CEG4311 Image Processing
Mid-term exam

Date: Oct. 27, 1999
Time: 11:30-12:50
Professor: E. Dubois

Closed-book exam: you may not use any books or notes. You may use a pocket (nonprogrammable) calculator. However, explain all calculations; I am more interested in the reasoning than in precise numerical answers. Unless otherwise specified, you may use the results provided on page 3 without proof.
Vous pouvez répondre en anglais ou en français.

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1. The two-dimensional discrete-space signal x is defined on a rectangular lattice with equal horizontal and vertical sample spacing T. The signal x is applied to a linear shift-invariant system with unit-sample response $h(n_1, n_2)$ to give the output signal y. Assume that

$$x(n_1, n_2) = \begin{cases} 1 & \text{for all } (n_1, n_2) \text{ such that } 0 \leq n_1 \leq 2 \text{ AND } -1 \leq n_2 \leq 1 \\ 0 & \text{otherwise} \end{cases}$$

$$h(n_1, n_2) = \begin{cases} 1/2 & (n_1, n_2) = (0, 0) \\ 1/8 & (n_1, n_2) = (\pm 1, 0), (n_1, n_2) = (0, \pm 1) \\ 0 & \text{otherwise} \end{cases}$$

$x(n_1, n_2)$ has nine non-zero samples and $h(n_1, n_2)$ has five non-zero samples.

2 (a) What are the indices (n_1, n_2) for which $y(n_1, n_2)$ is non-zero? (Hint: It may help in (a) and (b) to visualize the situation graphically.)

2 (b) Compute $y(n_1, n_2)$ using the convolution formula. Specify the result completely (i.e. for all (n_1, n_2))using the method of your choice.

3 (c) State (and justify) whether the unit sample response satisfies

   1. separability
   2. linear phase
   3. quadrantal symmetry

4 (d) Determine the frequency response $H(u_1, u_2)$ of the filter. Sketch a contour plot of $H(u_1, u_2)$ for $-\frac{1}{T} \leq u_1, u_2 \leq \frac{1}{T}$ c/ph. (Just show a few labeled contours, approximately but neatly, demonstrating clearly any periodicity. It will help to tabulate a few values first.)

2. A progressive-scan HDTV camera samples the input image with 1280 samples per scan line (1280 samples per pw), with 720 scan lines per frame (i.e. 720 samples per ph), where the aspect ratio is given by pw $= \frac{16}{9}$ph, and with 60 frames per second, in a rectangular sampling structure.

3 (a) Determine the 3×3 spatiotemporal sampling matrix for the corresponding sampling lattice. Show clearly the units, using units of picture heights (ph) for spatial distance and second (s) for time.

6 (b) Suppose that we wish to display the HDTV image on a standard-definition TV receiver that can display 720 samples per scan line, 480 scan lines per frame, with an aspect ratio of $\frac{4}{3}$, and 60 frames per second. We don't want to lose any of the picture, so black bars are inserted above and below the picture to account for the different aspect ratios. Draw a block diagram of a system to convert the HDTV image sequence to one that can be displayed on the given standard definition receiver. Give as complete a system as you can and provide as much detail as possible about the purpose and operation of each component of your system, giving numerical information where possible.

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Formulas

Discrete-space Fourier transform on a lattice Λ:

$$F(\boldsymbol{u}) = \sum_{\boldsymbol{x} \in \Lambda} f(\boldsymbol{x}) \exp(-j2\pi \boldsymbol{u} \cdot \boldsymbol{x})$$

$$f(\boldsymbol{x}) = d(\Lambda) \int_{\mathcal{P}^*} F(\boldsymbol{u}) \exp(j2\pi \boldsymbol{u} \cdot \boldsymbol{x}) \, \boldsymbol{du}$$