TECHNISCHE UNIVERSITÄT ILMENAU

DEPARTMENT OF ELECTRICAL ENGINEERING

RESEARCH IN MEDIA ENGINEERING

Comparison of DCT and MDCT Compression and Perceptual Similarity of Images

Group 1

Moeez Amjad - 65053

Sajid Ali Khan - 66414

Muhammad Hamza Aslam - 70413

Project Report

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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) for images. The focus is on finding an optimum window and evaluating perceptual similarity, compression ratio, and bits per pixel (BPP).

1.2 Solution Approach

MDCT for Images:

- Divide the image into Y, Cb, and Cr channels.
- Apply MDCT with various window functions (Hamming, Hann, Rectangular, Triangular, Cosine, Parzen) to each channel separately.
- Quantize the MDCT coefficients using a quantization matrix.
- Perform zigzag scanning on each quantized block.
- Retain only a subset of coefficients for compression.
- The Rectangular window is selected for its superior performance in terms of compression ratio and PSNR.

DCT for Images:

- Divide the image into Y, Cb, and Cr channels.
- Apply DCT to each channel separately.
- Quantize the DCT coefficients using a quantization matrix.
- Perform zigzag scanning on each quantized block.
- Retain only a subset of coefficients for compression.

Perceptual Similarity Metric for Color Images:

Use the pre-trained LPIPS model to compare the perceptual similarity between the original and compressed images.

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 Window Functions

The MDCT implementation uses various window functions: Hamming, Hann, Rectangular (Boxcar), Triangular, Cosine, and Parzen. The Rectangular window, also known as the Boxcar window, is highlighted for its superior compression ratio and PSNR values compared to the others.

3.2 Quantization Matrix

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

3.3 MDCT and IMDCT Functions

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

3.4 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 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

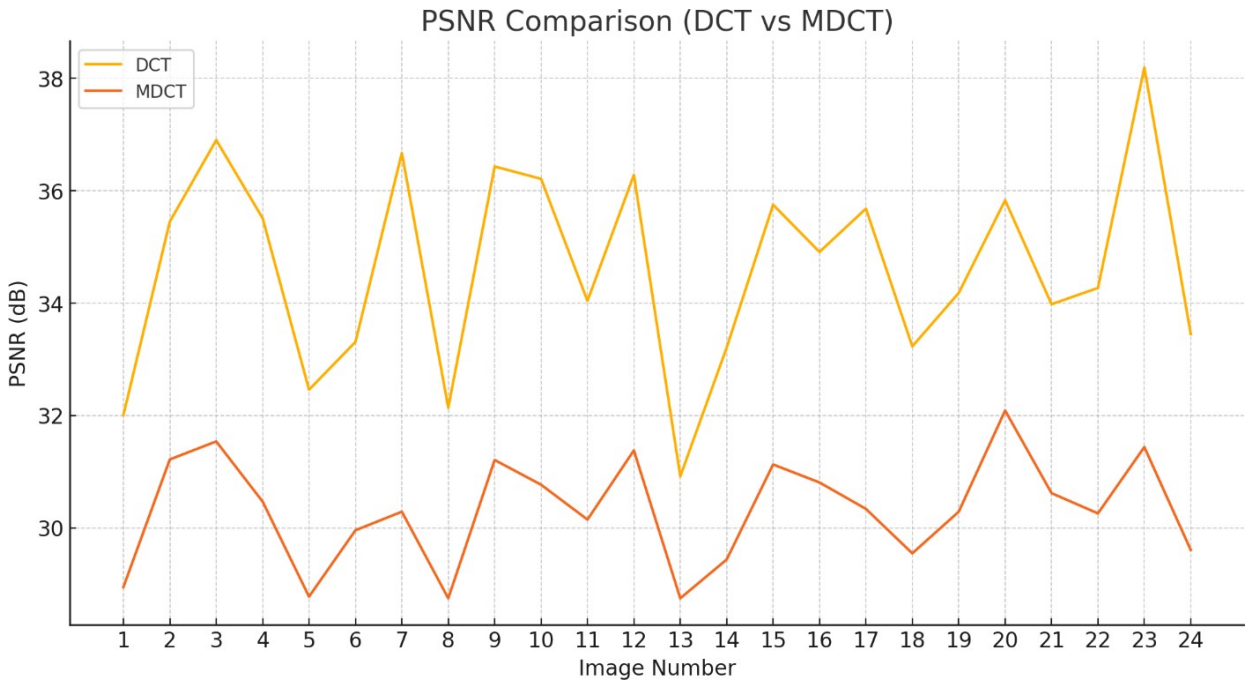
Compression Result by DCT:

Image Number	PSNR (dB)	Compression Ratio
1	32.01	21.18
2	35.45	37.17
3	36.90	46.77
4	35.51	37.36
5	32.46	20.26
6	33.31	25.11
7	36.67	41.34
8	32.14	19.68
9	36.43	47.08
10	36.21	40.65
11	34.04	28.01
12	36.28	39.24
13	30.92	17.09
14	33.21	23.83
15	35.75	41.01
16	34.91	32.64
17	35.68	36.70
18	33.23	25.25
19	34.18	30.76
20	35.83	45.27

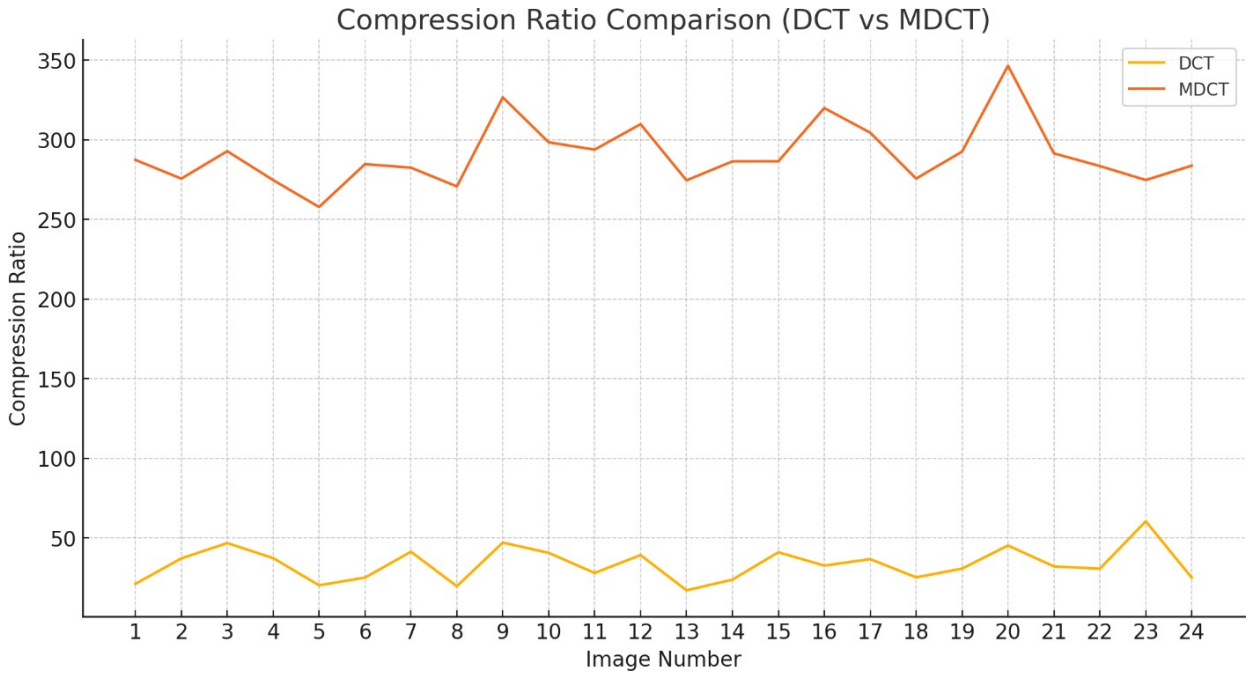
21	33.98	32.14
22	34.27	30.67
23	38.19	60.45
24	33.45	25.09

Graphs:

PSNR Comparison:



Compression Ration Comparison:



