

Multimedia Communications
Homework #1, Nov. 2, 2010, Due: Nov. 26, 2010

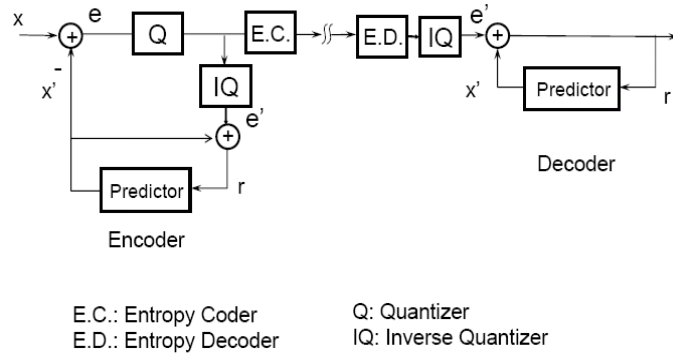
Note: all the following assignments should be implemented in C or Matlab programming languages (you may use Matlab or Excel for showing the pictures). You have to hand in the results (should be typed in the Word format) and all the codes (with comments) and executables (zipped in a single file) to the TA (許志仲 m121754@gmail.com).

1. Download the “Lena” image file (128x128, .bmp format) on the class homepage (<http://www.ee.nthu.edu.tw/~cwlinc/courses/multimedia/homework.htm>).

- (a) Compute the occurrence probability of each pixel value (0~255), show the histogram and compute the entropy.
- (b) Use the following JPEG lossless predictive coder to predict the pixel value X' of pixel X using the values of pixels A , B , and C , then to encode the prediction error ($X - X'$). If all the reference pixels are not available, then mode 0 (no prediction) is used. If only one of the reference pixels is unavailable, use the available one as the prediction. Compute the occurrence probability of each difference pixel value, show the histogram, and compute the entropies of the prediction error and the prediction type, respectively.

	Selection- value	Prediction																				
<table border="1" style="border-collapse: collapse; width: 100px; height: 100px; margin: 0 auto;"> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td style="text-align: center;">C</td><td style="text-align: center;">B</td><td> </td></tr> <tr><td> </td><td style="text-align: center;">A</td><td style="text-align: center;">X</td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td></tr> </table>						C	B			A	X										0 1 2 3 4 5 6 7	no prediction A B C A + B - C A + (B - C) / 2 B + (A - C) / 2 (A + B) / 2
	C	B																				
	A	X																				

- (c) For the residual image obtained in (b), write a program to construct two Huffman codes (one for the prediction error and the other for the prediction mode) and encode the image. In constructing the Huffman code, sort the occurrence probabilities, then group those 480 symbols with probabilities less than the first 31 highest ones' to form a new symbol (ESCAPE symbol). Design a Huffman table for the 31 highest-probability symbols and the ESCAPE symbol. Append a fixed-length code to the ESCAPE symbol to distinguish the low-probability symbols. What should be the length of the attached fixed-length code? Show the VLC codeword table for the 31 highest probability symbols + the ESCAPE symbol.
- (d) What's the compression ratio? Compare it with the Winzip or Winrar tool.
- (e) Use a 5-bit optimum uniform midrizer quantizer and the above predictor to implement the following encoder, then design a 32-symbol Huffman coder for the quantized error image. What's the compression ratio and the PSNR of the reconstructed image?



2. Assuming the probability distribution of the prediction residual obtained in 1(b) is Laplacian, estimate the model parameter(s) of the Laplacian distribution. Write a code to generate a 5-bit Lloyd-Max midrizer quantizer (Assume the input range is normalized to -1~+1) for the Laplacian distributed prediction residual. Replace the uniform quantizer used in 1(e) with the Lloyd-Max quantizer and repeat 1(e).

3. 2-D $N \times N$ DCT is defined as:

$$F(u, v) = \frac{2}{N} C(u)C(v) \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} f(m, n) \cos\left(\frac{(2m+1)u\pi}{2N}\right) \cos\left(\frac{(2n+1)v\pi}{2N}\right)$$

$$f(m, n) = \frac{2}{N} \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} C(u)C(v) F(u, v) \cos\left(\frac{(2m+1)u\pi}{2N}\right) \cos\left(\frac{(2n+1)v\pi}{2N}\right)$$

