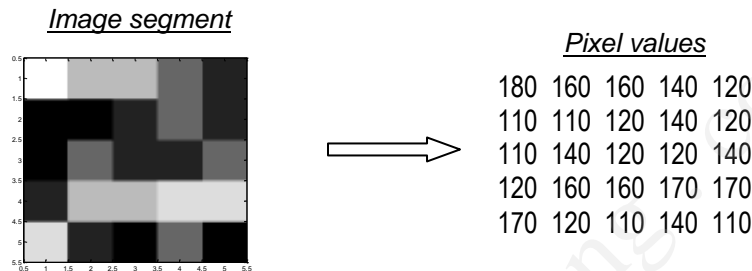




## EE 583 - Digital Image Processing Final Exam Tutorial

### QUESTIONS

1. Given a 5x5 pixel image and respective pixel values (8-bit code for each pixel) below,
- Calculate the respective Huffman Codes for each symbol (each pixel value) of the given image,
  - What is the compression ratio achieved by employing Huffman Coding instead of 8-bit fixed-length coding,
  - Calculate the relative data redundancy of the given 8-bit image and comment on the type of the redundancy used by Huffman coding,
  - Calculate the *entropy* and the *bpp*(bits per pixel) of the image after Huffman Coding.



- $p(110) = 5/25 = 0.2$   
 $p(120) = 7/25 = 0.28$   
 $p(140) = 5/25 = 0.2$   
 $p(160) = 4/25 = 0.16$   
 $p(170) = 3/25 = 0.12$   
 $p(180) = 1/25 = 0.04$

| Symbol | Prob | Code | Prob | Code | Prob | Code | Prob | Code | Prob | Code |
|--------|------|------|------|------|------|------|------|------|------|------|
| 120    | 0.28 | 01   | 0.28 | 01   | 0.32 | 00   | 0.40 | 1    | 0.60 | 0    |
| 110    | 0.2  | 10   | 0.2  | 10   | 0.28 | 01   | 0.32 | 00   | 0.40 | 1    |
| 140    | 0.2  | 11   | 0.2  | 11   | 0.2  | 10   | 0.28 | 01   |      |      |
| 160    | 0.16 | 000  | 0.16 | 000  | 0.2  | 11   |      |      |      |      |
| 170    | 0.12 | 0010 | 0.16 | 001  |      |      |      |      |      |      |
| 180    | 0.04 | 0011 |      |      |      |      |      |      |      |      |

Huffman Codes for the respective symbols

$$\text{b) } L_{avg} = \sum_{k=0}^{L-1} l(r_k) P_r(r_k) \Rightarrow L_{avg} = 0.28(2) + 0.2(2) + 0.2(2) + 0.16(3) + 0.12(4) + 0.04(4) = \mathbf{2.48} \text{ (bits/symbol)}$$

$$\text{Compression Ratio, } C = \frac{5 \times 5 \times 8}{5 \times 5 \times 2.48} = \mathbf{3.2258}$$

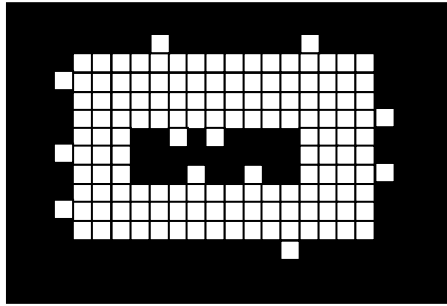
$$\text{c) Relative Data Redundancy, } R = 1 - \frac{1}{C} = 1 - \frac{1}{3.2258} = 0.69 \Rightarrow \mathbf{\%69}$$

$$\text{d) Entropy, } H = - \sum_{j=1}^J P(a_j) \log_2 P(a_j) \Rightarrow$$

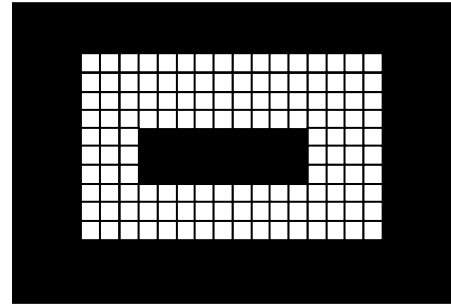
$$H = (0.04 \log_2(0.04) + 0.12 \log_2(0.12) + 0.16 \log_2(0.16) + 0.2 \log_2(0.2) + 0.2 \log_2(0.2) + 0.28 \log_2(0.28)) = \mathbf{2.4188 \text{ bpp}}$$

(bits /pixels)

2. Propose a morphological procedure to clear the edge artifacts of the image given in (a) such that the image in (b) is obtained. Clearly state the structuring element(s) and number of iterations that you would use in your procedure.