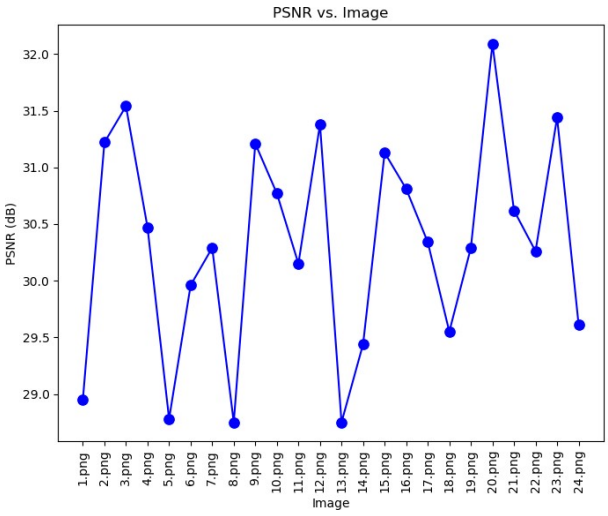
Sample Image

Compression Results by MDCT

1) Hamming Window:

Image	PSNR (dB)	Compression Ratio
1.png	28.95	287.36
10.png	30.77	298.38
11.png	30.15	293.80
12.png	31.38	309.78
13.png	28.75	274.51
14.png	29.44	286.42
15.png	31.13	286.46
16.png	30.81	319.89
17.png	30.34	304.44
18.png	29.55	275.61
19.png	30.29	292.54
2.png	31.22	275.58
20.png	32.09	346.47
21.png	30.62	291.43
22.png	30.26	283.49
23.png	31.44	274.70
24.png	29.61	283.70
3.png	31.54	292.82
4.png	30.47	274.66
5.png	28.78	257.77
6.png	29.96	284.69
7.png	30.29	282.47
8.png	28.75	270.69
9.png	31.21	326.61

Graphs:



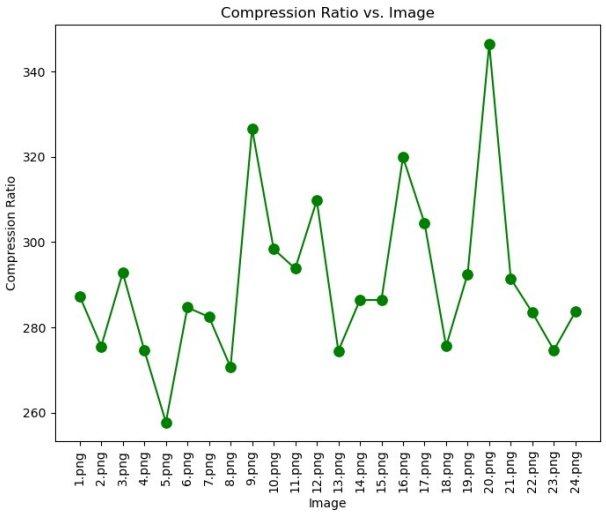


Image:

2) Hann Window:

Image	PSNR (dB)	Compression Ratio
1.png	28.88	286.71
10.png	30.42	298.51
11.png	29.95	294.88
12.png	30.93	310.15
13.png	28.68	275.31
14.png	29.29	285.87
15.png	30.66	286.93
16.png	30.46	318.90
17.png	30.08	303.85
18.png	29.37	276.22
19.png	30.00	292.44
2.png	30.81	277.08
20.png	31.48	346.26
21.png	30.22	291.69
22.png	29.99	283.10
23.png	30.96	274.89
24.png	29.44	283.65
3.png	31.08	293.17
4.png	30.16	274.88
5.png	28.70	258.21
6.png	29.77	285.56
7.png	30.03	282.72
8.png	28.68	271.52
9.png	30.79	325.78

Graph:

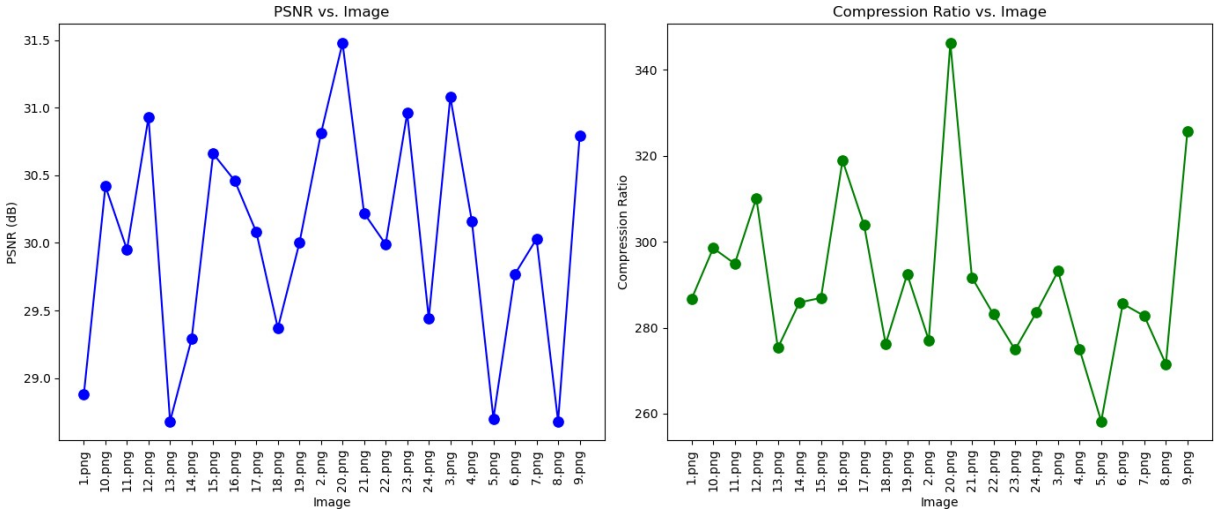


Image:

3)Rectangular Window (boxcar):

Image	PSNR (dB)	Compression Ratio
1.png	29.21	301.39
10.png	31.70	349.55
11.png	30.76	318.43
12.png	32.23	399.75
13.png	28.97	265.54
14.png	29.90	296.33
15.png	31.88	345.49
16.png	31.58	370.86
17.png	31.11	355.91
18.png	30.00	278.44
19.png	31.02	324.22
2.png	32.20	298.18
20.png	32.79	465.92
21.png	31.26	348.96
22.png	30.91	288.96
23.png	32.53	314.69
24.png	30.06	299.50
3.png	32.59	394.40
4.png	31.29	322.43
5.png	29.01	257.45
6.png	30.42	326.53
7.png	31.02	333.25
8.png	28.94	270.78
9.png	32.16	423.04

Graph:

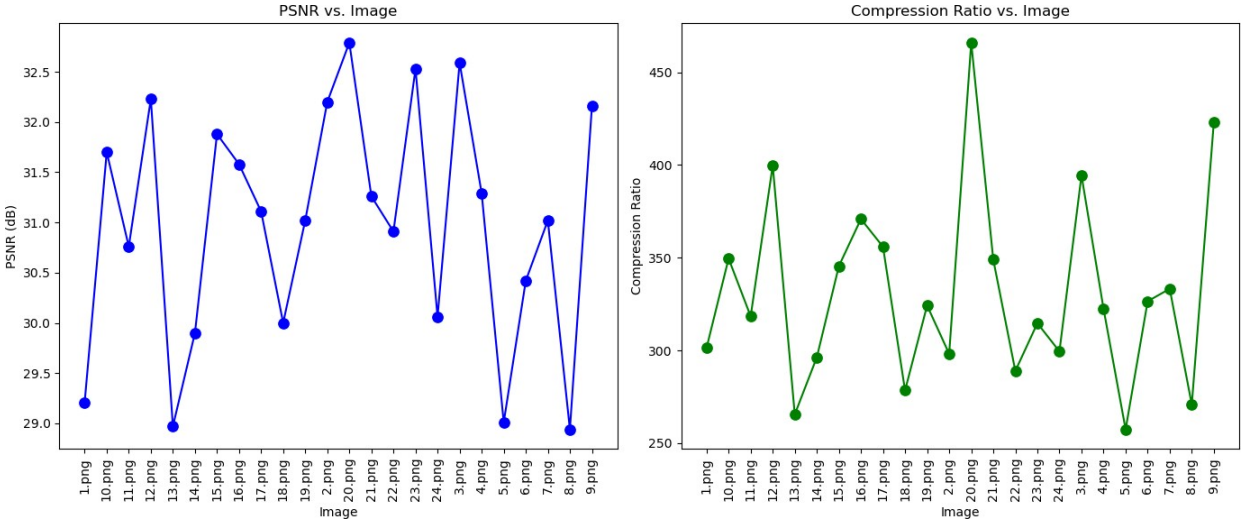

PSNR vs. Image
PSNR (dB)
Image
Compression Ratio vs. Image
Compression Ratio
Image

