Vector Quantization Image Compression

**Executive Summary**

This report presents a comprehensive analysis of image compression using Vector Quantization (VQ) in both RGB and YUV color spaces. The study processes 45 high-resolution images across three distinct categories, comparing compression efficiency, quality preservation, and computational performance.

**1. Project Specifications**

**1.1 Technical Parameters**

- Vector Size: 2×2 pixels

- Codebook Size: 256 vectors

- Color Spaces: RGB and YUV

- Image Resolution: 1920×1080 pixels

**1.2 Dataset Composition**

- Training Set: 30 images

- 10 nature scenes

- 10 facial portraits

- 10 animal photographs

- Test Set: 15 images

- 5 nature scenes

- 5 facial portraits

- 5 animal photographs

**2. Methodology**

**2.1 RGB Compression Pipeline**

1. Image preprocessing and normalization

2. RGB channel separation

3. Vector extraction (2×2 blocks)

4. Codebook generation using LBG algorithm

5. Vector quantization

6. Image reconstruction

**2.2 YUV Compression Pipeline**

1. RGB to YUV conversion

2. UV component subsampling (50% reduction)

3. Vector quantization

4. UV component upsampling

5. YUV to RGB conversion

6. Image reconstruction

**3. Performance Analysis**

**3.1 RGB Compression Performance**

Nature Category

- Average MSE: 259.17

- Average PSNR: 24.21 dB

- Quality Range:

- Best: MSE 172.34 (PSNR 25.77 dB)

- Worst: MSE 397.71 (PSNR 22.14 dB)

Animals Category

- Average MSE: 42.50

- Average PSNR: 32.55 dB

- Quality Range:

- Best: MSE 21.84 (PSNR 34.74 dB)

- Worst: MSE 93.57 (PSNR 28.42 dB)

Faces Category

- Average MSE: 57.87

- Average PSNR: 34.39 dB

- Quality Range:

- Best: MSE 5.10 (PSNR 41.05 dB)

- Worst: MSE 182.68 (PSNR 25.51 dB)

**3.2 YUV Compression Performance**

Nature Category

- Average MSE: 677.40

- Average PSNR: 19.98 dB

- Quality Range:

- Best: MSE 473.10 (PSNR 21.38 dB)

- Worst: MSE 980.70 (PSNR 18.22 dB)

Animals Category

- Average MSE: 78.00

- Average PSNR: 30.02 dB

- Quality Range:

- Best: MSE 21.71 (PSNR 34.76 dB)

- Worst: MSE 149.39 (PSNR 26.39 dB)

Faces Category

- Average MSE: 89.83

- Average PSNR: 30.27 dB

- Quality Range:

- Best: MSE 18.92 (PSNR 35.36 dB)

- Worst: MSE 174.14 (PSNR 25.72 dB)

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AI-generated content may be incorrect.

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**4. Comparative Analysis**

4.1 Quality Metrics Comparison

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | RGB PSNR (dB) | YUV PSNR (dB) | RGB MSE | YUV MSE |
| Nature | 24.21 | 19.98 | 259.17 | 677.40 |
| Animal | 32.55 | 30.02 | 42.50 | 78.00 |
| Faces | 34.39 | 30.27 | 54.87 | 89.83 |

**4.2 Performance Characteristics**

- Processing Time:

- Image Loading: 123 seconds

- Codebook Generation: 2 seconds

- Compression Processing: 27 seconds

- Total Execution: 152 seconds

**5. Technical Insights**

**5.1 RGB Compression Strengths**

1. Superior quality preservation

2. Better detail retention

3. Consistent performance across categories

4. Lower computational complexity

**5.2 YUV Compression Characteristics**

1. Color space transformation overhead

2. Quality loss in UV subsampling

3. Higher MSE in high-frequency areas

4. Additional processing requirements

**6. Applications and Recommendations**

**6.1 Recommended Use Cases**

- RGB Compression:

- High-quality image archives

- Medical imaging

- Professional photography

- Quality-critical applications

- YUV Compression:

- Video streaming

- Real-time applications

- Storage-constrained systems

- Web-based image delivery

**7. Future Improvements**

**7.1 Technical Enhancements**

1. Adaptive codebook size selection

2. Multi-resolution vector quantization

3. Perceptual quality metrics integration

4. Hardware acceleration support

**8. Conclusion**

The comprehensive analysis demonstrates that RGB compression consistently outperforms YUV compression in quality metrics while maintaining the same compression ratio. The RGB method shows particular strength in preserving fine details and natural textures, making it the preferred choice for quality-critical applications.