Mid-term Examination: ESE 558 Digital Image Processing
Date: 3/21/95, Duration: 2 hrs. 30 mins., Max. Marks: 50
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1. *(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.

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.

3. *(5 points) Ch. 2: Convolution*
   Write an algorithm (or function in a high level programming language such as C, Fortran, Pascal, etc) to compute the circular convolution of two digital images f[i][j] and h[i][j].

4. *(5 points) Ch. 2: Random fields*
   The random fields $\mathbf{f}$ and $\mathbf{g}$ are related as

   $$\mathbf{g}(x, y) = \int\int \mathbf{f}(x - \alpha, y - \beta)h(\alpha, \beta)d\alpha d\beta + \nu(x, y) \tag{1}$$

   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

   $$S_{gg}(u, v) = S_{ff}(u, v)|H(u, v)|^2 + S_{vv}(u, v) \tag{2}$$

   where $S_{gg}, S_{ff}, |H(u, v)|^2$ and S_{vv} represent appropriate spectral densities.

5. *(10 points) Ch. 4: Quantization*
   (a) Formulate and solve the problem of optimal quantization as discussed in class. Briefly outline a computational approach to solve the equations that you derive.
   (b) The pdf of a signal z is $p(z) = 0.75(1 - z^2)$ for $|z| \leq 1$ and $p(z) = 0$ for $|z| > 1$. Find optimal threshold values and quantization values if we need 2 distinct quantization levels.

6. *(10 points) Ch. 4: Sampling*
   See attached sheet.