Image:

4) Triangular (Triang) Window:

Image	PSNR (dB)	Compression Ratio
1.png	28.89	292.27
10.png	30.65	304.18
11.png	29.94	297.47
12.png	30.80	313.93
13.png	28.70	280.58
14.png	29.21	290.63
15.png	30.04	287.74
16.png	30.57	325.98
17.png	29.78	309.74
18.png	29.25	280.86
19.png	30.19	298.76
2.png	30.27	277.84
20.png	30.39	335.83
21.png	30.46	295.23
22.png	30.06	288.29
23.png	30.80	278.01
24.png	29.44	287.99
3.png	30.95	295.49
4.png	30.20	277.02
5.png	28.71	260.34
6.png	29.59	286.72
7.png	30.20	285.21
8.png	28.66	274.26
9.png	30.96	333.67

Graphs:

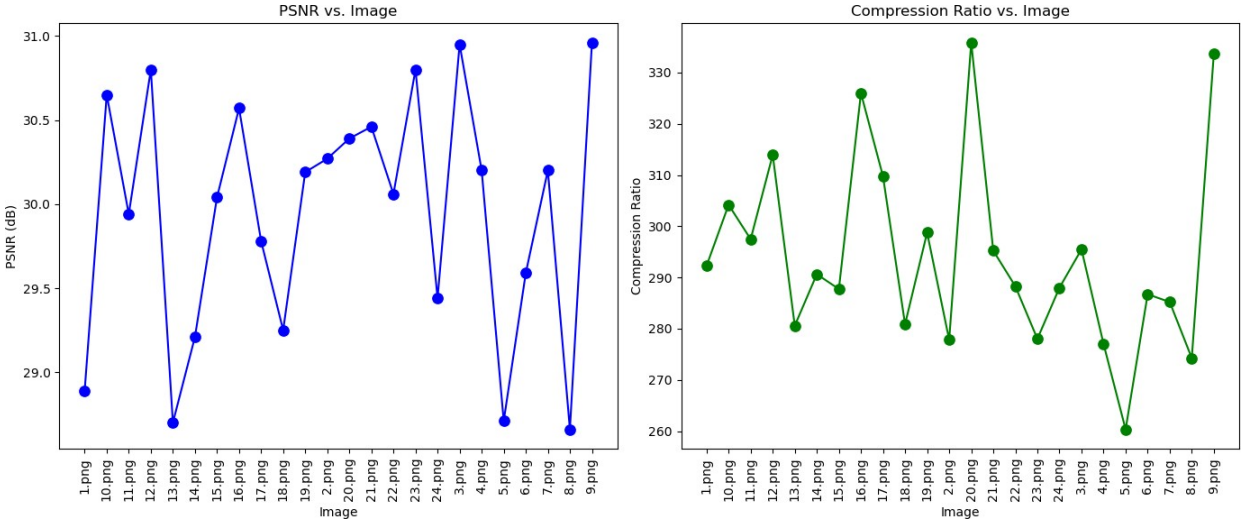


Image:

5) Cosine Window:

Image	PSNR (dB)	Compression Ratio
1.png	28.88	283.11
10.png	30.65	294.85
11.png	29.90	289.98
12.png	30.55	305.99
13.png	28.67	269.69
14.png	29.12	282.48
15.png	29.63	282.89
16.png	30.50	315.71
17.png	29.56	300.70
18.png	29.10	272.32
19.png	30.20	288.27
2.png	29.85	270.76
20.png	30.02	341.88
21.png	30.43	287.88
22.png	29.98	277.65
23.png	30.50	271.21
24.png	29.39	278.45
3.png	30.70	289.46
4.png	30.10	271.78
5.png	28.69	254.58
6.png	29.43	281.30
7.png	30.26	280.61
8.png	28.63	266.47
9.png	30.91	322.40

Graph:

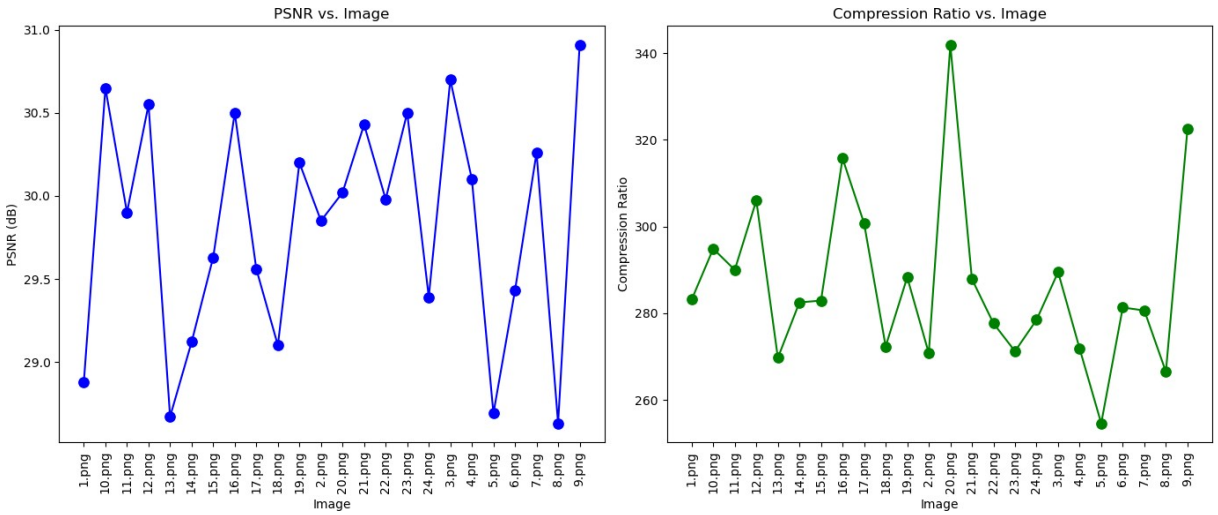


Image:

6) Parzen Window:

Image	PSNR (dB)	Compression Ratio
1.png	28.37	293.57
10.png	29.24	306.82
11.png	28.95	302.43
12.png	29.00	316.97
13.png	28.27	285.59
14.png	28.37	293.34
15.png	28.63	292.69
16.png	29.07	328.79
17.png	28.51	311.45
18.png	28.26	284.95
19.png	29.03	302.83
2.png	28.43	283.19
20.png	29.72	345.42
21.png	29.13	299.00
22.png	28.82	292.76
23.png	28.80	281.79
24.png	28.66	291.33
3.png	29.02	298.63
4.png	28.84	280.70
5.png	28.21	264.32
6.png	28.68	292.15
7.png	29.10	288.33
8.png	28.26	279.45
9.png	29.44	335.58

Graph:

