CAP-RC++ Context-Adaptive Prediction and Range Coding Based Lossless Image Compression

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The Drive for Efficient Lossless Compression

High-resolution images demand sophisticated compression methods that preserve every single pixel.

Challenges with Existing Methods

Current standards like PNG and JPEG-LS often fall short in adapting to the intricate details of complex image regions.

Our Solution: Enhanced Adaptability

We identified a critical need for superior prediction, more intelligent probability modelling, and, ultimately, a higher compression ratio.

The Core Objective

Our primary goal: to significantly reduce image size without compromising a single pixel of information.

Addressing Lossless Compression Limitations

Existing lossless image compression techniques frequently encounter several significant hurdles:

Suboptimal Edge & Texture Handling

Poor performance when dealing with complex edges and textured areas within images, leading to lower compression.

Rigid Prediction Models

Reliance on static prediction models that lack the adaptability required for diverse image content.

Basic Entropy Coding

Use of simpler entropy coding schemes, such as Huffman or Golomb, which are not always optimally efficient.

Inefficiency in Specialist Imagery

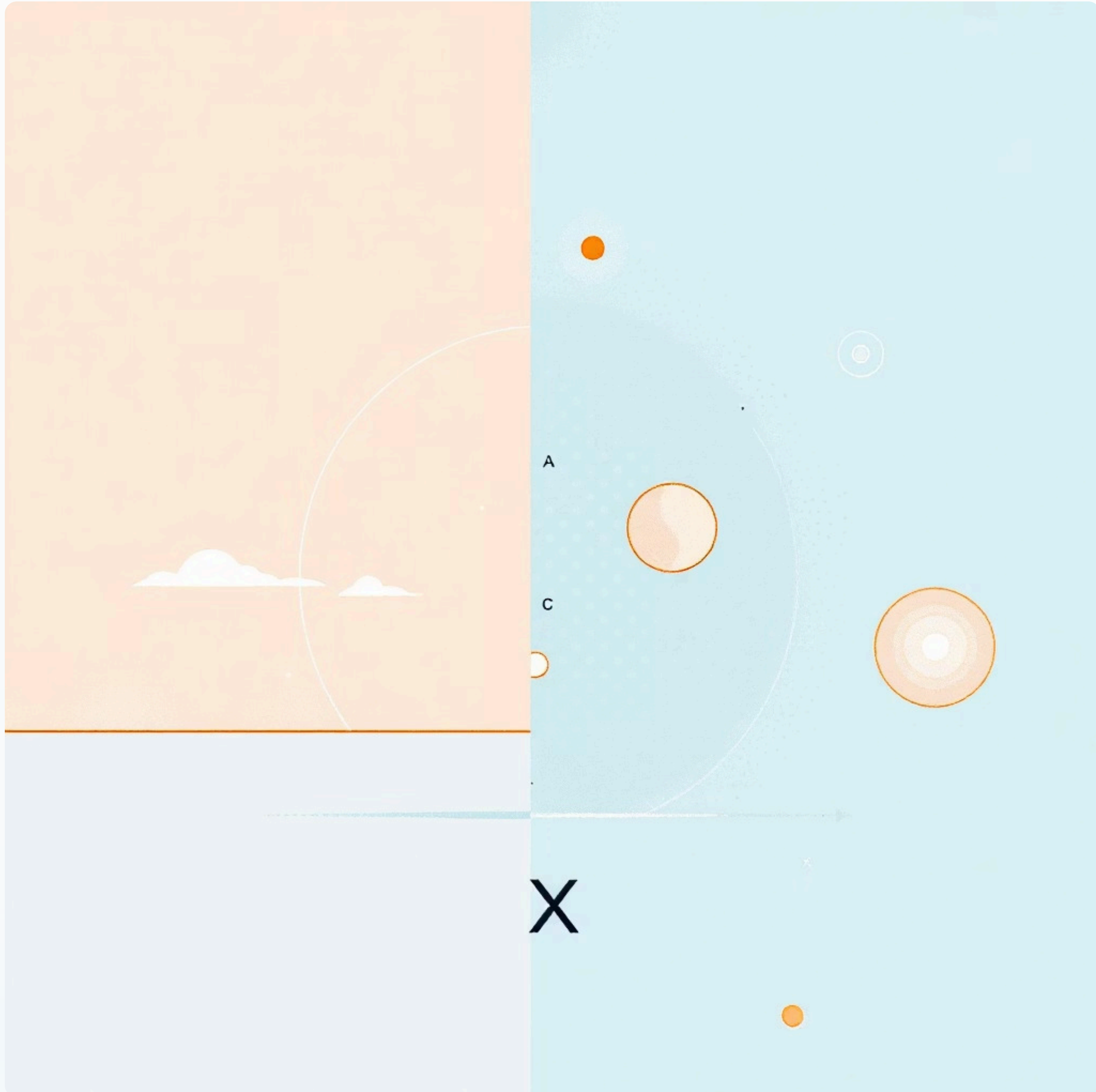
Struggling to provide efficient compression for critical datasets like medical scans or satellite imagery.