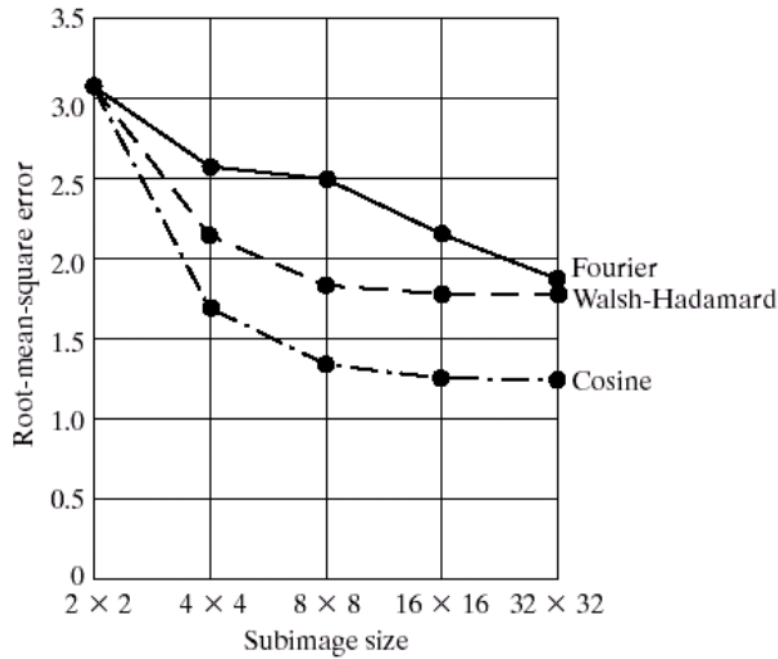
where $C(u), C(v) = 1/\sqrt{2}$ for $u, v = 0$ and $C(u), C(v) = 1$ otherwise.

- (a) Divide the “Lena” image into $N \times N$ blocks ($N = 8, 16, 32$), then apply the $N \times N$ DCT on each pixel block to get its DCT coefficients.
- (b) In addition to the DC coefficient, only keep $N/4 \times N/4$, $N/2 \times N/2$, and $3N/4 \times 3N/4$ lowest frequency coefficients and set all other coefficients to zero, and then perform the $N \times N$ inverse DCT.

- Compute the mean square error (MSE) in the pixel-domain:

$$MSE = \frac{1}{N^2} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} (\text{original_block_pixel}_{i,j} - \text{reconstructed_block_pixel}_{i,j})^2$$

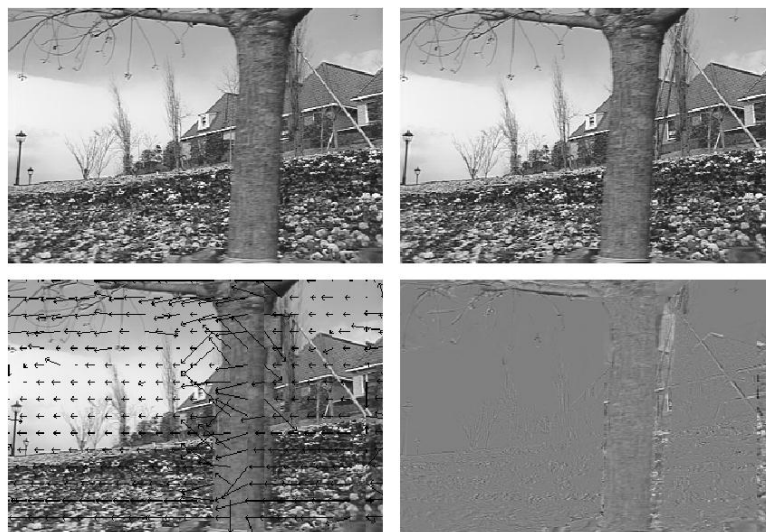
- Generate three figures similar to the example shown below (with DCT only) for the cases retaining $N/4 \times N/4$, $N/2 \times N/2$, and $3N/4 \times 3N/4$ low-frequency coefficients, respectively.



(c) Show the reconstructed image with retaining $N/4 \times N/4$, $N/2 \times N/2$, and $3N/4 \times 3N/4$ low-frequency coefficients for $N = 8$ and $N = 16$ (if the reconstructed pixel values are greater than 255 or smaller than 0; you need to clip the values to be in this range)

4. For the two consecutive 360x240 luminance raw images (pong1.y and pong2.y), divide the images into 8x8 blocks, then implement the following motion estimation algorithms with a search range of $-7 \sim +7$ pixels in both directions and the Sum of Absolute Difference (SAD): Full Search Algorithm (FSA), Three-Step Search (TSS), and Diamond Search (DS).

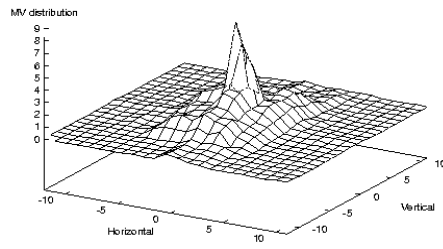
(a) Superimpose the obtained motion vectors on image pong2.y (contact TA if you don't know how to do this), and then show for the three methods the two raw images, the resultant error images after motion compensation, and the superimposed images (pong2.y with MVs) as similar to the figure below. Compare the MSE values of the error image for the three methods.