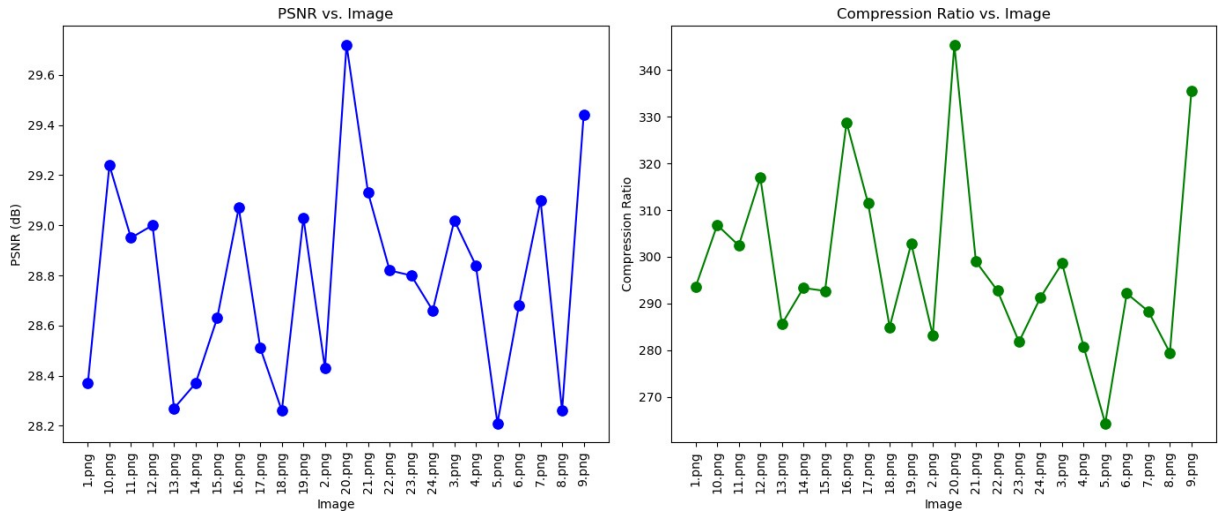
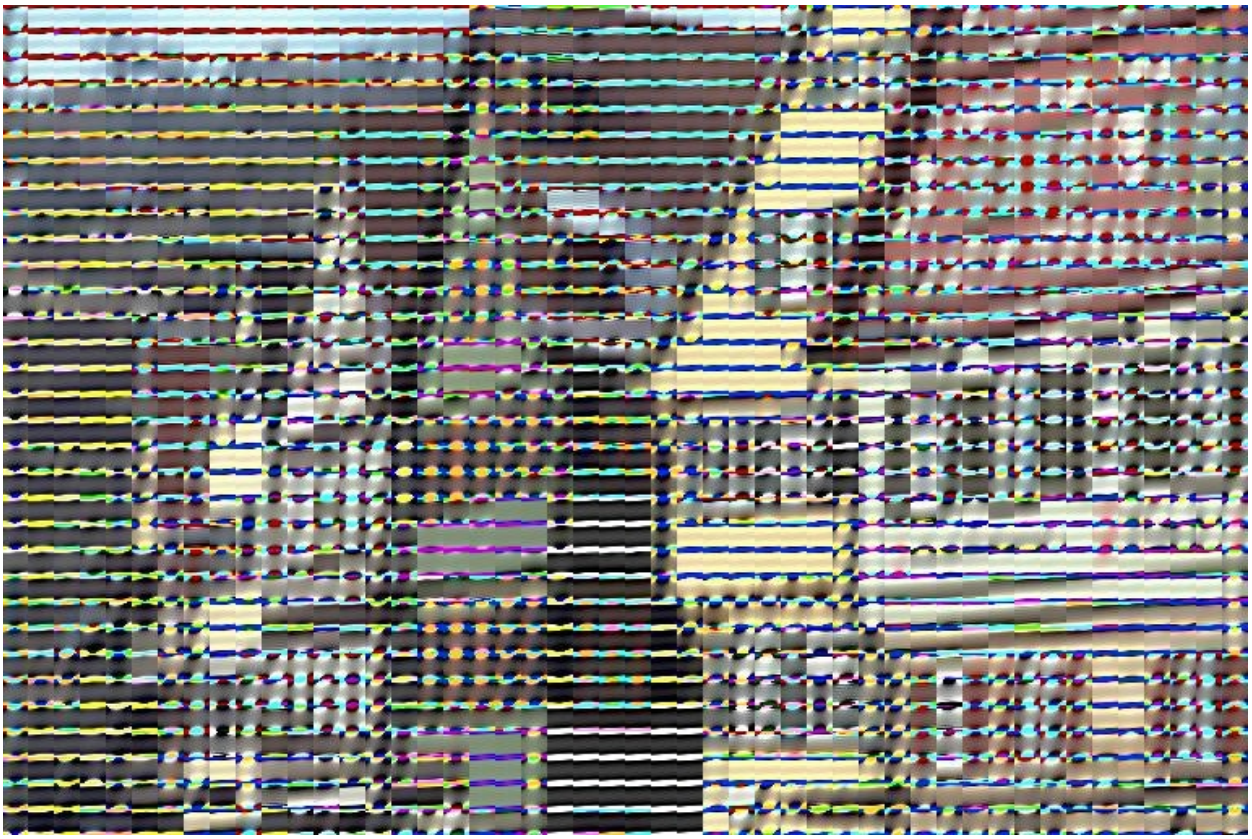


Image:

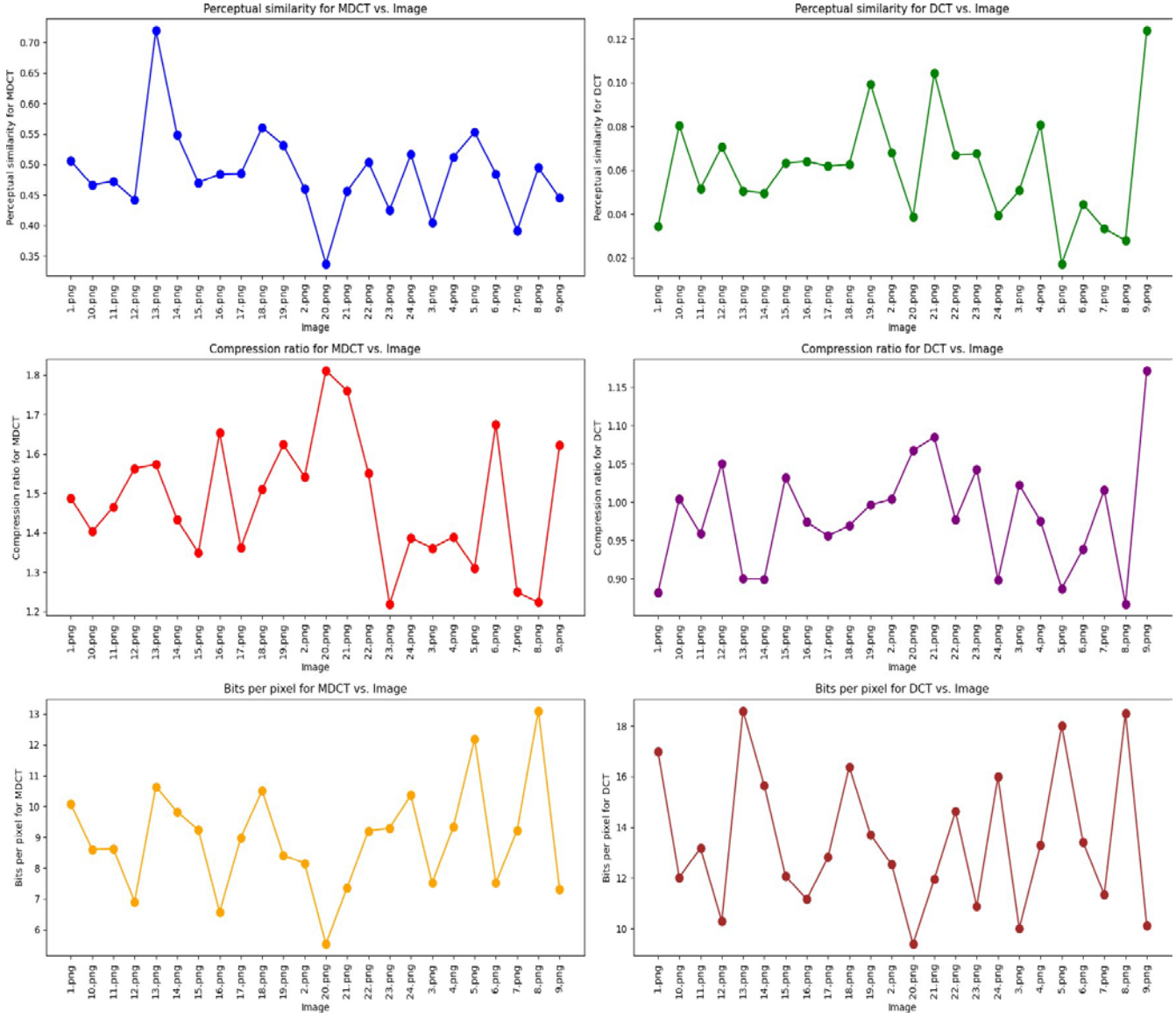


Perceptual Symmetry and Compression Metrics:

