Image Compression

Problem 1: (Graded on Effort Only - 20 pts)

A. In the image compression lecture I showed you an example where I added a significant amount of noise to an image and, as a result, the compressed size of the resulting JPG compressed file grew substantially. (Assume both files were compressed with the same JPG quality setting, or in other words, the same quantization matrix.) Describe why the image with more noise compresses less.

B. Which image do you think will be compressed to a smaller file size using JPG compression? Please describe why. Your explanation should reference the state of the coefficient matrix after the quantization step. What properties of each image make one more compressible than the other?


A

B
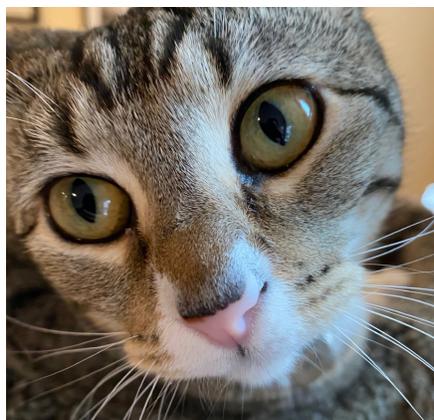
Problem 2: (Graded on Effort Only - 30 pts)

[This problem may depend on a part of the VR lecture, when we talk about cameras with lenses.] Seven students stand in a line at positions $P0 - P6$, and take pictures of the opposite wall of the room with pinhole cameras as shown in the figure. Each camera is a 7-pixel camera, and the image acquired by camera i in pixel j is encoded at $I(i, j)$ (For simplicity, let's assume our cameras take 1D images in this problem.)
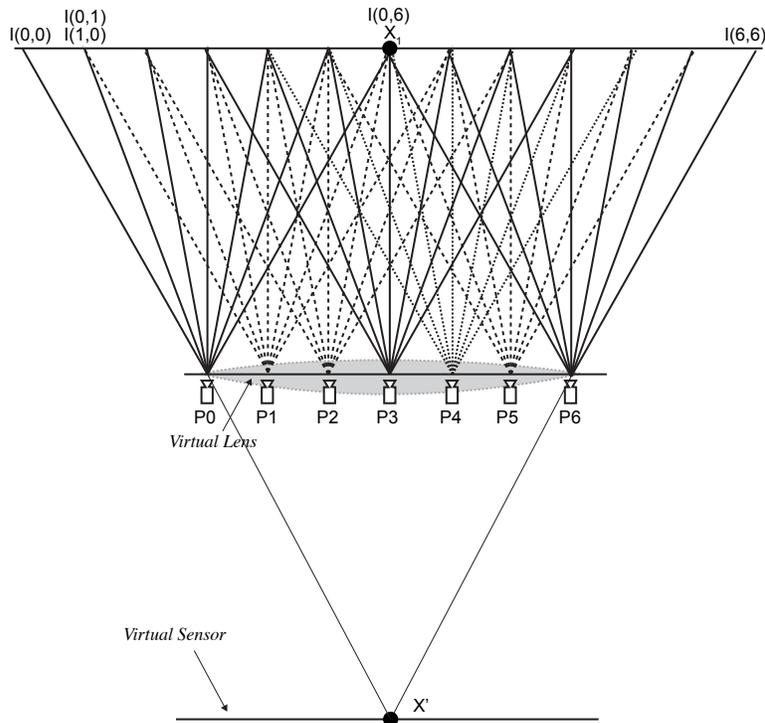
A. When a camera with a lens is IN FOCUS on a point in the scene, such as the point X_1 in the figure, all rays of light from X_1 through the lens are refracted to the same pixel on the sensor. Now imagine that the students in the class wanted to take their six photographs, and use the pixels I(i,j) in these photographs to *simulate what a VIRTUAL CAMERA with the ENORMOUS APERTURE SHOWN IN THE FIGURE (see "virtual lens") would have photographed!* Assuming you wanted to compute the value of the virtual camera's pixel X', what pixels I(i,j) should you add up? (Yes, we are approximating the image formed by a lens with a bunch of samples from pinhole cameras located on the virtual lens!)

