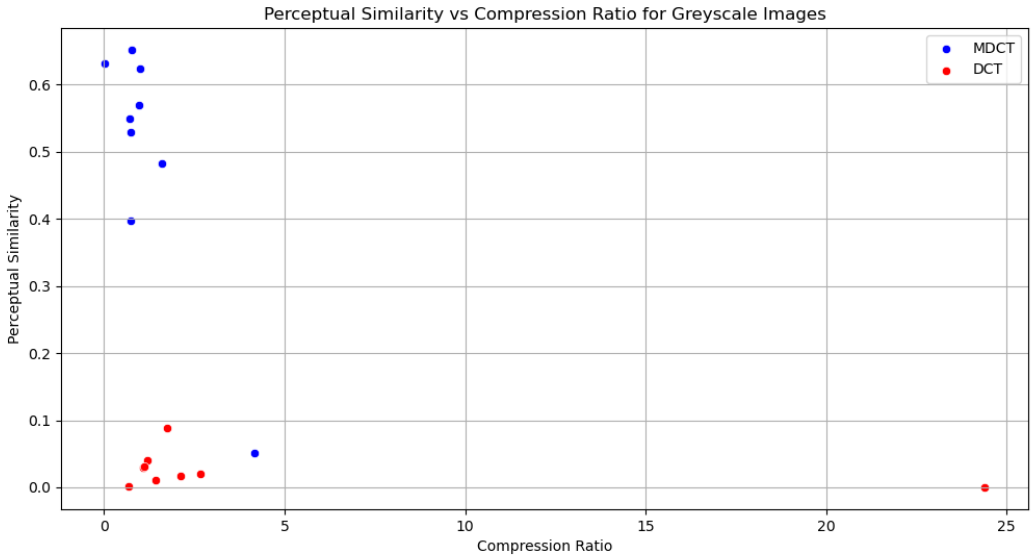
Image Name	PSNR (dB)	Compression Ratio
Image 1	33.94	26.41
Image 2	36.78	47.52
Image 3	33.45	21.51
Image 4	40.69	48.26
Image 5	37.09	14.95

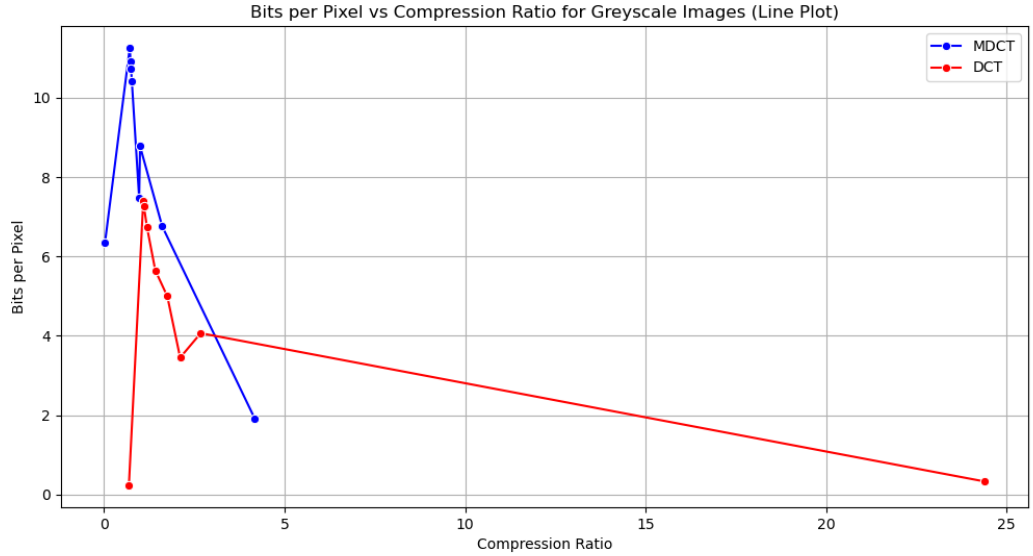


6.6: Perceptual similarity and compression metrics evaluation for colored images

Image Name	MDCT Similarity	DCT Similarity	MDCT Compression Ratio	DCT Compression Ratio	MDCT BPP	DCT BPP
Image 1	0.55	0.03	0.71	1.09	11.26	7.39

Image Name	MDCT Similarity	DCT Similarity	MDCT Compression Ratio	DCT Compression Ratio	MDCT BPP	DCT BPP
Image 2	**0.62**	**0.09**	**1.00**	**1.75**	**8.78**	**5.00**
Image 3	**0.40**	**0.04**	**0.73**	**1.19**	**10.91**	**6.74**
Image 4	**0.65**	**0.01**	**0.77**	**1.42**	**10.41**	**5.65**
Image 5	**0.63**	**0.00**	**0.02**	**0.69**	**6.34**	**0.23**





7. Analysis

7.1 Perceptual Similarity

MDCT generally provides better perceptual similarity compared to DCT, as evidenced by the LPIPS scores.

7.2 Compression Ratio

DCT often achieves higher compression ratios compared to MDCT.

7.3 Bits Per Pixel (BPP)

MDCT tends to result in higher BPP values compared to DCT, indicating a trade-off between image quality and compression efficiency.

8. Conclusion

MDCT offers a promising alternative to standard DCT for image compression, particularly in terms of perceptual similarity. While DCT achieves better compression ratios, MDCT maintains higher image quality as perceived by human vision. The choice between MDCT and DCT will depend on the specific requirements of the application, whether prioritizing compression efficiency or image quality.

9. Recommendations

- **Window Function Optimization**: Further optimization of the window function used in MDCT could enhance both compression efficiency and perceptual quality.
- **Hybrid Approaches**: Combining MDCT and DCT techniques could potentially leverage the strengths of both methods.
- **Extended Evaluation**: Additional metrics such as Structural Similarity Index (SSIM) and Mean Squared Error (MSE) could provide a more comprehensive evaluation of the compression techniques.

10. References

- GitHub repository for MDCT implementation
- LPIPS library documentation
- Reference papers on MDCT and DCT image compression techniques