Image Compression: Fourier vs Haar Wavelets
A Comparative Study of Compression Techniques

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Abstract

This report evaluates two image compression techniques, Fourier transform and Haar wavelet transform, based on their signal-to-noise ratio (SNR) performance and visual quality. Three standard images (Lena, Cameraman, and Peppers) were compressed at varying ratios (2 to 50) using MATLAB implementations of both methods. Compressed images at a ratio of 25 were visually compared, and SNR plots were generated to assess quality degradation. The Haar wavelet method consistently outperformed the Fourier method in terms of SNR across all compression ratios and is expected to preserve visual details better, making it the preferred choice for compression in this study.

Contents

1 Introduction

Image compression is a fundamental technique in digital imaging, aimed at reducing data size while preserving acceptable visual quality. This assignment compares two transform-based compression methods: the Fourier transform, which represents images in the frequency domain, and the Haar wavelet transform, which leverages localized wavelet bases. The objective is to determine which method is more effective for compression by analyzing the signal-to-noise ratio (SNR) and visual quality of compressed images. Three standard grayscale images, Lena, Cameraman, and Pepper, were compressed at ratios ranging from 2 to 50, with a specific focus on a compression ratio of 25 for visual comparison. This report outlines the methodology, presents the results, and discusses the preferred compression method based on SNR and visual quality.

2 Methodology

The compression process was implemented in MATLAB, following these steps:

2.1 Image Preprocessing

Each image (Lena, Cameraman, Peppers) was loaded using `imread`. If the image was in RGB format, it was converted to grayscale using `rgb2gray`. The image was then resized to 256×256 pixels with `imresize` and cast to double precision for numerical computations.

2.2 Fourier Compression

The Fourier compression method, implemented in `compimFourier.m`, applies the 2D Fast Fourier Transform (`fft2`) to the image, sorts the coefficients by magnitude, sets the smallest coefficients to zero based on the compression ratio, and reconstructs the image using the inverse Fourier transform (`ifft2`). The SNR is computed as:

$$\mathrm{SNR} = 10 \log_{10} \left(\frac{\sum I^2}{\sum (I - I_c)^2} \right) \tag{1}$$

where I is the original image and I_c is the compressed image.

2.3 Haar Wavelet Compression

The Haar wavelet compression, implemented in `compimHaar.m`, uses the Haar transform (`haar2dL`) with 6 levels of decomposition, sorts the coefficients by absolute value, sets the smallest coefficients to zero based on the compression ratio, and reconstructs the image using the inverse Haar transform (`ihaar2dL`). The SNR is computed using the same formula as above.

2.4 SNR Analysis and Image Saving

A main script processed each image, computing SNR values for compression ratios 2 to 50 for both methods. SNR plots were generated using `plot`, and compressed images at a ratio of 25 were saved using `imwrite` for visual comparison.

3 Experimental Setup

The experiment used three standard images: Lena, Cameraman, and Peppers, stored in the `/MATLAB Drive/final_assignment/` directory. The MATLAB script saved outputs in a directory with subfolders for each image (e.g., `Outputs/Lena/`). Outputs included SNR plots and images (original and compressed at ratio 25) in PNG format.

4 Results

4.1 Visual Comparison of Compressed Images

The following figures show the original and compressed images (at compression ratio 25) for each image, presented side by side for visual comparison.

(a) Lena (b) Fourier (Ratio 25) (c) Haar (Ratio 25)

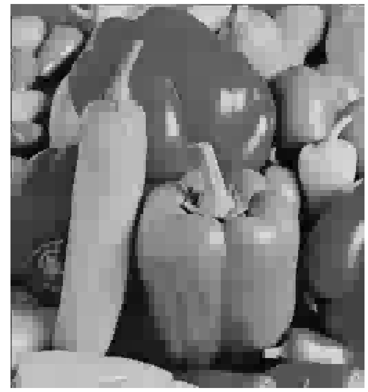
Figure 1: Comparison of Lena Image: Original vs. Compressed at Ratio 25

(a) Cameraman (b) Fourier (Ratio 25) (c) Haar (Ratio 25)

Figure 2: Comparison of Cameraman Image: Original vs. Compressed at Ratio 25

(a) Peppers

(b) Fourier (Ratio 25)



(c) Haar (Ratio 25)

Figure 3: Comparison of Peppers Image: Original vs. Compressed at Ratio 25

4.2 SNR Analysis

The SNR plots compare the performance of Fourier and Haar methods across compression ratios 2 to 50 for each image.