Image	Perceptual similarity for MDCT	Perceptual similarity for DCT	Compression ratio for MDCT	Compression ratio for DCT	Bits per pixel for MDCT	Bits per pixel for DCT
1.png	0.505588531494140 6	0.034232	1.4874300716954458	0.8820709296643704	10.07385	16.987467447916668
10.png	0.466397613286972 05	0.080366	1.4026807408317812	1.0044564426315523	8.607828776041666	12.020467122395834
11.png	0.472588062286376 95	0.051521	1.4653853868025815	0.9586351146923529	8.622131	13.17993
12.png	0.442427337169647 2	0.070722	1.5631	1.050145649211833	6.911722819010417	10.287821451822916
13.png	0.719161987304687 5	0.050544	1.572840554108979	0.8997632236579484	10.64197	18.602803548177082
14.png	0.548525273799896 2	0.049635	1.433143200240168	0.8996166042836349	9.826558430989584	15.6543

15.png	0.4702998 39973449 7	0.063297	1.349046984595 3952	1.032453	9.2383829752 60416	12.071268717 447916
16.png	0.4840764 40334320 07	0.064038	1.653237485765 2126	0.97407851 74596692	6.5745442708 33333	11.158528645 833334
17.png	0.4849663 97285461 4	0.061788	1.362010265783 8122	0.95579466 72931973	8.9935506184 89584	12.815836588 541666
18.png	0.560305	0.062585	1.510468586503 8887	0.96936186 58689472	10.518859863 28125	16.390584309 895832
19.png	0.5316400 52795410 2	0.099324	1.622961557518 7015	0.99631432 13247077	8.4174601236 97916	13.711751302 083334
2.png	0.4598415 19594192 5	0.067913	1.541795982316 6045	1.00394922 3801262	8.1548665364 58334	12.52368
20.png	0.3373687 86334991 46	0.03866813331 8424225	1.810821643286 5731	1.06727724 6927413	5.5329386393 22917	9.3875935872 39584
21.png	0.456155	0.10424833744 764328	1.760033042872 8512	1.08450088 01288358	7.3639729817 70833	11.950968424 479166
22.png	0.5039734 84039306 6	0.066922	1.551366343635 7006	0.97686457 60129141	9.2058308919 27084	14.619852701 822916
23.png	0.4253368 67570877 1	0.067496	1.219367437669 8893	1.04290999 4127043	9.3034464518 22916	10.87756
24.png	0.5164347 88703918 5	0.039442	1.386405164106 3988	0.89876508 33880432	10.366149902 34375	15.99048
3.png	0.4046276 21173858 64	0.050684	1.361143290207 3297	1.02256654 26299844	7.5166829427 08333	10.00549
4.png	0.5122326 61247253 4	0.08062	1.389119041133 2062	0.97530195 50961329	9.3358357747 39584	13.297
5.png	0.5525583 02879333 5	0.01721871271 7294693	1.310881546606 9526	0.88715660 66691736	12.192769368 489584	18.016296386 71875
6.png	0.4847629 96435165 4	0.044461	1.675035180775 0596	0.93853905 73350397	7.5179036458 33333	13.417399088 541666
7.png	0.3917215 16847610 5	0.033322	1.249441821471 1203	1.01586794 7678465	9.2215983072 91666	11.341878255 208334
8.png	0.4947243 33286285 4	0.027919	1.223859097957 4668	0.86694118 09980373	13.107279459 635416	18.503519694 010418
9.png	0.4453419 44694519 04	0.12374898791 313171	1.622435801087 749	1.17160918 15404406	7.309448	10.12207

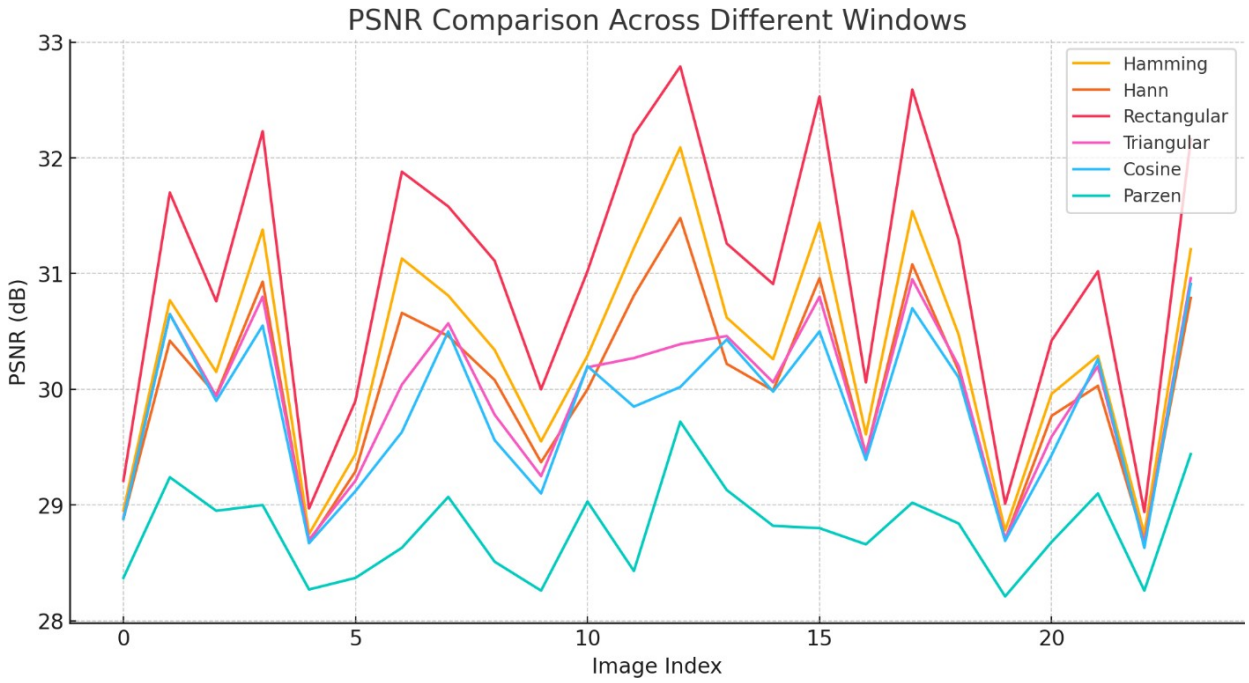
Graphs:

