RECOVERING MISSING COEFFICIENTS IN DCT-TRANSFORMED IMAGES

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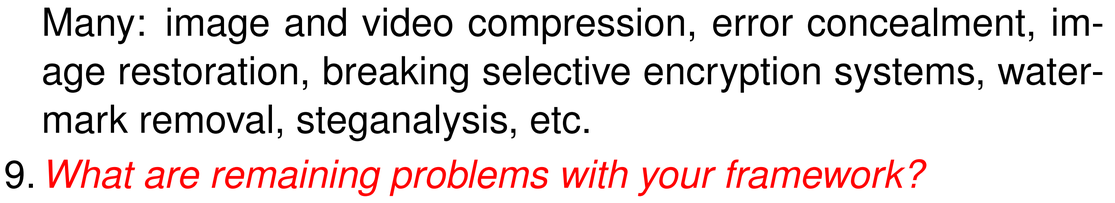
Quick Questions and Answers

1. *What is it about?*
   DCT2DCT = Recovering unknown DCT coefficients from known ones in blockwise DCT-transformed images.
2. *Is this a follow-up work?*
   Yes, it extends our previous work on AC2DC at ICIP2010.
3. *What did you do on AC2DC in the ICIP2010 work?*
   We showed that DC coefficients can be recovered from AC ones with better visual quality than a previous method.
4. *What have you done in this new work?*
   We proposed a general framework for recovering **any** set of unknown DCT coefficients from known ones.
5. *What is the key of the general framework?*
   The DCT coefficient recovery problem as a linear program.
6. *Is the general framework also better for the AC2DC case?*
   Yes! It statistically outperforms existing AC2DC methods.
7. *How many unknown DCT coefficients can be recovered?*
   For cameraman, we can still recover a lot of visual information even when **15** most significant DCT coefficients are missing from **each** block.
8. *What are potential applications?*
   Many: image and video compression, error concealment, image restoration, breaking selective encryption systems, watermark removal, steganalysis, etc.
9. *What are remaining problems with your framework?*
   Complexity: it is quadratic, but for large images the time and space complexity can still be huge.
10. *Do you have a web page of this work?*
    `http://www.hooklee.com/default.asp?t=ICIP2011`

1. Previous Work: AC2DC

- Two methods
  - **USO method**: [Uehara, Safavi-Naini and Ogunbona, IEEE Trans. Image Processing, 15(11): 3592-3596, 2006]
  - **FRM method**: [Li, Ahmad, Saupe and Kuo, ICIP2010]
- Two properties
  - **Property 1**: *The difference between two neighboring pixels is a Laplacian variate with zero mean and a small variance.*
  - **Property 2**: *The range of pixel values calculated from AC coefficients constrains the DC coefficient.*



original ⇒ corrupted ⇒ midpoint ⇒ USO ⇒ FRM

- Problems
  - AC2DC cannot be easily generalized to DCT2DCT.
  - Visual quality is still not good enough for some images.

original ⇒ corrupted ⇒ midpoint ⇒ FRM

2. New Approach: Linear Program

- Pixel values (variables): $x(i,j) \in \{x_{\min}, \ldots, x_{\max}\}$
- DCT coefficients (variables): $y(i,j)$
- DCT coefficients (ground truth): $y^*(k,l)$
- Blockwise DCT transform: $x = A \cdot y$

$$\begin{aligned} \text{minimize} \quad & \textstyle\sum_{\{\text{all pairs of adjacent pixels } (i,j),(i',j')\}} |x(i,j) - x(i',j')| \\ \text{subject to} \quad & x = A \cdot y, \\ & x_{\min} \le x(i,j) \le x_{\max}, \\ & y(k,l) = y^*(k,l) \text{ for all known DCT coefficients.} \end{aligned}$$

- Image size: $n \times m$
- Number of unknown DCT coefficients in each block: U
- Time complexity (average case): $O(n^2 m^2 U)$
- Space complexity: $O(nmU)$

