Exercise I: Image (10)

A. Consider the JPEG standard to code photographic images with a 1152×1440 luminance resolution, 4:2:0 color subsampling and 24 bits/pixel. How many pixels, samples and blocks exist in this type of image. (2) (2) (2)

B. Determine the average bits per pixel if a JPEG codec with a luminance compression factor of 25 and a chrominance compression factor of 15 is used. (4)

Exercise II: Video (15)

Assume that you are contacted by a company to design a digital storage system for video clips. The company requires some editing flexibility and needs to store the largest number of 4 minutes clips in a disk. The maximum access speed to the disk is 80 Mbit/s. The clips have the following characteristics: 3840 × 2160 (Y), 4:2:2, 24 bits/pixel at 25 Hz.

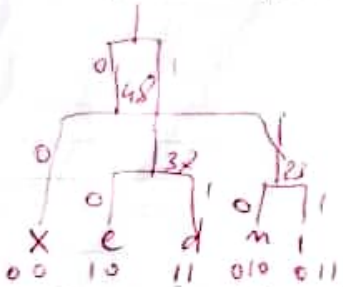
A. What is the size of a 4-minutes clip? (5)

B. How many complete 4-minutes clips can you store on a disk of size 2 TBytes? (5)

C. How many seconds do you need to send a complete clip knowing that the bitrate is 128 kbits/s? (5)

Exercise III: Compression (40)

A. Suppose having an alphabet composed of 5 symbols {i, n, d, e, x} and given the following symbol frequencies in a given message. Fill in the table with the Huffman codes.



Letter	Frequency	Huffman Code
i	7	
n	16	
d	17	
e	20	
x	25	

(5)

B. A text made of the symbols {a, b, c, d, e} with probabilities {0.11, 0.40, 0.16, 0.09, 0.24}. What is the average symbol length using the Huffman coding technique. (5)

C. Consider the following message to be encoded abbcddeee with codes satisfying the following rules: (1) a symbol must not have a code that is prefix of a code of another symbol; (2) If two letters have the same frequency, the symbol which comes before in the dictionary order should be assigned a code with a length that does not exceed the length of the second symbol. For example, b and d symbols have the same frequency but b comes before d in the dictionary. When you assign codes, the code length assigned to b should be less or equal to the one assigned to d.

Among the set of all binary code assignments that satisfy the above rules, what is the minimum length of the encoded message above. (5)

D. Consider the alphabet {A, B, C, D, E} with the frequencies {0.17, 0.11, 0.24, 0.33, 0.15}. Suppose we have received the following sequence 1000001101. What is the decoded message? (5)

E. Use the algorithm LZW to encode the sequence AAABBBCCCABCBA knowing that the ASCII code of A is 65, B is 66 and C is 67. (10)

F. If you receive the sequence <65> <66> <67> <66> <65> <260> <256> <66> <257> <67> <67>, what is the decoded message. (10)

Exercise IV: Motion Vectors Search (35)

Suppose having a video source generating 4-minutes video clips of the same characteristics as in Exercise II (3840 × 2160 (Y), 4:2:2, 24 bits/pixel at 25 Hz), a 16x16 macroblock size with k=15 window search.

A. How many macroblocks exist in a frame? Pay attention to consider all channels. (7)

B. How many MADs are done in total to encode one frame using sequential search? (7)

C. How many MADs are done in total to encode one frame using logarithmic search? (5)

D. How many MADs are done in total to encode one frame using 4-levels hierarchical search? (7)

E. if the GOP size is 25 frames and each GOP contains 1 I-frame and 24 P-frames, how many seconds does it take to encode the 4-minutes clip if an MAD takes 1 ms. (7)

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Exercise I : Image

A. - nb of pixels = 1152 x 1440 = 1,658,880 pixels

- nb of samples = nb of samples in Y + nb of samples in U + nb of samples in V

= 1152 x 1440 + 1152 x 1440/4 + 1152 x 1440/4

= 2488320 samples

- nb of blocks = nb of samples / 8x8 = 38880 blocks

size of blocks in jpeg

B.