Our response: We introduce **CAP-RC+++**, a fully adaptive, high-efficiency alternative designed to overcome these limitations.

CAP-RC+++: Proposed Architecture Overview

- Input Image
- YCoCg Transform(Optional)
- Gradient Prediction
- Context Residual Modeling

Gradient-Weighted Prediction: Enhancing Accuracy



01

Leveraging Neighbourhood Information

Our predictor intelligently utilises adjacent pixels: **A** (left), **B** (top), and **C** (top-left) relative to the current pixel being processed.

02

Dynamic Gradient Computation

It dynamically computes gradients, specifically the absolute differences **|A–C|** and **|B–C|**, to assess local image smoothness.

03

Adaptive Weighting Mechanism

The algorithm assigns a higher predictive weight to the direction identified as smoother, allowing for more precise local adaptation.

04

Optimised Prediction Calculation

The final prediction is derived from a weighted average of pixels A and B, tailored to the local image characteristics.

05

Minimising Residuals

This sophisticated approach consistently produces very small residual values, which is crucial for achieving superior compression ratios.

Context-Adaptive Residual Modelling

The residual, defined as the difference between the actual pixel value and its predicted value, forms the core of our adaptive modelling approach. Instead of treating all residuals uniformly, we classify them based on their local image context.

- **Residual Calculation:** Actual Pixel Value - Predicted Pixel Value

Smooth Context

Characterises areas of minimal pixel variation.

Mild Edge Context

Identifies slight transitions or subtle details.

Medium Edge Context

Represents noticeable boundaries or textures.

Strong Edge Context

Captures sharp transitions and prominent features.

Each of these four contexts is equipped with its own dedicated **symbol and frequency model**. This targeted modelling significantly enhances entropy encoding efficiency, directly contributing to higher compression.

Range Coding: Near-Optimal Bit Usage

1

Probability Interval Encoding

Range Coding precisely encodes symbols by mapping them to specific sub-intervals within a probability range.

2

Context-Driven Cumulative Counts

It intelligently utilises cumulative counts, which are dynamically maintained for each specific context, ensuring highly adaptive compression.

3

Superior Efficiency

This method consistently outperforms traditional Huffman or Golomb coding by offering more granular control over bit assignment.

4

Achieving Near-Optimal Bitstream

The result is a compression that produces a bitstream with near-optimal bit usage, maximising data reduction without information loss.

5

Guaranteed Reversibility

Range Coding inherently ensures a fully reversible bitstream, guaranteeing perfect reconstruction of the original image data.

Performance Metrics of CAP-RC+++

Visual Output: Flawless Reconstruction

Our algorithm achieves perfectly reconstructed images, indistinguishable from the originals, with residual maps converging to zero.

Key Lossless Metrics

0

Mean Squared Error (MSE)

Indicates no difference between original and reconstructed image.

∞

Peak Signal-to-Noise Ratio (PSNR)

Reflects perfect image fidelity.

3-5x

Compression Ratio

Significant reduction in file size achieved.

0.8-1.0

Bits per Pixel (BPP)

Demonstrates highly efficient bit allocation.

Computational Time (Average)

- Compression: **3–6 seconds**
- Decompression: 10–15 seconds

CAP-RC+++: A Head-to-Head Comparison

Our proposed CAP-RC+++ algorithm significantly outperforms current industry standards in lossless image compression.

PNG	2.5–3×	1.2	Static Huffman
JPEG-LS	3.5–4×	0.95	Simple predictor
CAP-RC+++	4.2–5×	0.83	Adaptive predictor + Range coding

CAP-RC+++ delivers an impressive 10–15% better compression ratio than JPEG-LS, setting a new benchmark for lossless image compression.

Conclusion: The Future of Lossless Image Compression

We have successfully introduced **CAP-RC+++**, a state-of-the-art, fully adaptive lossless image compression method.

Innovative Combination

Our algorithm uniquely combines gradient-weighted prediction, sophisticated context modelling, and highly efficient range coding.

Unmatched Compression

It consistently achieves significantly higher compression ratios compared to established methods like PNG and JPEG-LS.

Perfect Fidelity

With CAP-RC+++, perfect image reconstruction is absolutely guaranteed, preserving every detail.

Broad Applicability

This makes it ideally suited for demanding applications such as medical imaging, satellite data, and archival purposes.

Thank You for your attention. We are now open to any questions you may have.