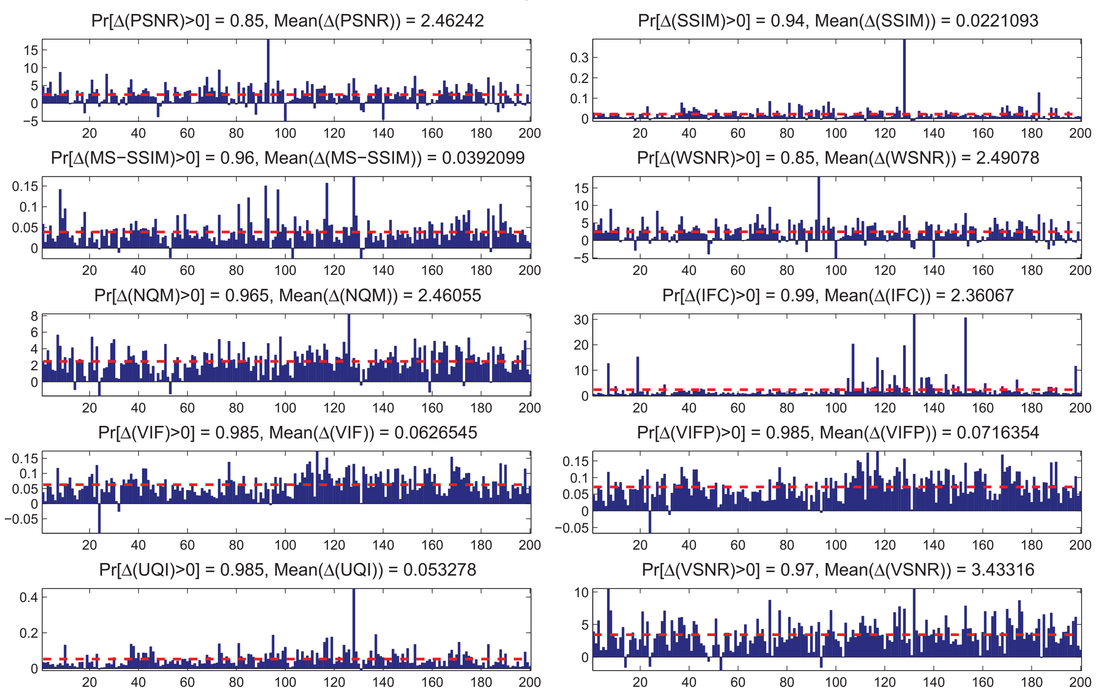
3. Experimental Results

- LP solver: IBM CPLEX 12.2, constrained barrier optimizer
- Image database: 200 test images
- Visual quality assessment: 10 metrics (PSNR, SSIM, etc.)

3.1 AC2DC ($U = 1$)

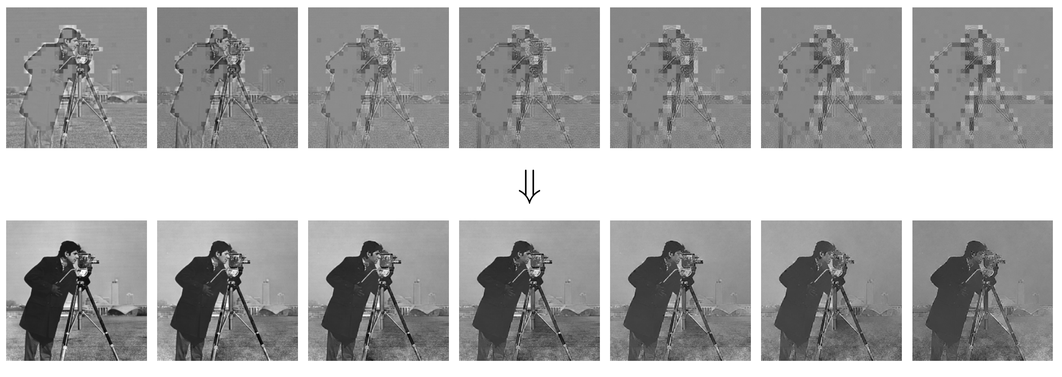
original ⇒ corrupted ⇒ midpoint ⇒ FRM ⇒ LP

PSNR: 22.8 ⇒ 26.5, SSIM: 0.902 ⇒ 0.958



The visual quality of reconstructed images: LP − FRM.

3.2 DCT2DCT ($U > 1$)



From left to right: $U = 2, 4, 6, 8, 10, 12, 15$