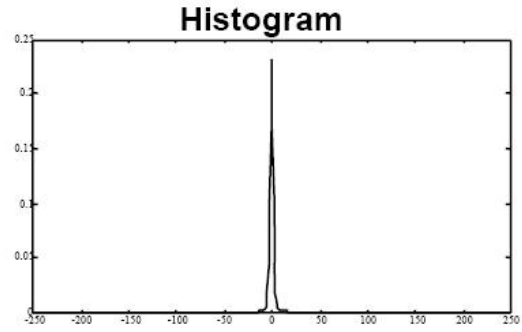
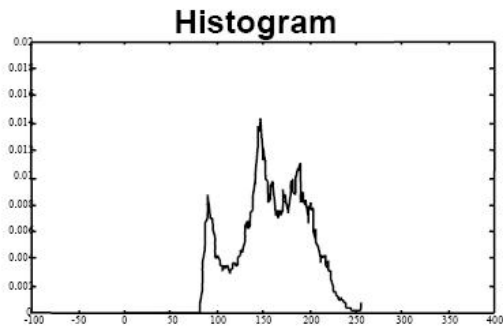
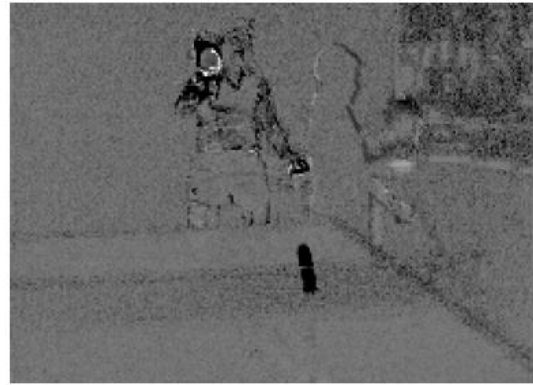
(b) Show the MV distributions of the three methods (see the example shown below).

MV Distribution (Block Size 8x8) with Full Search for 15 frames/sec sequence

2D Full Search —

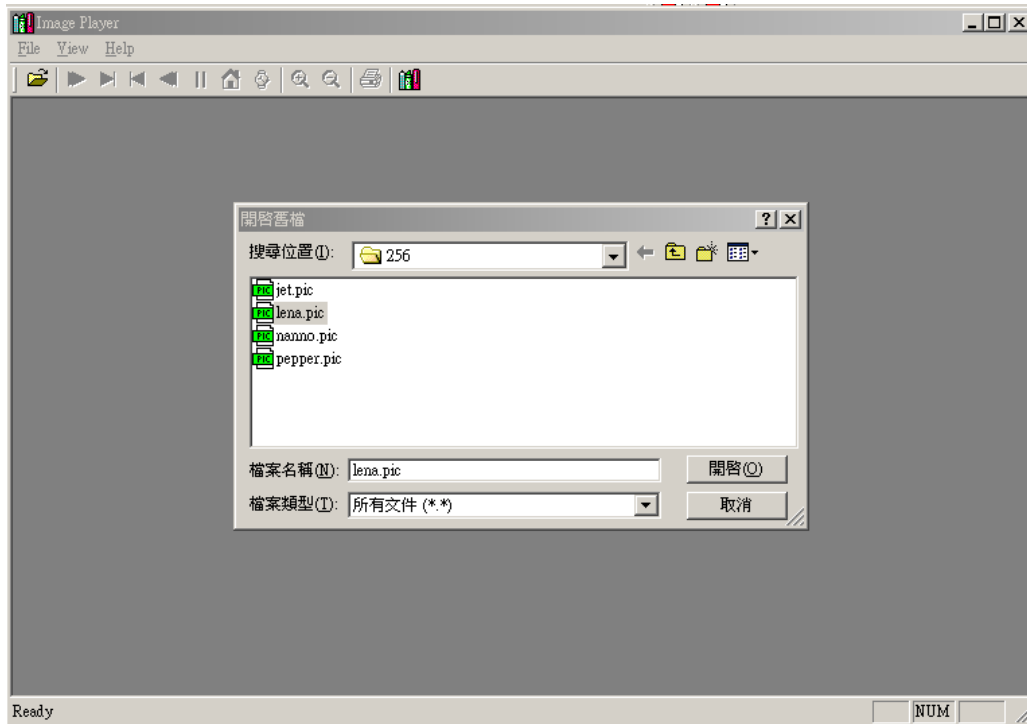


(b) Show the original video frame and the prediction residual frame (show the absolute values) of pong2.y and the two histograms of the two frames (similar to the following example).