B. Now consider simulating the behavior of this virtual camera when it is NOT FOCUSED on the wall, but instead focused at the closer point X_2 (it is marked on the figure). Describe (in words is fine) how you might go about computing the the color of virtual camera's pixel X' in terms of the I(i,j)'s. Hint 1: the red lines in the figure might help you visualize where rays originating from X_2 in the world land on the virtual sensor. Hint 2: the word interpolate might be useful too.
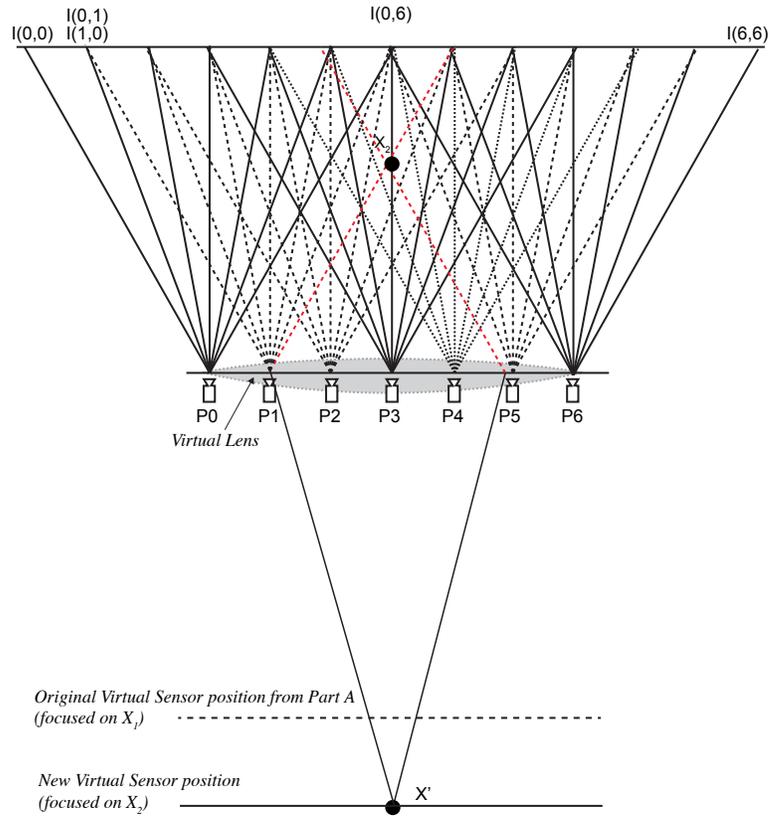
Problem 3: (Graded for Correctness - 30 pts)

In class we talked about JPG compression, but many images on the web are compressed using the PNG format. PNG, unlike JPG, is a *lossless* format, meaning that the compressed image can be decoded back to the same same pixels as the original image. JPG is a "lossy" format, meaning that the decompressed image is not the same as the source image prior to compression. PNG files compress images using scheme that describes the next pixel in an image based on the values of prior pixels.

One of several possible modes in PNG compression is a simple delta encoding, where instead of storing the value of pixel `I(x,y)`, PNG instead stores *the difference* between `I(x,y)` and `I(x-1,y)`. For example, if the pixel values are:

`244, 64, 64, 64, 65, 10`

Then the encoded version of the values is:

`244, -180, 0, 0, 1, -55`

After performing delta encoding, the sequence of values is compressed using normal data compression techniques, such as Huffman encoding, which uses short bit patterns to represent commonly-occurring numbers in a file. In other words, the final compression step will be very effective when a file contains the same value with high frequency.

A. (10 pts) Given this description of PNG tell me whether you think PNG would significantly reduce the size of the following image. Please explain why?

B. (10 pts) Do you think PNG compression would significantly reduce the size of this image of a very cute set of cat paws? Why or why not?

C. (10 pts) Consider the image in part A again. Give one advantage of using PNG to compress this image compared to JPG assuming that JPG compression is configured to use a "medium" quality level. (Consider the quality of the image compressed using PNG.)

Problem 4: (Graded on Effort Only - 20 pts)

A. It's nearing the end of the quarter and to blow off some steam you decide to go out clubbing to celebrate the end of CS248A! You check the club's website and learn that tonight is "yellow light night", where the entire dance floor is illuminated in yellow-looking light that is emitted from light sources that have red, green, and blue primaries. Your friend, who is in a glum mood, says, "I find it hard to party because I'm so sad that CS248A is almost over! I wish I could wear black tonight to show off my feelings, but I only have red shirts and blue shirts to choose from." You tell your friend, "Oh you can still look like you are wearing black!" Which shirt to you advise your friend to wear, and why?

B. Give one reason why color representations that explicitly separate the luminance (brightness) and chroma components of a color (e.g., hue-saturation-brightness (HSB) or Y'CbCr) can be useful color representations compared to RGB.

C. Imagine the human visual system could directly measure and interpret the full spectrum of incident light. (That is, your brain received and used full spectral information $L(\lambda)$ rather than just the response of S,M,L-cones). Why would this change to human perception make recording and displaying digital images and rendering pictures far more challenging? (Hint: consider reproducing the appearance of a real world scene on a display. The word *metamer* might be useful.)

D. Describe the biological reason why, even though a spectrum may contain power over all wavelengths, human perception of color is only three-dimensional. We'd like to see the phrase "response function" in your answer.

E. Imagine if all three types of cone cells in your eye had *the same spectral response function*. If this were the case, would you have color vision (the ability to differentiate different colors)? Why or why not?

PRACTICE PROBLEM 1:

A common rule taught to graphics designers and web developers is "never save images as JPG files if they contain text". Below is an image that contains text, along with a zoomed view. Please briefly summarize why a compressed JPG file exhibits these compression artifacts for images that contain text. Mention key properties of the input image in your answer.

Zoomed view of compressed image.