T-61.5100 Digital Image Processing

EXAM 05.01.2007

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1. Explain briefly, with 20–40 words or a mathematical definition, the following concepts or abbreviations: 6p.

(i) Mach bands
(ii) homomorphic filtering
(iii) two-dimensional convolution
(iv) salt and pepper noise
(v) Wiener filtering
(vi) discrete Laplace operator

2. We will study the use of wavelets in multiresolution processing of a 4×4 -sized image. (i) Haar's scaling function is

$$\varphi(x) = \begin{cases} 1 & , \quad 0 \leq x < 1 \\ 0 & , \quad x < 0 \vee x \geq 1 \end{cases} .$$

Show graphically the set of expansion functions $\varphi_{j,k}(x) = 2^{j/2}\varphi(2^j x - k)$, produced from the above function, that is needed when the length of the processed sequence is four. (ii) Show mathematically how does Haar's wavelet function $\psi(x)$ look like and draw the wavelet set that corresponds to the above expansion functions. (iii) Show how $\varphi_{1,0}(x)$ and $\varphi_{1,1}(x)$ can be formed by using $\varphi_{0,0}(x)$ and $\psi_{0,0}(x)$. What is the more general dependence of which this is an example? (iv) Form from $\varphi_{0,0}(x)$, $\psi_{0,0}(x)$, $\psi_{1,0}(x)$ and $\psi_{1,1}(x)$ the transform matrix $\mathbf{H}$ that can be used in multiresolution processing of a 4×4 -sized image. (v) By using the above matrix, calculate the transform $\mathbf{T} = \mathbf{HFH}^T$, where the analyzed image is

$$\mathbf{F} = \begin{matrix} 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 \\ 1 & 1 & 1 & 0 \end{matrix} .$$

(vi) Comment the operations you performed, study the contents of matrix $\mathbf{T}$ in view of multiresolution processing and explain what has been the sense in all this. 6p.

Turn page!

3. Below is a piece from the upper-left corner of a 256-level gray-scale image. (i) Quantize the image with truncation so that the resulting image has 16 gray levels. (ii) What is the compression ratio of the new image compared to the original one? (iii) Requantize the original image to 16 gray levels by using now horizontal IGS quantization instead of truncation. (iv) Compare the results qualitatively and explain why the IGS-quantized image is better. (v) What are the three basic data redundancies present in image compression and which of them IGS quantization tries to exploit? (vi) How does the run-length coding of the bit planes of a gray-scale image conform with quantization which reduces the number of gray levels in general and with IGS quantization in particular? 6p.

97	100	103	106	109	112	⋯
98	102	105	109	111	115	⋯
100	104	108	111	114	119	⋯
102	106	110	114	118	122	⋯
⋯	⋯	⋯	⋯	⋯	⋯	⋯

4. (i) Sketch the chromaticity diagram by using as its extreme points the following (x, y, λ) values: $(0.75, 0.25, 780\,\text{nm})$, $(0.05, 0.8, 520\,\text{nm})$, $(0, 0.65, 505\,\text{nm})$ and $(0.2, 0, 380\,\text{nm})$. Explain how the hue, saturation and intensity axes are located in the diagram. (ii) Let us suppose that a radiating body produces the (unitless) tristimulus values $(X, Y, Z) = (110, 70, 20)$. Calculate the normalized tristimulus values or trichromatic coefficients (x, y, z) and place the calculated (x, y) in the above chromaticity diagram. (iii) Place the names of the spectrum's colors and white in their correct places in the chromaticity diagram. Also name the color of the previous question. (iv) Consider any two valid colors c_1 and c_2 with coordinates (x_1, y_1) and (x_2, y_2) in the chromaticity diagram. Derive the necessary general expressions for computing the relative percentages of colors c_1 and c_2 composing a given color c that is known to lie on the straight line joining these two colors. (v) A third color c_3 with coordinates (x_3, y_3) is then added. Explain and visualize how the relative percentages would now be calculated. (vi) Explain why no combination of three radiating bodies can be used to produce all the colors producible from the spectrum's colors. 6p.