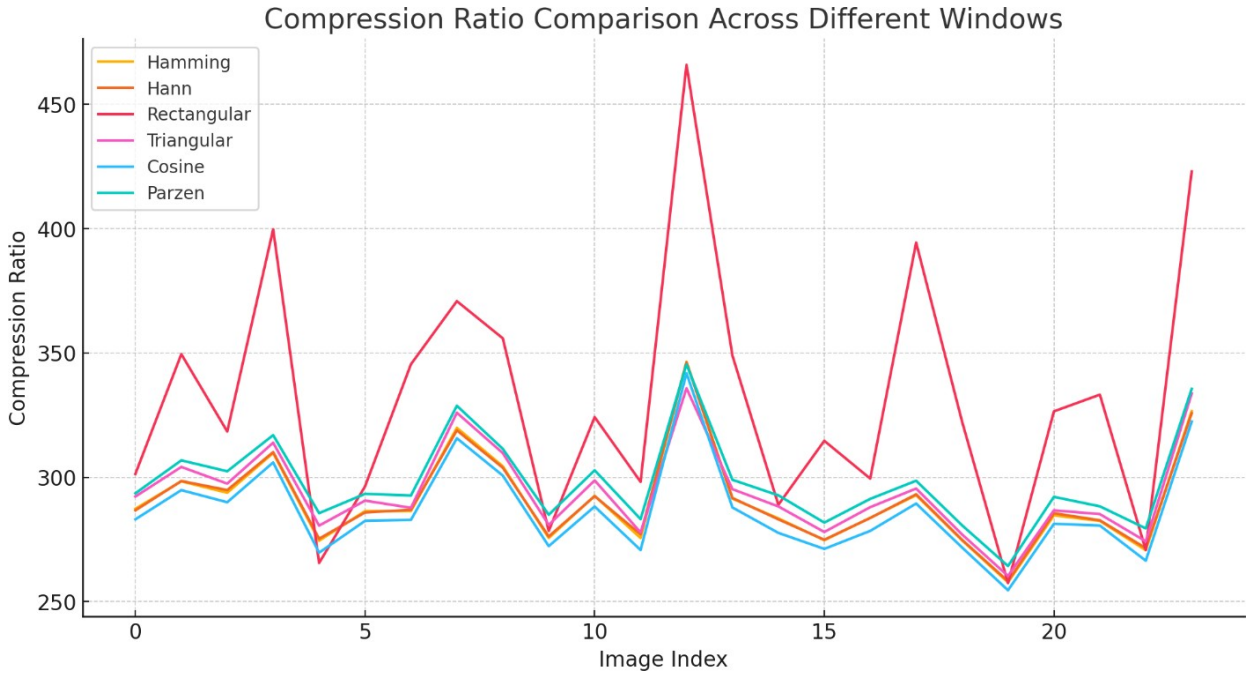


7. Analysis

7.1 Rectangular Window Performance

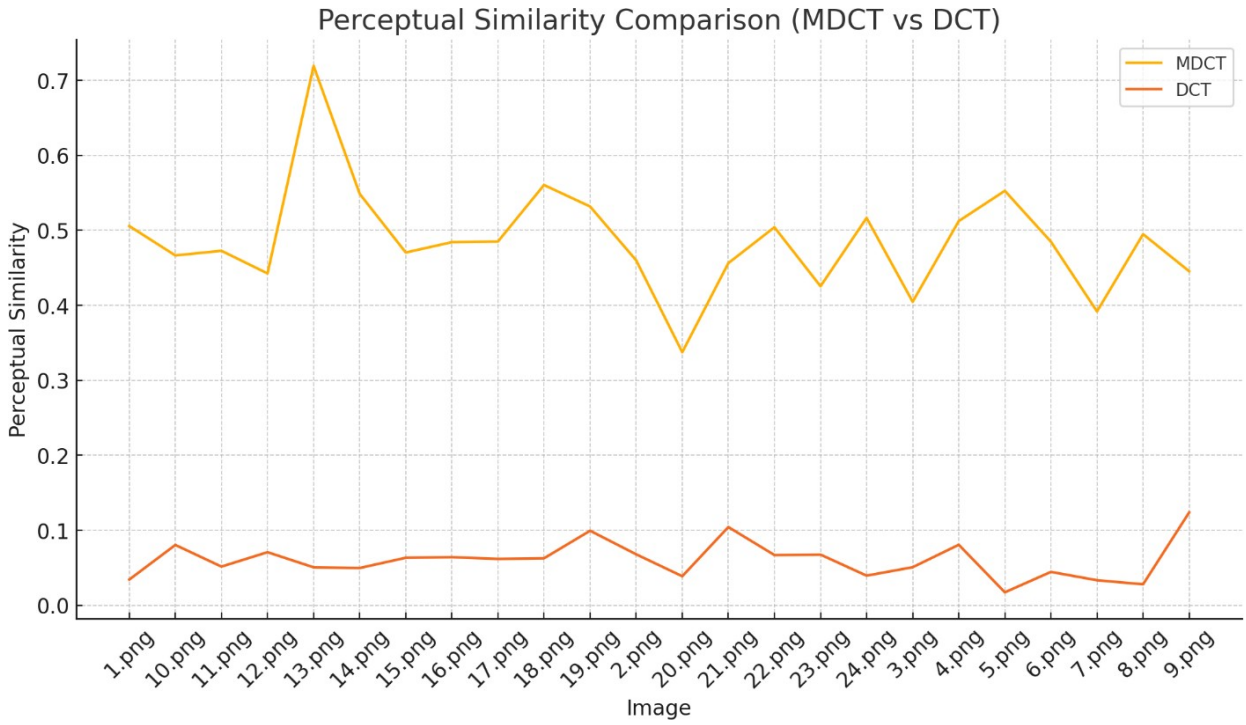
The **Rectangular window** provides a good balance between compression efficiency and image quality, as indicated by higher PSNR values and better compression ratios compared to other window functions.





