6/30 画像信号処理特論

Schedule

- 5/12 "Hello World!" of image processing
- 5/19 Image filtering
- 5/26 Binarization
- 6/2 (Prof. Tehrani)
- 6/9 (Prof. Tehrani)
- 6/16 (Prof. Tehrani)
- 6/23 Histogram ← 1st report deadline
- 6/30 Discrete Cosine Transform
- 7/7 JPEG
- 7/14 (Prof. Fujii)
- 7/21 (Prof. Fujii) ← 2nd report deadline

Today's issue

- Image Compression

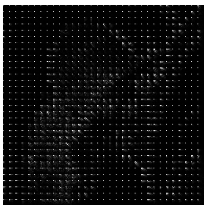
Original
(65,551 byte)

JPEG Compressed
(7,365 byte)

Today's issue

- Discrete cosine transform (DCT)
  - key to understand JPEG compression

Input



DCT coefficients

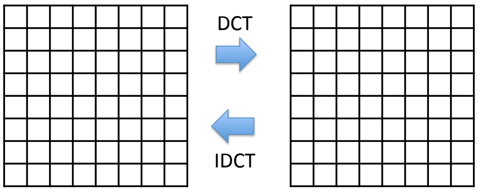
Why images are compressible?

- Redundancy
  - Images are not random signals
  - Neighboring pixels are likely to take similar values, e.g. neighboring pixels are correlated
- How to remove redundancy
  - Neighboring pixels should be uncorrelated
  - Information should be concentrated by transform
  - Optimal solution: Principle component analysis
  - Practical solution: Discrete cosine transform

Discrete cosine transform

Spatial Domain

Freq. Domain



DCT

IDCT

$f(m,n)$

$F(k,l)$

Definition of DFT

$$C(i) = \begin{cases} 1 & i \neq 0 \\ 1/\sqrt{2} & i = 0 \end{cases}$$

DCT

$$F(k,l) = \sum_{n=0}^{7}\sum_{m=0}^{7}\frac{C(k)C(l)}{4} f(m,n)\cos\left(\frac{\pi}{16}(2m+1)k\right)\cos\left(\frac{\pi}{16}(2n+1)l\right)$$

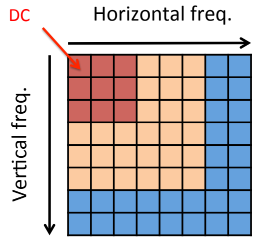
IDCT

$$f(m,n) = \sum_{k=0}^{7}\sum_{l=0}^{7}\frac{C(k)C(l)}{4} F(k,l)\cos\left(\frac{\pi}{16}(2m+1)k\right)\cos\left(\frac{\pi}{16}(2n+1)l\right)$$

Detail of Frequency representation

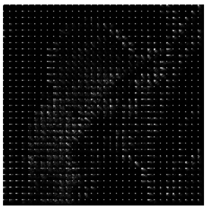
- Coefficients are real values

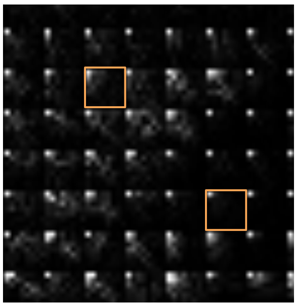
- Most of the energy concentrates in the low frequencies



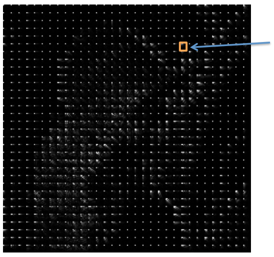
$F(k,l)$

Close look at DCT coefficients





Energies of DCT coefficients



DCT coefficients for (i, j)-th block

$F_{i,j}(k,l) \quad 0 \le k,l \le 7$

$$\frac{1}{IJ}\sum_{i,j}\left|F_{i,j}(k,l)\right|^2$$

Energies of DCT coefficients

Horizontal freq.

Vertical freq.

1040.441	112.749	56.066	33.291	20.691	15.488	10.353	6.354
61.753	53.983	35.305	23.570	17.729	13.008	8.943	6.206
28.973	28.218	24.825	20.898	14.655	11.781	8.094	4.949
14.606	17.255	18.875	15.541	14.228	9.838	7.798	4.831
10.227	11.827	12.049	11.908	10.398	9.649	6.327	4.763
6.621	7.174	7.336	8.391	7.362	6.485	4.827	3.501
4.469	5.364	4.992	4.924	5.188	4.414	3.560	2.812
2.893	3.064	3.188	3.151	3.136	2.919	2.462	2.001

Exercises

- Implement below using “myDCT.h”
  - Divide an image into non-overlapping 8x8 pixel blocks
  - Apply DCT/IDCT to each of the blocks
  - Confirm that the image is not changed before and after DCT+IDCT.
- Analyze the amplitudes of DCT coefficients
  - Visualize DCT coefficients for all blocks as an image
  - Calculate the energy for each coefficient
  - Analyze random images as well as natural images.