(a)

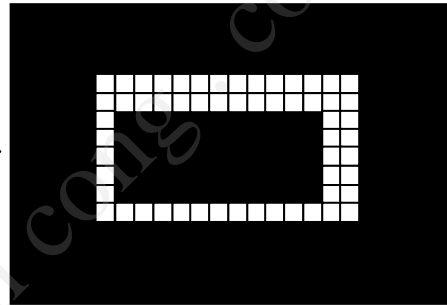
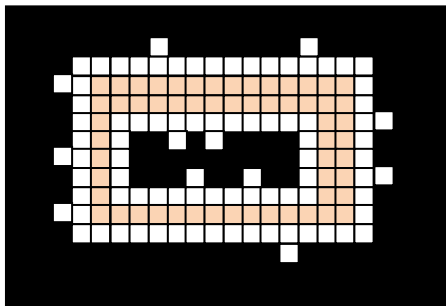


(b)

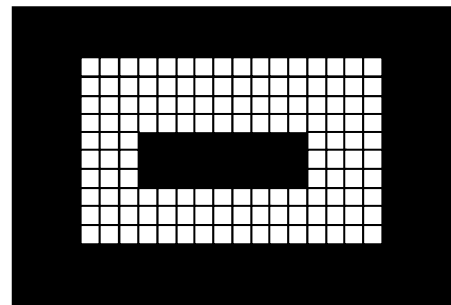
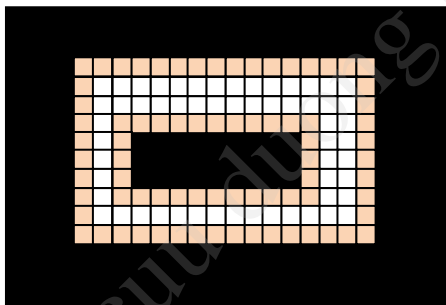
Erosion after dilation (opening) by using the following structuring element will clear the edge artifacts.

$$B = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

After erosion by B, the image becomes.



After dilation by B, the image becomes.



3. a) Give an example application where the HSI color space is more advantages than RGB and CMY color spaces.
- b) What is the effect of adding  $120^\circ$  to the Hue components on the R, G, and B components of the given image?
- a) Filtering in HSI color space is more advantages than RGB color space. Filtering in HSI only requires filtering in the luminance (I) color channel. You don't need to perform filtering in Chrominance channels. However filtering in RGB color space requires filtering in all channels (R, G and B).
- b) Adding to the Hue components shifts the RGB components such that R becomes G, G becomes B and B becomes R.

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4. Assume that the degradation transfer function in the frequency domain is given below.

$$H(u, v) = -\sqrt{2\pi}\sigma(u^2 + v^2)e^{-2\pi^2\sigma^2(u^2+v^2)}$$

Generate the resulting simplified expression of the Wiener filter by assuming that the ratio of power spectra of the noise and undegraded image is constant,

$$\hat{F}(u, v) = \left[ \frac{H^*(u, v)}{|H(u, v)|^2 + S_\eta(u, v)/S_f(u, v)} \right] G(u, v)$$

$$|H(u, v)|^2 = (-\sqrt{2\pi}\sigma(u^2 + v^2)e^{-2\pi^2\sigma^2(u^2+v^2)}) \times (-\sqrt{2\pi}\sigma(u^2 + v^2)e^{+2\pi^2\sigma^2(u^2+v^2)}) = (-\sqrt{2\pi}\sigma(u^2 + v^2))^2$$

$$H^*(u, v) = -\sqrt{2\pi}\sigma(u^2 + v^2)e^{+2\pi^2\sigma^2(u^2+v^2)}$$

$$\hat{F}(u, v) = \left[ \frac{H^*(u, v)}{|H(u, v)|^2 + S_\eta(u, v)/S_f(u, v)} \right] G(u, v) = \left[ \frac{-\sqrt{2\pi}\sigma(u^2 + v^2)e^{+2\pi^2\sigma^2(u^2+v^2)}}{(-\sqrt{2\pi}\sigma(u^2 + v^2))^2 + K} \right] G(u, v)$$

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