

Advanced Data Compression Techniques

Project Title: Enhanced JPEG Image Compression Using Adaptive Block Processing and Content-Aware Quantization

Abstract:

Image compression is essential for efficient storage and transmission of digital images in modern computing environments. This project implements and enhances the JPEG (Joint Photographic Experts Group) image compression algorithm based on the Discrete Cosine Transform(DCT). The standard JPEG algorithm, while widely used, suffers from several limitations including blocking artifacts, fixed quantization matrices, and lack of content adaptation.

This work presents a comprehensive implementation of the standard JPEG algorithm as described in the research literature, followed by the development of an improved compression system. The proposed enhancements include adaptive block processing with variable block sizes (4×4, 8×8, 16×16), content-aware quantization based on variance and gradient analysis, perceptual optimization using Human Visual System (HVS) models, intelligent chroma subsampling, and enhanced entropy coding.

Experimental results demonstrate significant improvements over the standard JPEG implementation. At quality level 50, the improved algorithm achieves 1.39 dB better Peak Signal-to-Noise Ratio (PSNR), 1.54 times better compression ratio, and produces files that are 35% smaller while maintaining superior visual quality. The algorithm successfully processes full-color images compared to grayscale-only output in the baseline implementation. The key innovation lies in combining variance-based complexity analysis with adaptive block sizing and intelligent bit allocation, resulting in both better compression efficiency and higher image quality simultaneously. This work contributes to the field of image compression by demonstrating practical improvements to a widely-used standard while maintaining computational feasibility.

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