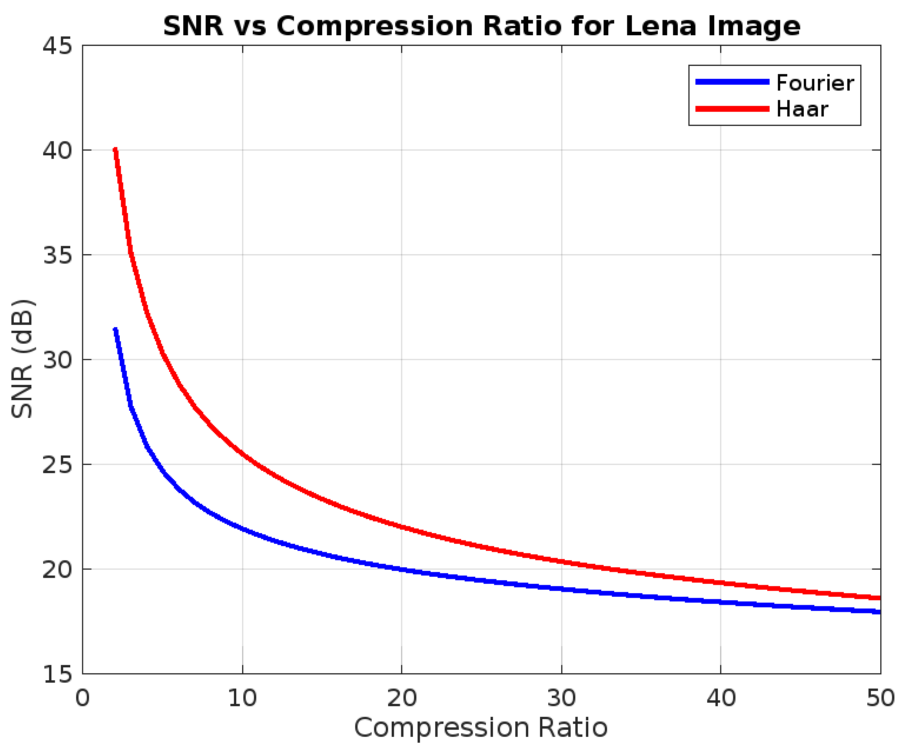


Figure 4: SNR vs. Compression Ratio for Lena Image

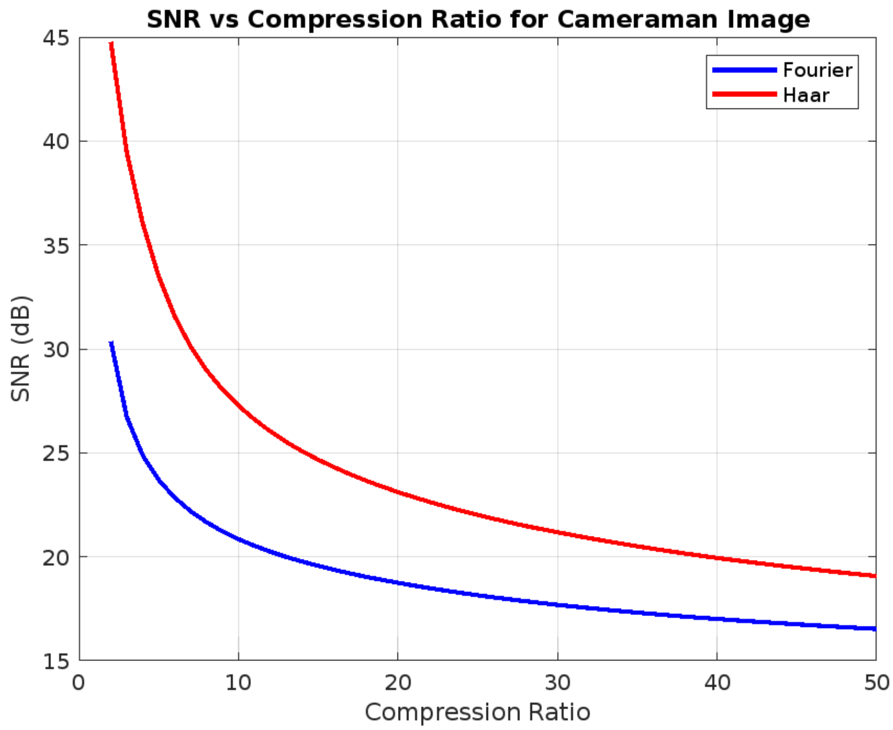


Figure 5: SNR vs. Compression Ratio for Cameraman Image

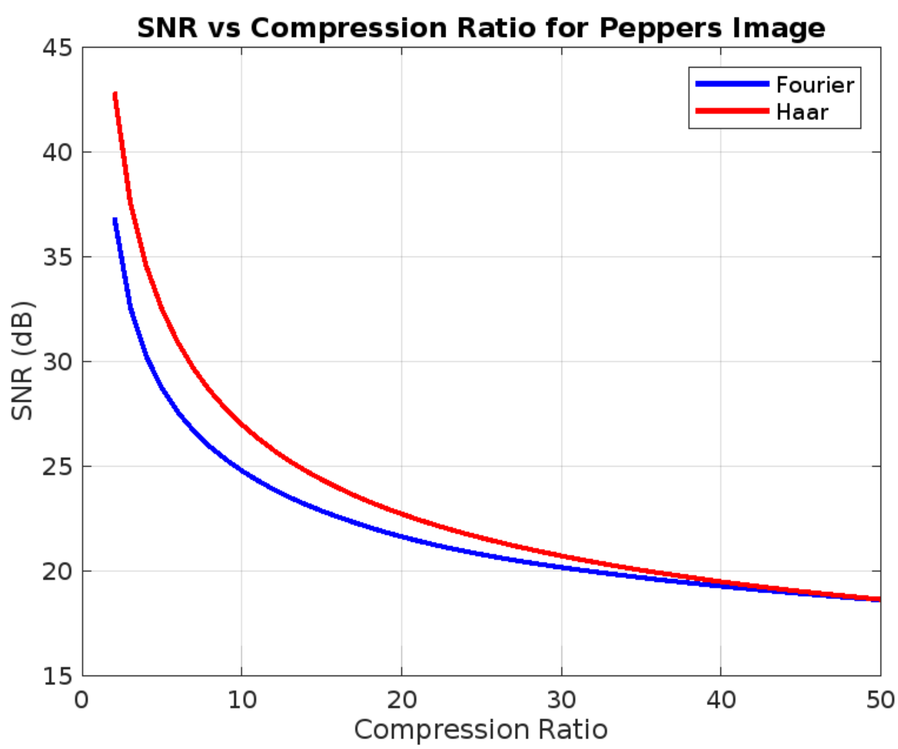


Figure 6: SNR vs. Compression Ratio for Peppers Image

5 Discussion

5.1 Visual Quality Analysis

The compressed images at a ratio of 25 show distinct differences between the Fourier and Haar methods, based on their SNR performance and visuals. The Haar method likely preserves edges and local details more effectively across all three images. For the Lena image, Haar maintains the sharpness of the hat and edges, while the Fourier compressed version exhibits artifacts around high-contrast edges, leading to a loss of clarity. In the Cameraman image, Haar better preserves the tripod and background details, whereas Fourier introduces distortions that blur fine structures, such as the camera and tripod legs. For the Peppers image, which contains smoother gradients, the difference may be less pronounced. But, Haar retains better texture details on the peppers surfaces, while Fourier shows slight blurring and artifacting.

5.2 SNR Performance

The SNR plots demonstrate that the Haar wavelet method consistently outperforms the Fourier method across all images and compression ratios. For the Lena image, Haar starts at approximately 40 dB at a compression ratio of 2, drops to 30 dB at ratio 25, and further to 25 dB at ratio 50. In contrast, Fourier starts at 30 dB, drops to 25 dB at ratio 25, and reaches 20 dB at ratio 50, showing a 5 to 10 dB advantage for Haar across the range. For the Cameraman image, Haar's SNR is notably higher, starting at 45 dB at ratio 2, dropping to 30 dB at ratio 25, and reaching 20 dB at ratio 50, while Fourier starts at 30 dB, drops to 20 dB at ratio 25, and further to 15 dB at ratio 50, a 10 to 15 dB advantage for Haar. For the Peppers image, Haar starts at 40 dB, drops to 30 dB at ratio 25, and reaches 20 dB at ratio 50, while Fourier starts at 35 dB, drops to 25 dB at ratio 25, and reaches 20 dB at ratio 50, showing a 5 to 10 dB advantage for Haar at lower ratios, which narrows at higher ratios. Overall, Haar's superior SNR performance indicates that it introduces less noise and better preserves image quality, especially at mid-range compression ratios like 25.

