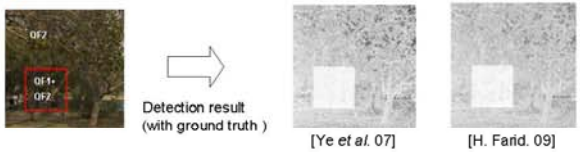
Detecting Doubly Compressed Images Based on Quantization Noise Model and Image Restoration

Yi-Lei Chen and Chiou-Ting Hsu
Department of Computer Science, National Tsing Hua University, Taiwan

Introduction

- Forgery on JPEG images
  - Recompression must be involved
  - How to characterize the doubly compressed properties?
- Related work
  - Quantization table inconsistency [Ye *et al.* 2007]
    - Measuring the block inconsistency resulted from different quantization tables
      - To estimate the **primary quantization table**
    - Less effective for recompressed images
  - JPEG ghosts [H. Farid 2009]
    - Detecting by manual recompression
      - To estimate the **primary quality factor**
    - Exhaustive test for all possible quality factors
    - No theoretical formulation



※ The two models are both sensitive to image content

- Motivation
  - A theoretical model to locate forged regions
    - Effective to recompressed images
    - Insensitive to image content

Quantization noise model

- For each 8x8 block,
  - Quantization noise

$$\mathbf{Ax} = \mathbf{c} = \mathbf{c}' + \mathbf{n}' = \mathbf{c}'' + \mathbf{n}''$$

What's the difference between $\mathbf{n}'$ and $\mathbf{n}''$?

$\mathbf{A}$: DCT component basis (64x64 Matrix)
$\mathbf{x}$: intensity of RAW image (64x1 vector)
$\mathbf{n}'$: quantization noise of single compression (64x1 vector)
$\mathbf{n}''$: quantization noise of double compression (64x1 vector)

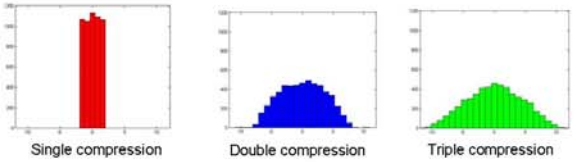
- Quantization constraint set theorem
  - Bounded by quantization step

$$-\left\lfloor \frac{q'}{2} \right\rfloor \le c' - c = n' \le \left\lfloor \frac{q'}{2} \right\rfloor \quad \text{(uniform quantizer)}$$

- After recompression,

$$-\left\lfloor \frac{q'}{2} \right\rfloor \le c' - c \le \left\lfloor \frac{q'}{2} \right\rfloor$$
$$-\left\lfloor \frac{q''}{2} \right\rfloor \le c'' - c' \le \left\lfloor \frac{q''}{2} \right\rfloor$$
$$\Rightarrow \quad -\left(\left\lfloor \frac{q'}{2} \right\rfloor + \left\lfloor \frac{q''}{2} \right\rfloor\right) \le c'' - c = n'' \le \left\lfloor \frac{q'}{2} \right\rfloor + \left\lfloor \frac{q''}{2} \right\rfloor$$

※ Quantization noise distribution



- Modeling
  - Single compression

$$p(\mathbf{n}_k \mid w_1) = \prod_{i=1}^{\dim} p(n_{k,i} \mid w_1) = \prod_{i=1}^{\dim} U(c_{k,i} - \hat{c}_{k,i} \mid -q_i, q_i)$$

  - Recompression

$$p(\mathbf{n}_k \mid w_2) = \prod_{i=1}^{\dim} p(n_{k,i} \mid w_2) = \prod_{i=1}^{\dim} N(c_{k,i} - \hat{c}_{k,i} \mid 0, \sigma^2{}_i)$$

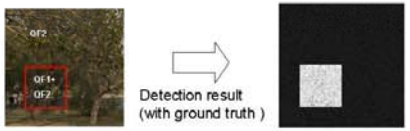
  - Unknown information
    - The uncompressed DCT coefficient $C_{k,i}$

Ground truth estimation

- To eliminate compression artifacts
- Image restoration techniques
- Deblocking [Kin et al. 2003]
  - Filtering in DCT domain
- Low frequency compensation
  - VQ based approach [Liaw et al. 2002]
  - Modification
    - Compensation in DCT domain (1st~15th DCT component)
    - Only considering the magnitude of QN

Experimental results

- Robustness of QN model

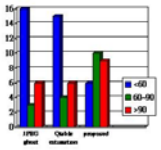


※ Almost independent to image content

  - 500 images for each quality setting

QF1 \ QF2		50	60	70	80	90
50	Proposed	49.0	83.7	94.7	98.3	99.4
	[Ye *et al.* 07]	58.5	62.2	82.0	93.2	98.7
	[H.Farid 09]	0.84	59.3	84.0	94.0	96.8
60	Proposed	76.8	49.1	89.9	97.8	99.5
	[Ye *et al.* 07]	42.6	56.5	66.0	94.6	98.1
	[H.Farid 09]	45.8	1.12	72.7	96.6	97.0
70	Proposed	82.7	84.1	49.2	95.7	99.5
	[Ye *et al.* 07]	34.5	38.6	56.8	76.4	97.4
	[H.Farid 09]	37.8	41.3	1.92	74.3	95.1
80	Proposed	66.1	89.4	88.5	49.4	99.2
	[Ye *et al.* 07]	59.9	45.1	33.9	57.3	97.5
	[H.Farid 09]	47.6	39.5	32.8	4.03	94.2
90	Proposed	57.2	66.1	65.4	93.7	49.9
	[Ye *et al.* 07]	53.7	52.4	52.1	53.0	57.9
	[H.Farid 09]	40.5	40.5	44.2	40.5	12.8

90 ↑
60~90
60 ↓



- Forgery detection
  - MRF
  - To optimize quantization noise