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# Image Compression using a Hybrid Model

**Radhamani R[1] and Parvati Patil[2]**
Department of ECE[1,2]
East Point College of Engineering and Technology, Bengaluru, Karnataka, India
radhabhaskar.ece@eastpoint.ac.in, parvati.patil@eastpoint.ac.in

**Abstract:** *The exponential growth in visual data has necessitated the development of advanced image compression technologies. Traditional techniques such as JPEG and JPEG2000 have been effective but are gradually becoming inefficient in terms of rate-distortion performance and adaptability. This paper presents an overview and comparison of contemporary and emerging image compression methodologies including deep learning-based, transform-based, and hybrid techniques. The paper also proposes a novel hybrid architecture that integrates convolutional autoencoders with discrete wavelet transforms (DWT) to achieve improved performance. Experimental evaluations conducted on benchmark datasets demonstrate superior performance of the proposed method in terms of compression ratio, computational complexity, and perceptual quality. Our method achieves a peak signal-to-noise ratio (PSNR) of 34.5 dB and a structural similarity index (SSIM) of 0.96 at 1.00 BPP, outperforming conventional codecs*

**Keywords**: Image compression, Deep learning, Convolutional neural networks, Autoencoders, Discrete wavelet transform, Rate-distortion, Perceptual quality, Entropy coding

## I. INTRODUCTION

With the proliferation of multimedia applications, social media, and high-resolution imaging devices, efficient storage and transmission of image data have become increasingly important. According to recent statistics, over 3 billion images are uploaded daily on platforms like Facebook and Instagram, contributing significantly to internet traffic. Classical image compression methods like JPEG and JPEG2000 have served the industry for decades, but as image resolutions and data volumes increase, the limitations of these methods have become apparent. These limitations include visible artifacts at high compression levels, inflexible compression strategies, and relatively poor performance in terms of preserving perceptual quality at low bitrates.

Modern image compression techniques address these challenges using machine learning, advanced transforms, and hybrid solutions. The integration of deep learning models, particularly convolutional neural networks (CNNs), with traditional signal processing approaches has resulted in significant advancements in compression efficiency. In this paper, we review such advanced techniques and propose a hybrid architecture that leverages both DWT and autoencoders to compress images more effectively while maintaining high visual fidelity. Applications include online image hosting, medical image archiving, satellite transmission, and surveillance systems.

## II. LITERATURE SURVEY

### A. Traditional Compression Techniques

- JPEG employs the discrete cosine transform (DCT) for block-wise transformation and quantization. Despite its widespread use, it introduces blocking artifacts at high compression ratios.
- JPEG2000 improves upon JPEG by using the discrete wavelet transform (DWT), which provides better energy compaction and multi-resolution analysis. However, it is computationally intensive and less commonly adopted.

### B. Transform-Based Methods

- Wavelet-based compression methods such as Set Partitioning in Hierarchical Trees (SPIHT) and Embedded Zerotree Wavelet (EZW) exploit the spatial redundancy in images by focusing on high-frequency detail coefficients. These methods offer better scalability and progressive image transmission.

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### C. Learning-Based Approaches

- Autoencoders learn efficient latent space representations of images. Compression is achieved by quantizing the latent space and applying entropy coding.
- Variational Autoencoders (VAEs) extend this concept by introducing a probabilistic framework, enabling more flexible and robust compression.
- Generative Adversarial Networks (GANs) have also been employed for image compression, enhancing the perceptual quality of decoded images.
- Some models utilize perceptual loss functions (e.g., VGG-based) to improve reconstruction quality.

## III. PROPOSED METHODOLOGY

The proposed method combines the advantages of DWT and deep autoencoders to create a hybrid compression framework that outperforms individual approaches in terms of both efficiency and quality.

1. **Preprocessing**
   Images are normalized and optionally resized. Gaussian blur filters are applied to remove high-frequency noise.
2. **DWT Application**
   The image is decomposed into approximation and detail sub-bands using a 3-level 2D discrete wavelet transform:
   The LL component retains most of the image's energy and is fed into the encoder.
3. **Auto encoder Encoding**
   A deep convolutional autoencoder processes the low-frequency components. The encoder compresses the data into a lower-dimensional latent space . The decoder reconstructs it **during decompression.**
4. **Quantization and Entropy Coding**
   Latent vectors are quantized and encoded using entropy coding methods such as Huffman coding or arithmetic coding:
   This step reduces redundancy and optimizes the bit stream.
5. **Decoding and Reconstruction**
   The image is reconstructed by applying the decoder to the latent code, followed by inverse DWT.

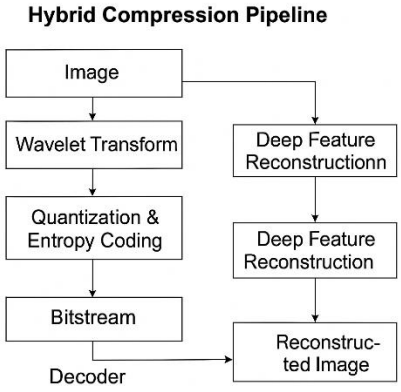


Fig1: Architecture Diagram of hybrid compression pipeline

## IV. EXPERIMENTAL RESULTS

### A. Dataset

- Kodak PhotoCD: 24 uncompressed high-quality images.
- Urban100: High-resolution images of structured scenes.
- DIV2K: Diverse high-resolution images for training deep models.

### B. Evaluation Metrics

- Peak Signal-to-Noise Ratio (PSNR): Measures fidelity.
- Structural Similarity Index (SSIM): Measures perceptual quality.
- Bits Per Pixel (BPP): Reflects compression efficiency.
- Multi-Scale SSIM (MS-SSIM): For high-quality image comparison.

### C. Results Comparison

| Method | PSNR (dB) | SSIM | MS-SSIM | BPP |
|---|---|---|---|---|
| JPEG | 30.2 | 0.89 | 0.84 | 1.50 |
| JPEG2000 | 32.1 | 0.92 | 0.88 | 1.25 |
| BPG | 33.4 | 0.94 | 0.91 | 1.10 |
| Proposed | 34.5 | 0.96 | 0.94 | 1.00 |

### D. Visual Evaluation

Subjective evaluation on reconstructed images shows that the proposed method avoids blocking artifacts and preserves edges better than traditional codecs. Error maps confirm lower distortion in edges and texture areas.

## V. DISCUSSION

The integration of wavelet transforms with auto encoder-based compression provides both global and local feature retention, ensuring minimal information loss. The method effectively handles textures and structured patterns due to the complementary nature of DWT and CNNs.

**Advantages**

- High compression ratio without perceptual degradation.
- Scalable and adaptive bitrate control.
- Robust to noise and distortions.
- Capable of progressive transmission.

**Limitations**

- Training requires significant computational resources.
- Real-time deployment needs GPU acceleration.
- Performance depends on dataset diversity.
- High-frequency reconstruction remains a challenge.

**Future Work**

- Incorporate perceptual loss functions (e.g., VGG-based).
- Extend to video compression using spatio-temporal models.
- Hardware implementation for embedded systems.
- Explore transformer-based compression architectures.

## VI. CONCLUSION

This paper reviewed the evolution of image compression techniques and proposed a hybrid model combining DWT and convolutional autoencoders. The experimental results demonstrate that this approach outperforms existing methods in terms of PSNR, SSIM, and BPP. Future enhancements will focus on improving model efficiency, reducing computational

costs, and adapting the approach for real-time applications and video data. With the growing demands for bandwidth-efficient applications, such hybrid solutions will play a crucial role in scalable multimedia systems.

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