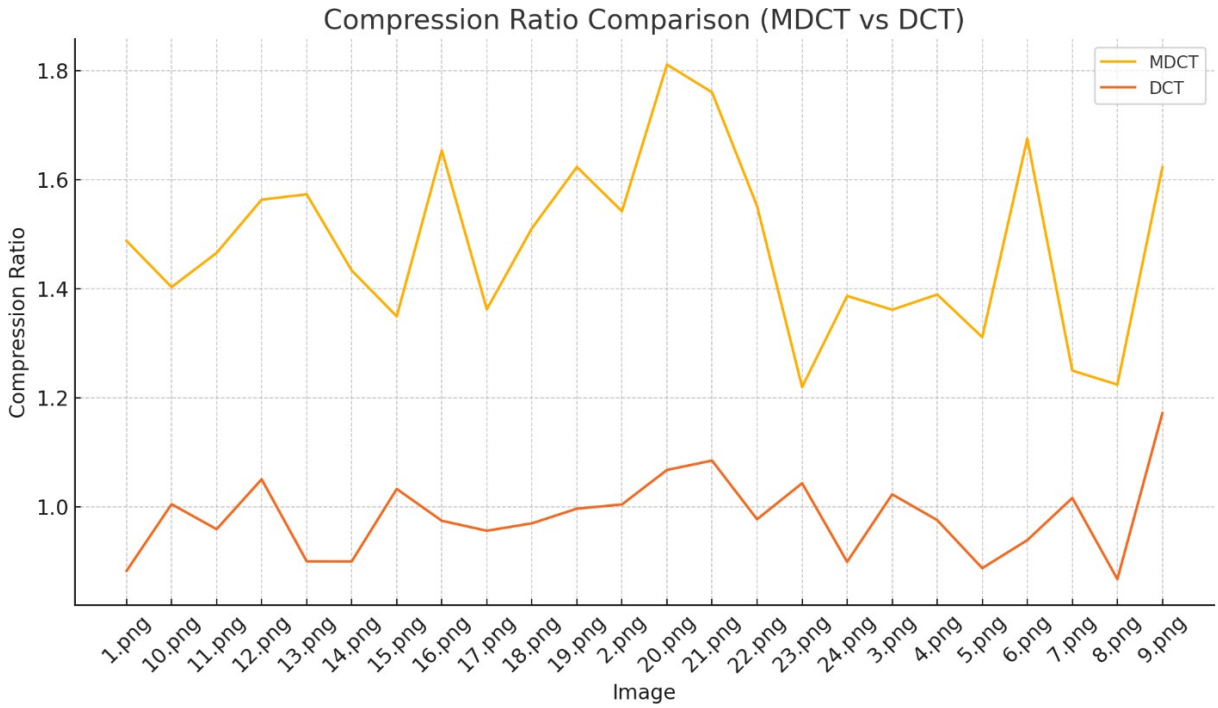
7.1 Perceptual Symmetry

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



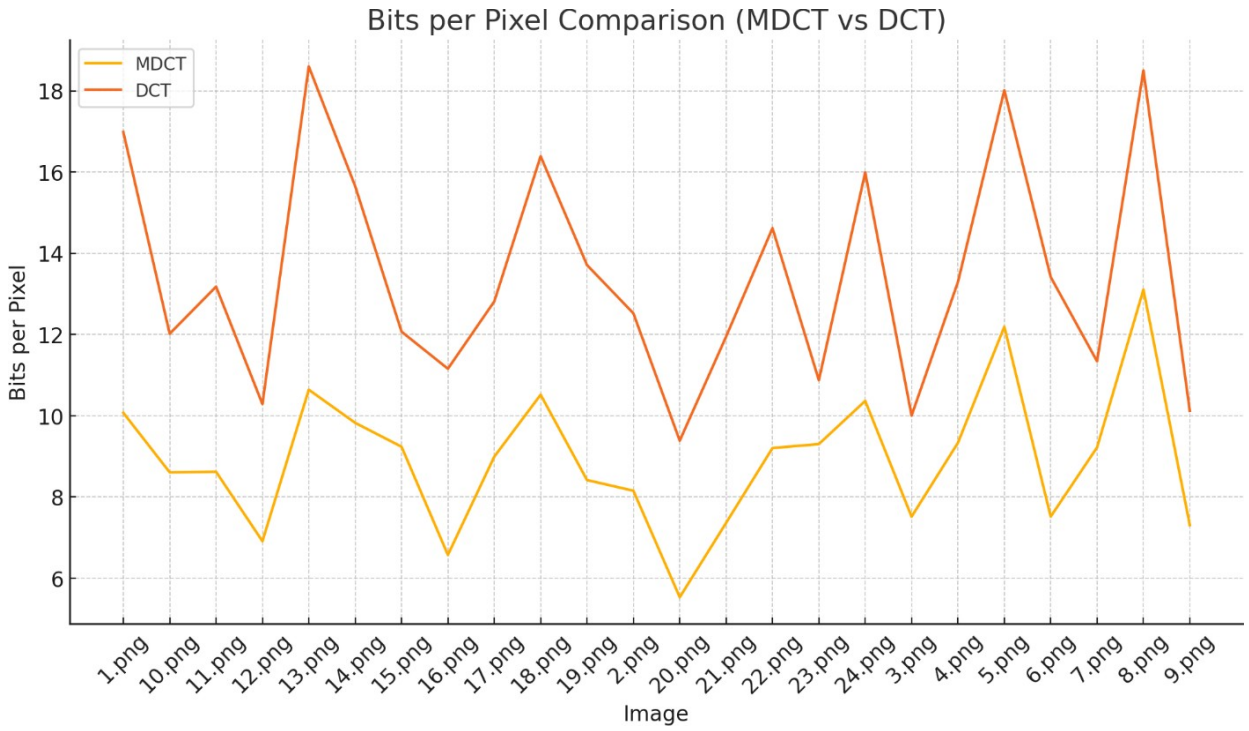
7.2 Compression Metric(File Size)

MDCT often achieves higher compression ratios compared to DCT.



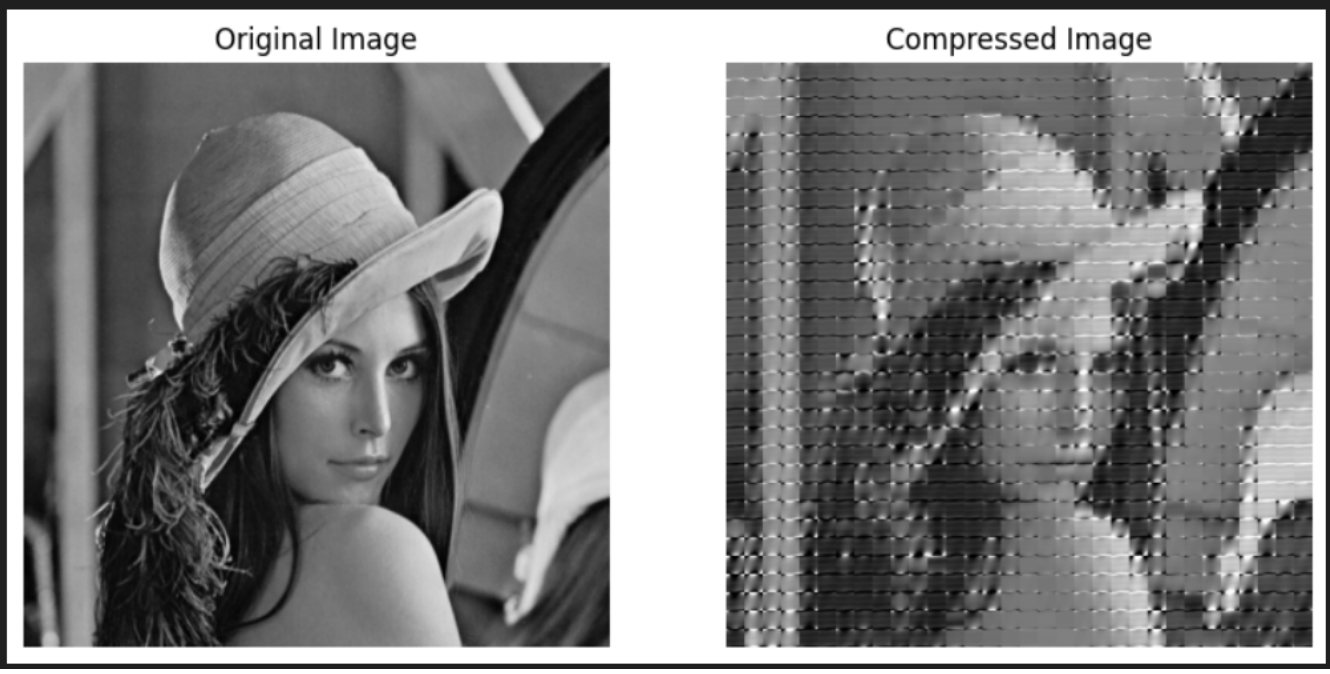
7.3 Bits Per Pixel (BPP)

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

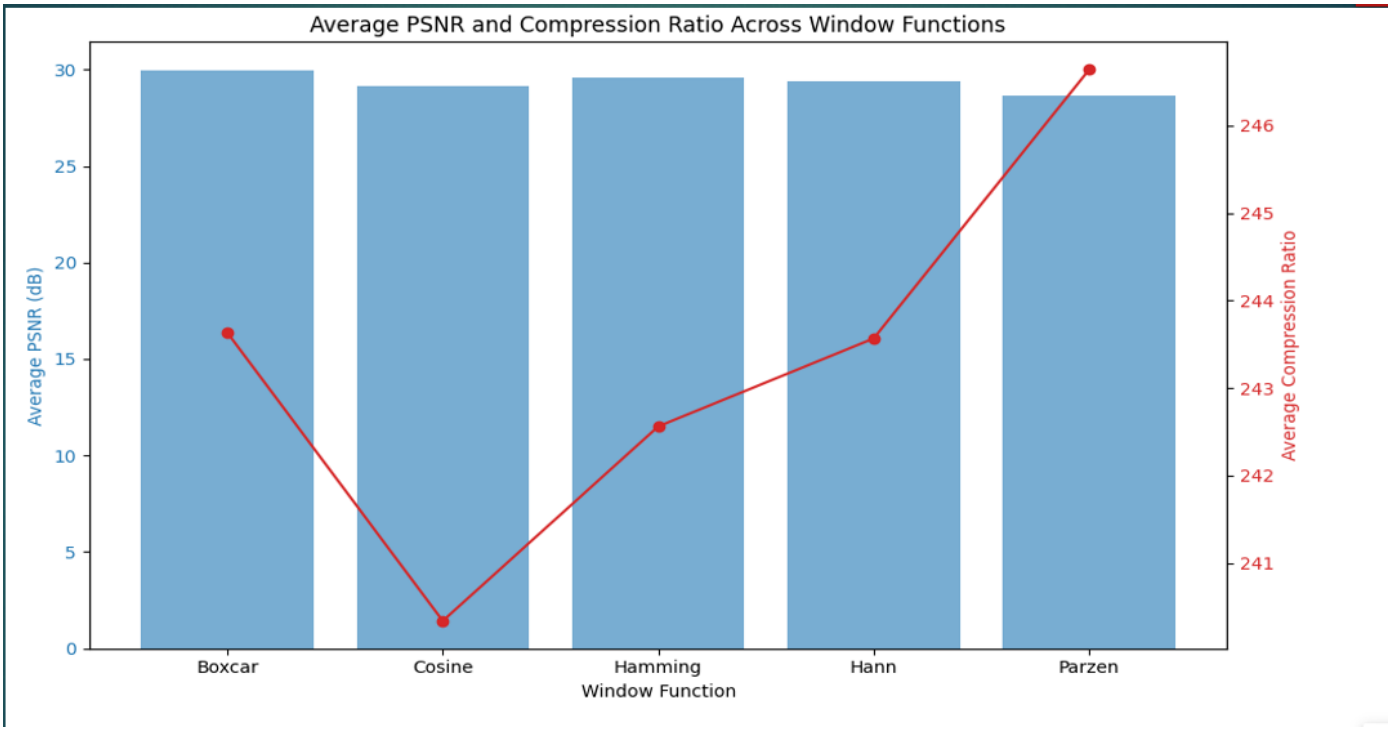


GREY SCALE IMAGE COMPRESSION

```
Processing image: /home/jupyter-66414/VC_Seminar_Project/images/greyscale/5.tif
PSNR: 30.21 dB
Compression Ratio: 242.19
Compressed image saved as /home/jupyter-66414/VC_Seminar_Project/greyscale/triang_mdctall/5_compressed.
```



