ECE 438 Lecture Monday 24 April

Announcements

- Office hours today 2:30p EDT & 4:00p EDT
- posted HW 10 last week - not be collected
- Final Exam - Monday 1 May 2023
  7:00p - 9:00p in MSEE B012
- will not cover image reconstruction
  (computed tomography)

Final Exam

5 problems

3 from first 3 hour exams

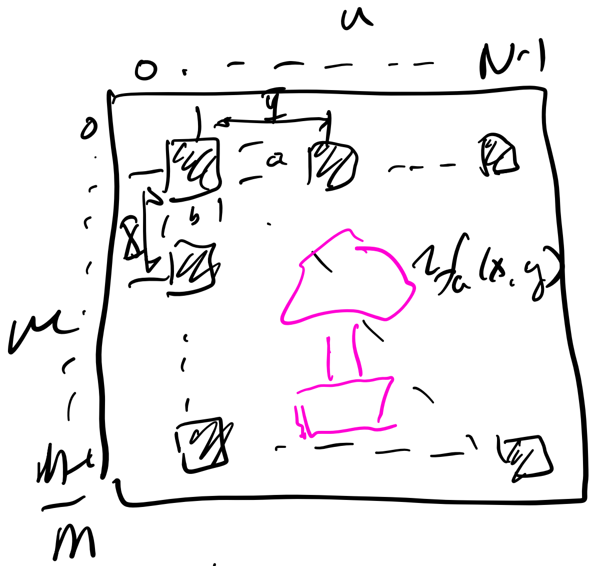
2 New Material:

20 signals & System

Image processing (rest of this week)

Imaging Systems

Focal plane array image capture system



$$f_d[m,n] = \int_{mX-a/2}^{mX+a/2} \int_{nY-b/2}^{nY+b/2} f_a(x,y)\, dx\, dy$$

↑ digital

blur

$$\tilde{f}_a(x,y) = f_a(x,y) ** \mathrm{rect}\left(\frac{x}{a}, \frac{y}{b}\right)$$

As (a,b) increases, camera becomes faster, but blurrier increases

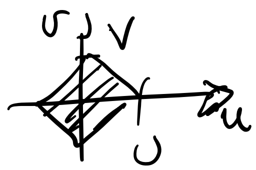
$$\tilde{F}_a(u,v) = F_a(u,v)\, ab\, \mathrm{sinc}(au;\, bv)$$

$$\hat{F}_s(u,v) = \frac{1}{XY} \mathrm{rep}_{\frac{1}{X}\frac{1}{Y}} \left[\tilde{F}_a(u,v)\right]$$

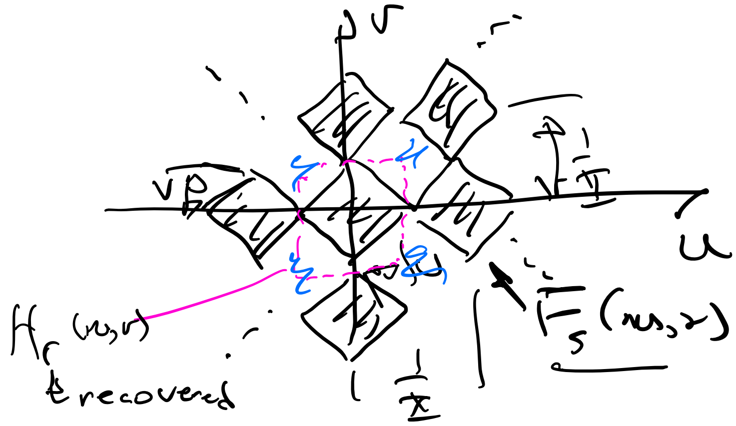
$$f_s(x,y) = \sum_m \sum_n f_d[m,n]\, \delta(x - mX, y - nY)$$

$$f_d[m,n] = \tilde{f}_a(mX, nY)$$

Ignore aperture effects for rest of development



$F_a(u,v)$



Sampled at Nyquist rate, have

$\frac{1}{X} > 2U$, $\frac{1}{Y} > 2V$ ⇐ sufficient but not necessary

$$F_r(u,v) = H_r(u,v)\, F_s(u,v)$$

$$H_r(u,v) = XY \,\text{rect}(Xu, Yv)$$

Sampling on a non-rectangular lattice packs the spectral replications more tightly and reduces sampling rate in spatial domain (Module 2.2.4)

Not responsible for Modules 2.2.4 (sampling on non-rectangular lattices and 2.2.5 (Analysis of sampling, except for focal plane arrays)

$$f_r(x,y) = h_r(x,y) ** f_s(x,y)$$

$$f_s(x,y) = comb_{XY}\left[f_a(x,y)\right]$$

$$h_r(x,y) = sinc\left(\frac{x}{X}, \frac{y}{Y}\right)$$

So $$f_r(x,y) = \sum_m \sum_n f_a(mX, nY)\, sinc\left(\frac{x-mX}{X}, \frac{y-nY}{Y}\right)$$

2D version of Whitaker-Kotelnix-Shannon (WKS) sampling expansion

See 2D aliasing example on p. 13 of Module 2.3.2

Module 2.4.1 Image processing or image enhancement

Overview of image processing strategies:

① **Enhancement**

- degradation is not well-defined
- criteria for improvement are only qualitatively stated

example: image sharpening

② **Restoration**

Will cover this in ECE 438

- detailed model for image degradation
- process image to maximize a mathematically defined quality measure

example: motion blur of license plates

③ Reconstruction

- generate images from non-image data
- detailed description of mathematical process used to generate the data
- supports an analytical description of reconstruction process

may talk about this in lecture - not on final exam

example: computer-aided tomography (CAT) scans

Enhancement

Types of image enhancement operations:

① gray scale transformations
② spatial filtering (linear or nonlinear)

morphological operations → (nonlinear)

Notation

digital image f[m,n] $0 \le m \le M-1$

$0 \le n \le N-1$

M & N can be quite large - thousands

have M × N array of integers, one for R, G, & B each. Each integer lies between 0 & 255

⇒ 1 byte/pixel/channel (8 bits)

Mainly focus on monochrome (b/w) images

Histogram ~ density function describing distribution of gray values in the image

$$h_f[b] = \frac{1}{MN}\{\text{No. pixels for which } f[m,n] = b\}$$

$$= \frac{1}{MN}\sum_{m=0}^{M-1}\sum_{n=0}^{N-1}\delta[f[m,n]-b]$$

$$0 \le b \le 255$$

properties

① $0 \le h_f[b] \le 1$

② $\sum_{b=0}^{255} h_f[b] = 1$

end of Module 2.4.1

Grayscale transformations Module 2.4.2