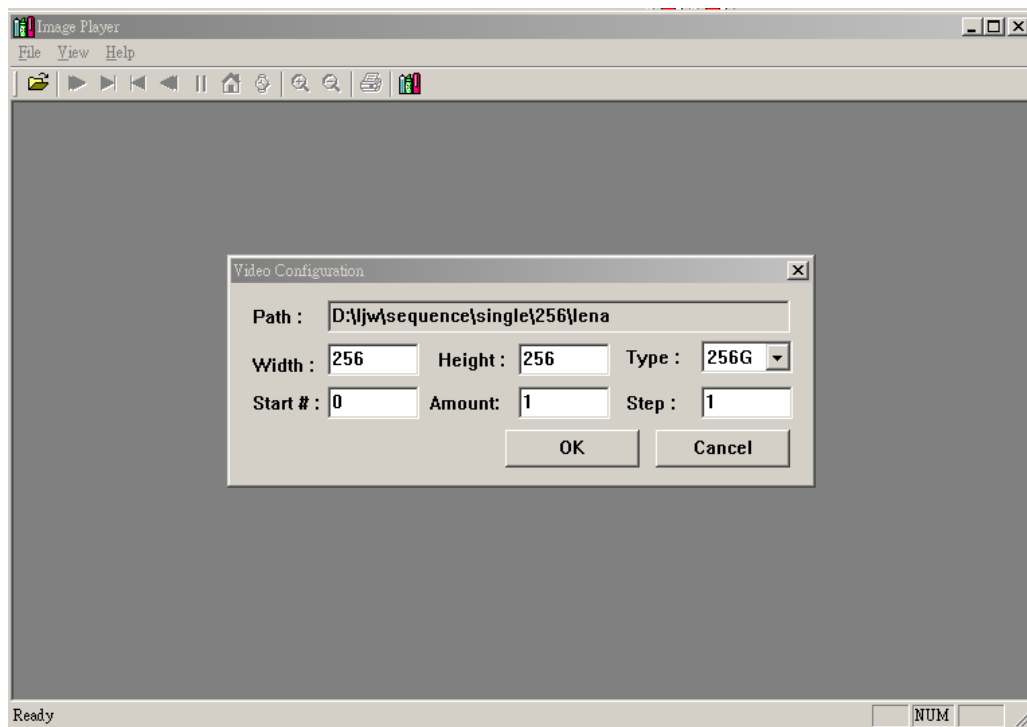


You can download the image display tools from the class homepage (The zipped files including ImPlayer.exe and ImPlayer.reg) to view the monochrome and color raw image/video

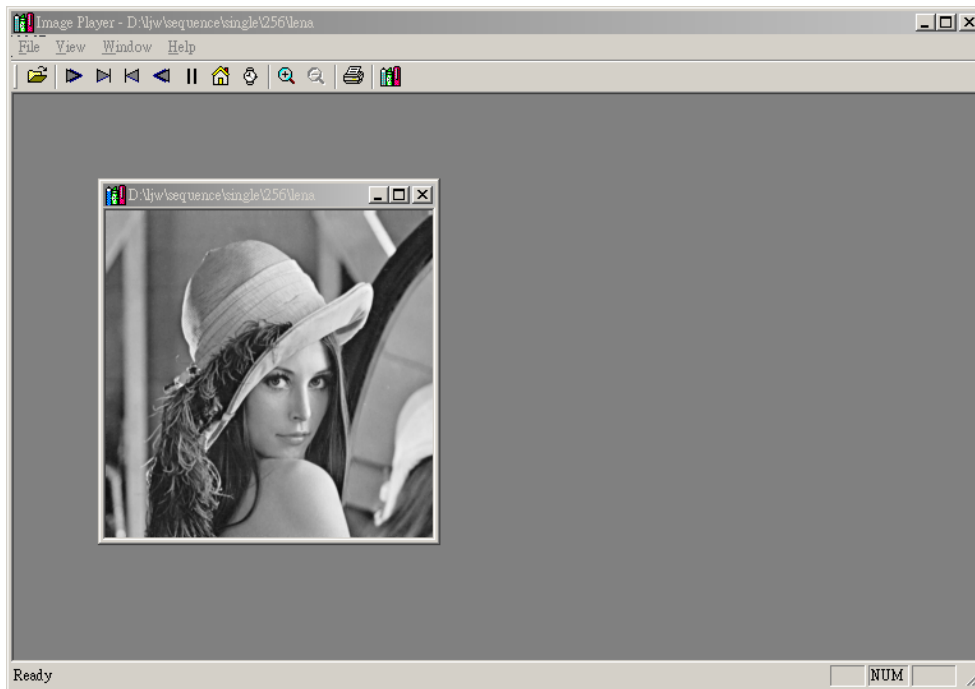
(1) Run ImPlayer, and use the “File” option to select the file as follows:



(2) After choosing the file, set up the video configuration as follow:



(3) Finally you can view the image as shown below.



Please keep the software for future's assignments.