Lab. 4 - Image Coding: Transform methods

Study of transform coding methods: DCT, Walsh transform coding and JPEG coding.

1. Principles of block transform coding

4.1.1 Investigate DCT image coding efficiency for different images and different coding parameters (program **dctcodng.m**). Observe artifacts due to the block size and coding mask size. Optimize nonlinear *P*-th law quantization of spectral coefficients.
4.1.2 Investigate 2-D Walsh transform image coding efficiency for different images and different coding parameters (program **walsh_codng.m**). Observe artifacts due to the block size and coding mask size. Optimize nonlinear *P*-th law quantization of spectral coefficients

2. JPEG coding standard[*)]

4.2.1. Image blocks. Compute DCT coefficients for a 8x8 block of the original image (8-bit). Subtract from the block values value of 128 (in 8-bit scale) and compute DCT. Compare the range of resulting DCT values for both cases. Explain the reason for such a subtraction used in conventional JPEG.

4.2.2. Quantization. In JPEG standard, the DCT coefficients are quantized, using a quantization table for DCT coefficients of luminance (intensity). A standard quantization table is shown in Fig. 1. The entries $\{w_{r,s}\}$ in this table define the interval, to which a coefficient value is mapped.

16	11	10	16	24	40	51	61
12	12	14	19	26	58	60	55
14	13	16	24	40	57	69	56
14	17	22	29	51	87	80	62
18	22	37	56	68	109	103	77
24	35	55	64	81	104	113	92
49	64	78	87	103	121	120	101
72	92	95	98	112	100	103	99

Figure 1. Intensity Quantization Table $\{w_{r,s}\}$

In order to control the tradeoff between reconstructed image quality and the bit rate, the quantization table can be modified using the quality parameter $\boldsymbol{Q}$ that can assume values from 1 to 100. Quantized DCT coefficients $\{\alpha_{r,s}\}$ are obtained as

$$\hat{\alpha}_r = \boldsymbol{round}\left(\alpha_{r,s} / \tilde{w}_{r,s}\right),$$

where

$$\tilde{w}_{r,s} = \boldsymbol{floor}\left\lfloor\left(\boldsymbol{ScFact} \cdot w_{r,s} + 50\right)/100\right\rfloor$$

and

[*)] The Matlab implementation presented here is based on C. Weidmann's mini project ([5]), K. Scretting's Entropy Coding Matlab Implementation ([6]) and IJPEG software ([4]).

$$ScFact = \begin{cases} \mathbf{1}, & \boldsymbol{Q} = \mathbf{100} \\ \mathbf{200} - \mathbf{2} * \boldsymbol{Q}, & \mathbf{50} \le \boldsymbol{Q} \le \mathbf{99} \\ \mathbf{5000} / \boldsymbol{Q}, & \mathbf{1} \le \boldsymbol{Q} \le \mathbf{50} \end{cases}$$

1. Generate different quantization matrices and use matlab program **encode_jpg_block.m** to perform quantization of 8x8 blocks of the input image. Calculate bit allocation for each quantized DCT coefficient.
2. Design different quantization tables for different Q-quality factors (matlab program **scld_qnt_jpg.m**)
3. Calculate quantization matrices for Q = 1,50,100. Find which Q corresponds to conventional JPEG quality (no scaling), to the worst quality, to the to best quality (compression with no losses at all).
4. Define the range in which DCT coefficients of 8x8 block of 8-bit image vary and estimate the number of quantization levels for DCT coefficients for different values of the quality factor.

4.2.3 Zigzag rearrangement. JPEG reorders the coefficients in each block by means of zigzag scan, thus converting a 8x8 squared array of quantized DCT coefficients to a 1-D string of 64 elements with the first one representing the DC component and the others representing AC elements.

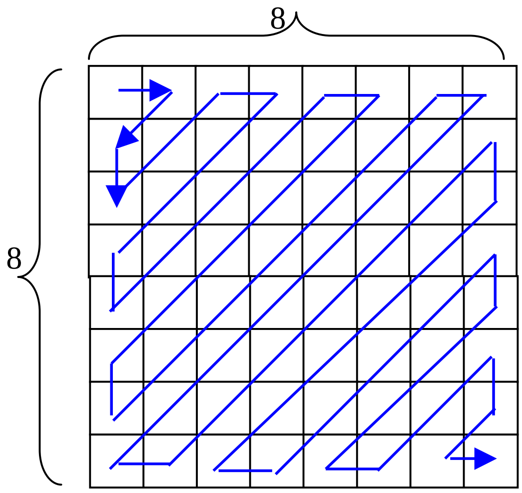

Figure 2. Zigzag reordering scheme

1. Use matlab program **zigzag_block.m** to rearrange quantized DCT coefficients. Compare streams obtained from adjacent blocks of the same image, not adjacent blocks of the same image and blocks from different images. Write a program for zigzag rearrangement of a table of arbitrary size.
2. Compare zigzag ordered streams and those sorted in descending order.
3. Calculate the number of trailing zeros in each stream. In standard JPEG, a special symbol End Of Block (EOB) is used to indicate the end of trailing zeros. Thus, for each block one needs at most 6 additional bits ($\log_2 64$) to specify the length of the "nonzero" vector (it might contain zeros, but its last element is nonzero). Concatenate the "stripped" vectors and compute the entropy, then add the overhead information of 6 bits/block.

4.2.4 Entropy coding. In JPEG, a run length/entropy coding is applied to quantized AC coefficients (the sequence of DC coefficients is DPCM coded separately). The baseline implementation of the JPEG standard uses Sannon-Huffman coding.

1. Using program **entrpy_calc.m** calculate the entropy of encoded data at different stages of the coding:

   a. Entropy of 8x8 block of the original image
   b. Entropy of the block after substraction of 128.
   c. Entropy of the quantized DCT block.
   d. Entropy of Sannon-Huffman encoded string

Compare these entropy values for different blocks. Which coding stage (DCT transformation, DCT coefficients quantization or Entropy coding) mostly contributes to compression efficiency?

2. Compute the entropy of quantized DCT block for different quality factors. Explain the dependence of quantized DCT block entropy on scaling factor of the quantization table.
3. Using program **JPEGlike.m,** perform Sannon-Huffman coding of quantized and rearranged DCT matrices. Encode the string, investigate the encoding results in "**res**"-output (see program help for more details), and finally decode the string using the same program **JPEGlike.m**. Check the "Losslessness" of this stage of coding-decoding.

<u>4.2.5. Decoding</u>

1. Use Matlab program **jpgcodng.m** to get JPG-coded images using different input parameters. Compare visual image quality coded with different Q factors.
2. Compare output parameters of coding with different Q factors.
    a. PSNR/MSE.
    b. Entropy at the different stages of coding vs. Q-factor
    c. BPP vs. Q-factor.
3. Measure PSNR/MSE vs. Compression Ratio
4. Investigate the Quality Losses due to coding/compression. Compare coding error of images coded with different Q-factors. Investigate Fourier spectra of compression errors. In which regions of the image the largest errors are? Which artifacts appear at very low rates (high compression)?

Submit: Results and m-files**.**

<u>References</u>

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6. Arithmetic Coding and Sannon-Huffmann Coding in Matlab by Karl Skretting www.ux.his.no/~karlsk/proj99/
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