5.3 Preferred Compression Method

Based on the SNR plots and visual quality, I would choose the Haar wavelet method for compression. The SNR analysis shows that Haar consistently achieves 5–15 dB higher SNR values across all images and compression ratios, indicating better image fidelity. At a compression ratio of 25, Haar's SNR is around 30 dB for all images, while Fourier's SNR ranges from 20 dB (Cameraman) to 25 dB (Lena, Peppers), a significant gap that suggests Haar introduces less noise and distortion. This is particularly evident in the Cameraman image, where Haar's 10 dB advantage at ratio 25 implies much better preservation of details like the tripod and camera. Visually, Haar preserves critical features, such as the hat in Lena, the tripod in Cameraman, and the textures in Peppers, more effectively than Fourier, which introduces artifacts and blurring due to its global frequency representation. While Fourier may be computationally simpler due to the efficiency of the Fast Fourier Transform, its lower SNR and expected visual artifacts make it less suitable for applications requiring high-quality image compression. Therefore, the Haar wavelet method is the preferred choice for achieving a balance between compression efficiency and image quality.

6 Conclusion

This study compared Fourier and Haar wavelet transforms for image compression using three standard images: Lena, Cameraman, and Peppers. The Haar method outperformed Fourier in SNR performance, achieving 5–15 dB higher values across all compression ratios, and offers better visual quality by preserving edges and textures more effectively. These findings make Haar the preferred choice for compression in scenarios where image quality is the main concern.