Invert-and-project (IVP)-A Lossless Compression Method of Multi-scale JPEG Images via DCT Coefficients Prediction

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Introduction

- Why recompress JPEG?
  - Several billion of JPEG images are produced everyday.
- Several existing methods?
  - Dct coefficient prediction for jpeg image coding by Gopal Lakhani.
  - Brunsli – lossless JPEG repacking library developed by google.
  - Lepton – another JPEG repacking library developed by dropbox.
- Problem?
  - All existing methods try to explore spatial redundancy either inside DCT block or between DCT blocks within the same image. None of them explore spatial redundancy at block level between images.

Introduction

A new method, IVP (invert and project) is proposed, main contributions are:

- We raise the idea that image level redundancy could be exploited to recompress JPEG files.
- We explore the hidden correlation between DCT coefficients of JPEGs in different resolutions which enjoy the same content, and propose a feasible recompression algorithm based on the correlation.
- We analyze the error bound of the proposed method and it supports the experienmental results.

Problem Formulation

- Given two images x and x', let $\mathrm{F}: R^n \rightarrow R^n$ be discrete consine transform and $\mathrm{Q}: R^n \rightarrow R^n$ be quantization function:

$$X = Q \circ F \circ x$$
$$X' = Q \circ F \circ x'$$

Where X and X' are quantized DCT coefficients in the frequency domain.

- The difference between the two coefficients is bounded by the difference between two images:

$$\begin{aligned} ||X - X'||_\infty &= ||Q \circ F(x) - Q \circ F(x')||_\infty \\ &\leq ||F(x) - F(x')||_\infty + 1 \\ &= ||F(x - x')||_\infty + 1 \\ &\leq ||F||_\infty ||x - x'||_\infty + 1 \\ &\leq C||x - x'||_\infty + 1 \end{aligned}$$

Where $C < 3$ from the DCT transform matrix.

- Most of the difference are concentrated near 0 and the entropy is heavily decreased.

Methodology

Main Idea:

The main steps are *as follows:*

- ***Invert:*** Inverse DCT
- ***Project:*** Resize to the proper size using bilinear interpolation
- Apply DCT again
- ***Predict:*** Compress the prediction error with entropy encoder

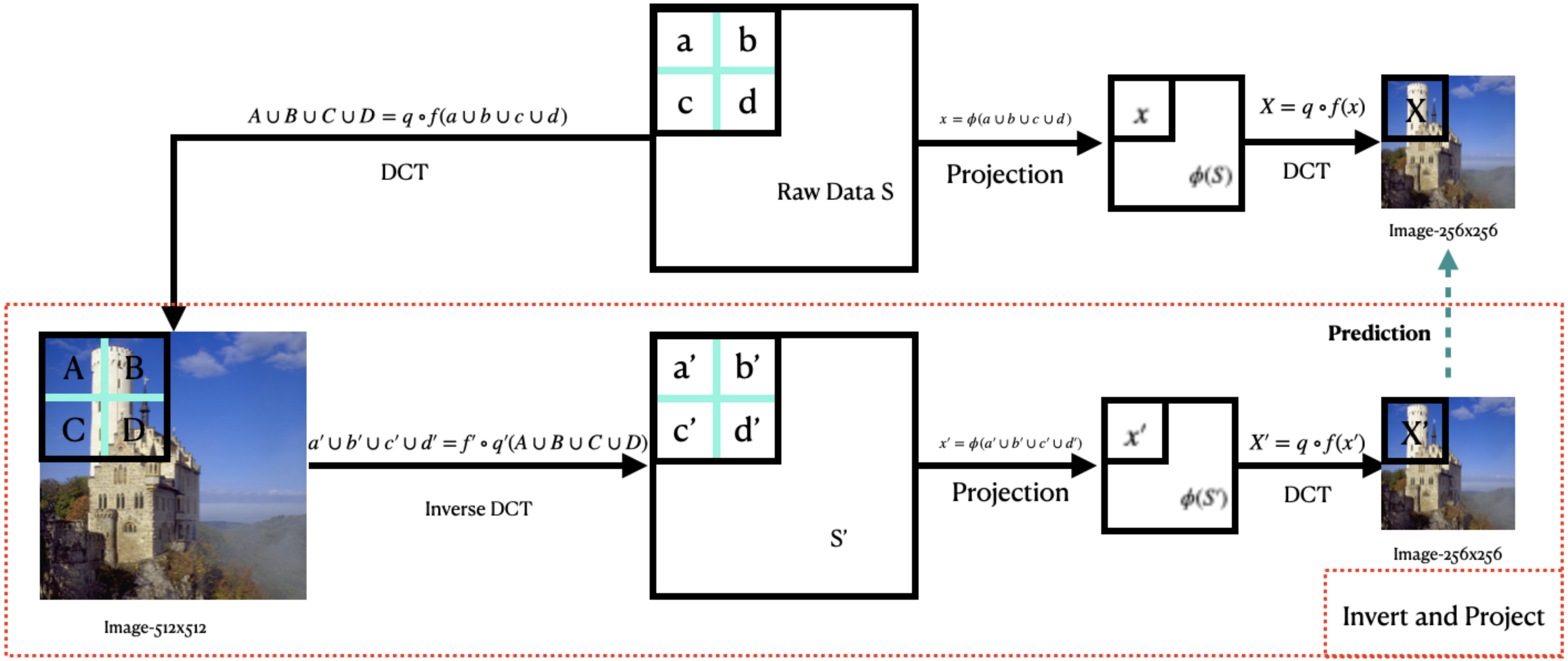

Figure 1: Exploring block redundancy for DCT

Main Results

Datasets	Resolution	Method	Compression Ratio
MUX	5632*5120	Brunsli	1.40
		Lepton	1.30
		IVP	**4.18**
	2816*2560	Brunsli	1.45
		Lepton	1.31
		IVP	**3.85**
WFV	4096*6656	Brunsli	1.48
		Lepton	1.32
		IVP	**3.43**
	2048*3328	Brunsli	1.45
		Lepton	1.31
		IVP	**3.47**

Table 1: Results of Brunsli, Lepton and our method. Invert and Project method achieves a recompression ratio that is over 65% better than the state-of-art lossless compression method in both MUX and WFV satellite image datasets.

Conclusions

- We have developed the “invert-and-project” method, an end-to-end compression scheme to compress, losslessly, the lower-resolution JPEG image.
- Our method achieves compression ratio over 65% better than the state-of-art lossless compression methods specialized for JPEG data which fails to account for information from a related source (here the higher-resolution JPEG).
- It is easy to extend the results here to more general scenarios, for example projection (this work), shifts and rotations.