~~Exercise II : Video~~

B. we have 8 bits for Y, 8 bits for U, 8 bits for V

with 25 compression factor for Y & 15 for U & V

average bits per Y value = $\frac{8}{25}$ & average bits per U & V = $\frac{8}{15}$

average bits per pixel = $\frac{4 \times \frac{8}{25} + \frac{8}{15} + \frac{8}{15}}{4} = \frac{1.28 + 1.0666...}{4} \simeq$ 0.586 bits

Exercise II : Video

A. size of one clip = 3840 x 2160 x (8 + ~~$\frac{8}{4} + \frac{8}{4}$~~ $8 + \frac{8}{2} + \frac{8}{2}$) x 25 x 4 x 60

= ~~597,196,800,000~~ = ~~597.1968 Gbits~~ 796.2624 Gbits

= ~~74.6496 Gbytes~~ x $\frac{16}{12}$ → 99.5328 Gbytes

B. 2 TBytes can hold $\frac{2 \times 1000}{\text{~~74.6496~~ } 99.5328}$ = ~~26.79~~ 20.09 ⇒ 20 complete 4-min clips.

C. size of one clip = ~~597.1968 Gbits~~ 796.2624 Gbits

796,262,400 kbits

⇒ time to send = $\frac{\text{~~597,196,800 kbits~~}}{128 \text{ kbits/s}}$ = ~~4665600~~ 6.220.800 seconds

= ~~54~~ 72 days

(1)

D. at level 4 → k = $\frac{15}{8}$ = 1 or 2 if you approximate

⇒ full search = $(2\times k+1)^2 = (2\times1+1)^2 = 9$ (or 25)

at lower levels : 8 × 3

⇒ Total = 9 + 8×3 = **36** or (49)

⇒ Total = 64800 × 36 = **2 332 800**

E. let nb of blocks to do for searching all macroblocks be X

25 frames → we consider only P-frames

we have one GOP per second

⇒ Total MADs = 45×60 × 24 × X × 1 ms

(macroblocks, frames, P-frames)

→ X depends on the type of search

Exercise III : Compression

A. l → 101, n → 100, d → 000, e → 11, x → 01

B. 2.16

C. 23

D. BACE

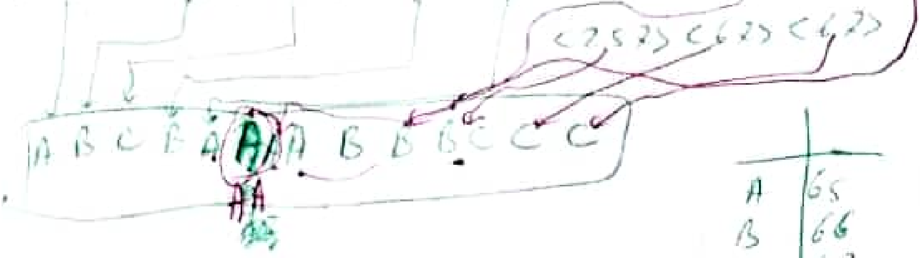
E. A AA B B B C C C A B C B A

<65> <256> <66> <258> <67> <260> <65> <66> <67> <66> <65>

A	65
B	66
C	67
AA	256
AAB	257
BB	258
BBC	259
CC	260
CCA	261
AB	262
BC	263
CB	264
BA	265

F. <65> <66> <67> <66> <65> <260> <256> <66>

<257> <67> <67>



A	65
B	66
C	67
AB	256
BC	257
CB	258
BA	259
AA	260

Exercise IV : Motion vector search

A. nb of macroblocks for Y = $3840 \times 2160 / 16 \times 16$ = 32400

— for U = 32400/2 = 16200

— V = 32400/2 = 16200

⇒ Total = 64800 blocks

B. one frame search = $(2K+1)^2 = (2 \times 15 + 1)^2$ = 961 MAD

⇒ Total = 64800 × 961 = 62 272 800.

C. one frame search = 9 + 8 + 8 = 25 (K/2, K/4, K/8) or 25+8 if ceil is used instead of floor

⇒ Total = 64800 × 25 = 1 620 000

(2)