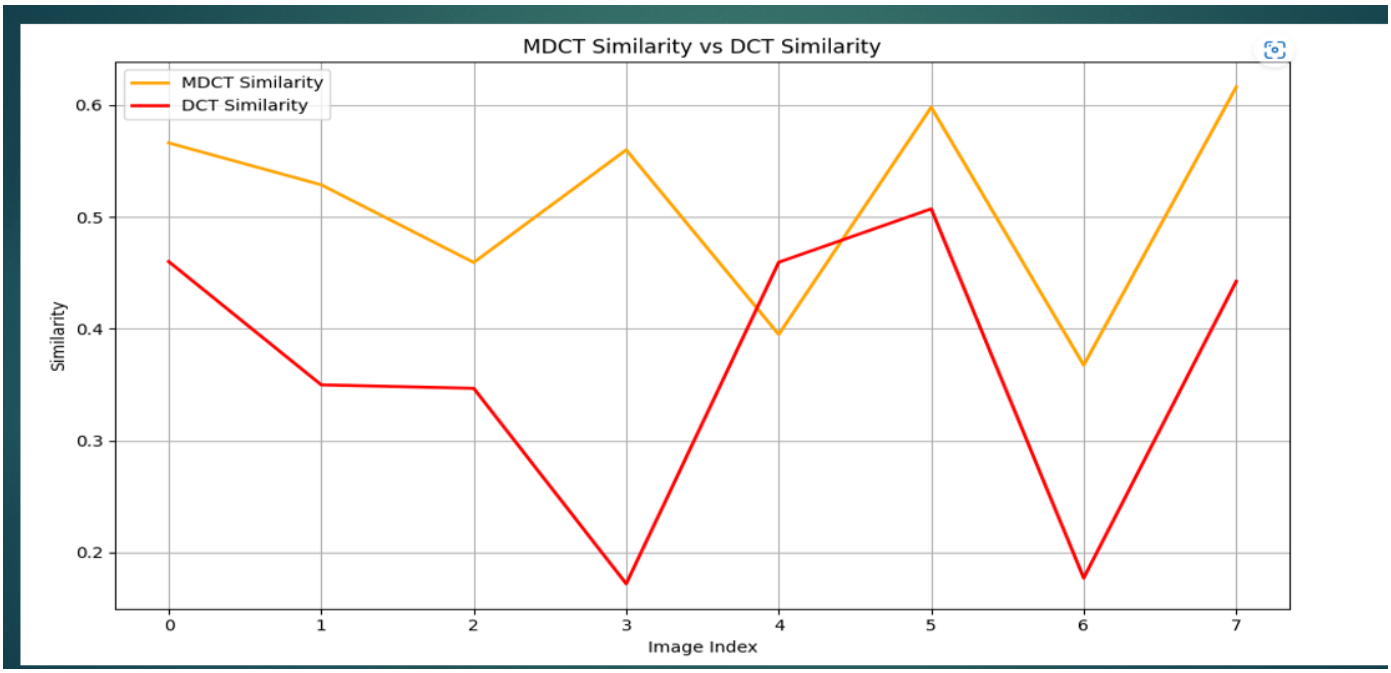
The effects of applying a high compression ratio to a grayscale image, leading to noticeable quality degradation, as evidenced by the visible artifacts in the compressed image. The provided psnr value suggests that while the compression is quite aggressive



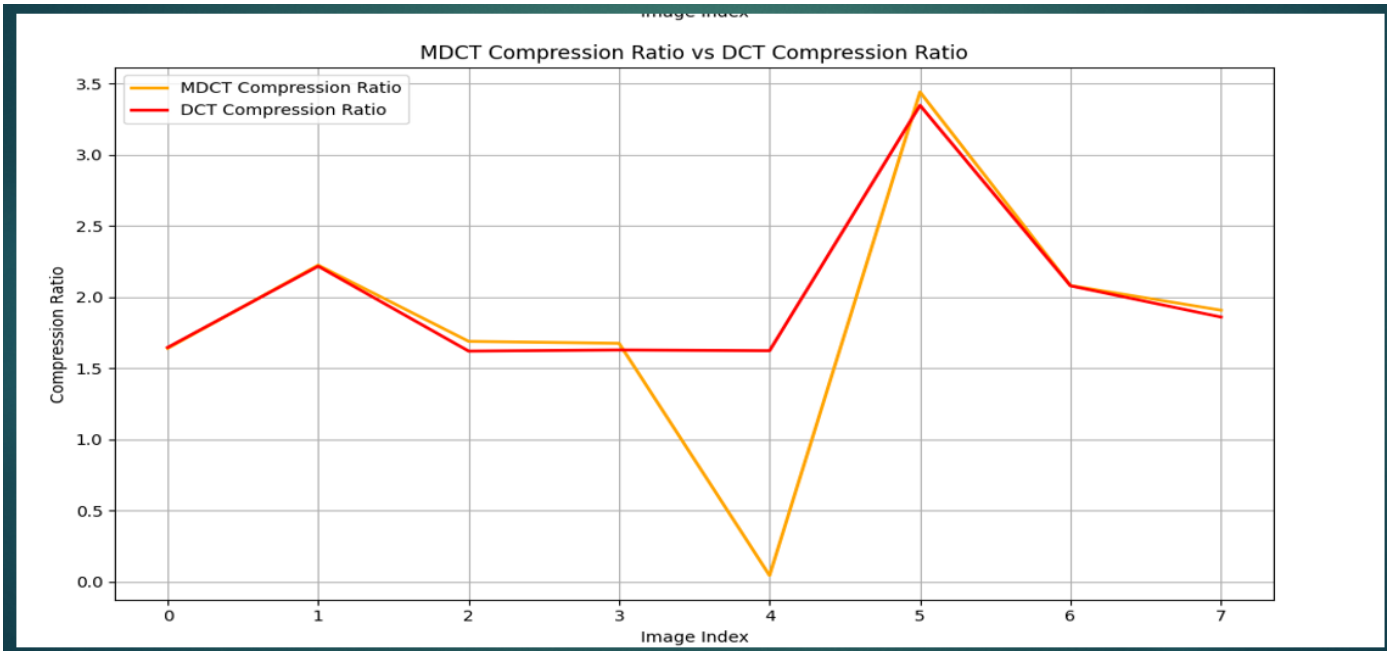
Boxcar and Parzen windows provide high PSNR, suggesting good image quality after compression.

Cosine window gives the lowest PSNR, meaning it results in the worst image quality but also has a low compression ratio.

The Parzen window achieves the highest compression ratio, which might be desirable in scenarios where file size is more critical than maintaining the highest possible image quality.



This chart suggests that MDCT generally provides better similarity than DCT when transforming images in this dataset. This could imply that MDCT is better at preserving image quality during transformation, making it potentially more suitable for applications where maintaining image fidelity is critical.



This chart highlights the relative performance of MDCT and DCT in terms of compression ratio. While both methods generally yield similar results, certain images show marked differences, suggesting that specific image characteristics can influence the effectiveness of each transformConclusion

Conclusion

MDCT offers a promising alternative to standard DCT for image compression, particularly in terms of perceptual similarity by LPIPS Deep Learning Module. While DCT achieves better

image quality, DCT 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.

8. References

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