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SIGNALS PROJECT

I. Image filtering and restoration:

Illustration of Convolution used between the given image and the following kernels:

- Convolution is a general purpose filter effect for images.
- Is a matrix applied to an image and a mathematical operation

  comprised of integers.

- It works by determining the value of a central pixel by adding the weighted values of all its neighbors together.
- The output is a new modified filtered image.

- 1.edge detection kernel

[0 -1 0

-1 4 -1

0 -1 0]

Justification: implement a 3x3 x-derivative image filter

The following formula for that task in the x-direction (h=1), (f(x+h;y)-f(x-h;y)) / 2*h. From our course we have studied that differentiation in time domain corresponds to multiplication by jw in frequency domain therefore high frequency compnents(harmonics) representing sudden transitions(edges) of the image are enhanced.

Relative from my current pixel (x), I take the pixel value +1 ahead of my current pixel and subtract the value from the pixel on the position -1 behind my current pixel. Since Kernel represents the function we are performing ,therefore,the kernel is [1 0 -1]. Adding similar matrices with the same idea and enhancing other edges of the image. Summing up them together will end up with a matrix that can be applied over the image through convolution to emphasize the edges.

HINT: Differentiator act as high pass filter(emphasis details of the image)

- 2. image sharpening kernel

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

  Justification: adding edge detection kernel to our image of matrix [0,0,0;0,1,0;0,0,0] will result in the image sharpening kernel shown above.

- 3. Blurring (averaging) kernel:

$$1/16 * \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Or ones(3,3)/9 .

Note : 16=sum of elements of the matrix for averaging as required

Justification: this kernel is a mathematical representation of integrator system that we have studied in signals and systems course. Gaussian blur is a low-pass filter, attenuating high frequency signals. Each pixel's new value is set to a weighted average of that pixel's neighborhood. The original pixel's value receives the heaviest weight (having the highest Gaussian value) and neighboring pixels receive smaller weights as their distance to the original pixel increases. This results in a blurred image.

HINT:Integrator act as low pass filter that blocks high frequency compnents of the image(hide fine details of the image).

- 4.horizontal motional blurring kernel:

1/7 *[0000000

0000000

1111111

0000000

0000000]

Justification: horizontal row of ones to accomplish this task and divided by the average of the matrix. For vertical motional blurring another matrix with middle coloumn full with ones is used instead. We have noticed that as the dimensions of the used kernel get larger motional blurring is much more obvious ,that’s why we have used 9*9 matrix divided by 9(average), division by the average of the kernel to avoid chaning the intensity of the image.

C. Finding the inverse of a system in frequency domain would be very complex

[h(t) convolution h ^-1 (t)]=impulse (t)]

, therefore we have transformed our motional blurred image and kernel to Frequency Domain , to convert convolution process to multiplication. Once the image is restored we have transformed it back to time domain using ifft2().

Hint: restoring image was very challenging , one of the images attached represents restoring image without noise removal!! For a better quality we used snr with ratio=0.2 to reduce noise in the FD as much as possible. Finally better results are obtained and the image is attached too.

HINT SNR=signal power/noise power

II. Communication system simulation:

a)the next values are mainly based on lec. 11 slide 16

fs=44.1 khz

bits per sample= 16bits/sample

justification:

converting discrete time signal to freqyency domain corresponds to periodic signal in frequency domain shifted at multiples of Fs. So we have picked an appropriate sampling rate to avoid interference in frequency domain. Based on our course fs has to be greater than (2fm) (Nyquist rate) , since the record is of duration 10 secs. ,hence we were able to pick a convenient fs.

b) this step is considered as denoising and anti aliasing stage to make the signal band limited

c)the resulted spectrum after filtering is the same as that before the filter except that high harmonic compnents(noise) has disappeared because of LPF.

d)carrier : cos(t)

carrier frequency 1: 1300 hz

carrier frequency 2:1700 hz

for a frequency –division multiplexing system , the modulated signals has to be risen to higher frequencies to decrease the wavelength to fit the antenna size and Transmit multiple signals simultaneously

(frequency division multiplexing) . The carrier frequency, the picked carrier frequencies are chosen wisely to avoid overlapping between the 2 signals as illustrated in lec. 10 slide 41 , b> a+ m/2

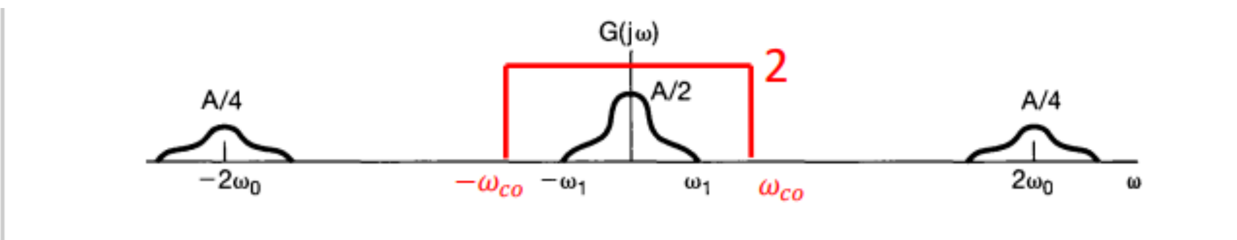
e)receiver perform demodulation of each signal simultaneously .

Time domain	Frequency domain
Cos(ct)= (e^j ct+e^-j ct)/2	0.5[(+)+ (−)] Shifting modulated singal at carrier frequency (c) and (- c) with half of their amplitudes and adding them.

Then pass LPF of gain=2 (AMPLITUDE MODULATION) ,

And width : abs( )> c1 && abs( )< c2

,we didn’t need to pass a band pass filter due to wide gap between 2 carrier frequencies .



References:

1. https://en.wikipedia.org/wiki/Kernel_(image_processing)
2. https://www.songho.ca/dsp/convolution/convolution2d_example.html
3. https://setosa.io/ev/image-kernels/
4. https://rpg.ifi.uzh.ch/docs/teaching/2023/MatlabPrimer.pdf
5. https://web.pdx.edu/~jduh/courses/Archive/geog481w07/Students/Ludwig_ImageConvolution.pdf
6. **Course slides**