Mid-Term Examination: ESE 558 Digital Image Processing

Date: 3/11/97, Due 3/18/97 Spring 1997, SUNY at Stony Brook, Murali Subbarao

1. *(10 points) Ch. 2: Random fields*
   (Excercise 7 one page 45 in the text book): The random fields **f** and **g** are related as
   $$\mathbf{g}(x,y) = \int\int \mathbf{f}(x-\alpha, y-\beta)h(\alpha,\beta)d\alpha d\beta + \nu(x,y) \quad (1)$$
   where the random field $\nu(x,y)$ represents additive noise. If **f, g** and ν are homogeneous random fields and if **f** and ν have zero means and are uncorrelated, show that
   $$S_{gg}(u,v) = S_{ff}(u,v)|H(u,v)|^2 + S_{vv}(u,v) \quad (2)$$
   where $S_{gg}, S_{ff}, |H(u,v)|^2$ and S_{vv} represent appropriate spectral densities.

2. *(10 points) Ch. 3 Human visual system*
   (a) Name any 4 Gestalt laws of organization and explain 2 of them with examples and diagrams.
   (b) Define or explain any five of the following items:
   (i) Weber's law, (ii) metacontrast effects, (iii) brightness constancy, (iv) mach bands, (v) hue and saturation of color, (vi) size and shape constancy, and (vii) acuity, (ix) Photopic and scotopic vision.

3. *(10 points) Ch. 1 and Ch. 2: Model for image sensing in a CCD camera*
   The schematic diagram of the sensing process in a CCD camera is shown in Fig. 1. The optical system is a thin lens with a circular aperture.
   (a) Briefly explain how the input image $f_{in}(x,y,\lambda,t)$ is transformed at each step in the schematic diagram (about 1 to 4 sentences for each step).
   (b) Derive a relation between $f_{in}(x,y,\lambda,t)$ and $f_{out}(x,y,t)$. Note that f_{out} is the image signal **before** discrete to analog conversion.

4. *Ch. 4: Sampling, 10 points*
   (a) Give a detailed proof (i.e. show all steps) of the Theorem on page 94 in the text book.
   (b) What is optimal sampling? Explain how it may be implemented.

5. *10 points: Optimal quantization:*
   The probability density function of the continuous brightness variable z of an image is $p(z) = (1 + \text{Cos}z)/(2\pi)$. The image brightness needs to be quantized to 2 bits (i.e. 4 grey levels). Obtain the solution to the optimal quantization problem for this image as the roots of an equation of the form $f(s) = 0$ where s is a threshold level or quantization level and f is an algebraic explicit expression involving s, Sin$s$ and Cos$s$.
   (b) Use any numerical technique that you like to solve the above optimization problem and give the actual numerical results. Explain (in one or two paragraphs, but not to exceed one page) the computational technique that you used to solve this problem.