HW2

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1. Give an example of a separable filter and explain the primary advantages of using them.

   [1,2,4,2,1] * [1
   2
   4
   2
   1]

   The 1* 5 and 5 * 1 filters are the separable filters of the 5 *5 Gaussian filter below

   [1,2,4,2,1
   2,4,8,4,2
   4,8,16,8,4
   2,4,8,4,2
   1,2,4,2,1]

   The separable filters need 2* (5 + 4) + 1 = 19 operations / pixel,
   while the 5 *5 Gaussian filter needs (25 + 24 + 1) = 50 operations / pixel.
   So, the separable filters have much more time efficiency for filter operations.

2. What does it mean if a filter is an edge-preserving filter? Give an example of one.

   An edge-preserving filter zero out (or reduce) the noise in an image while keeping edges. It preserves areas with significant intensity changes (edges) and smooths other regions, making it useful for removing noise without blurring object boundaries.

   The bilateral filter is an example. With having space weight, range weight and normalization factor, it ensures that only nearby pixels with similar intensities to the central pixel are considered for blurring, while keeping the sharp intensity are maintained.

3. A Gaussian filter is a low-pass filter. Explain what that means by visualizing the Fourier Transform of the image after multiplying it by a Gaussian in the Fourier domain (look at the demo from class). What is being "passed" through a low-pass filter?

The Fourier Transform of the image shows its frequency spectrum, and then through multiplication with a Gaussian filter, we have a multiplication in Fourier domain, which is used to **highlight low frequencies by reducing higher ones.** In the end, the result is converted back to the spatial domain using the inverse Fourier Transform, producing a smoothed image, where high frequency is suppressed.

4. A Sobel filter or a Laplacian filter are high-pass filters. Can you visualize what that might be doing to the Fourier Transform of an image in the Fourier domain? What is being "passed" through a high-pass filter?

   A Sobel or Laplacian filter's visualization **focuses on the high-frequency** parts of an image, which are where edges and fine details show up.

   It would reduce or remove the low-frequency components near the center (which represent smooth variations) while keeping the high-frequency components at the edges (which represent sharp details). This would make the center of the spectrum darker and the edges brighter, emphasizing fine details in the frequency domain.

5. I am building a convolutional network. Given an image with 3 channels (RGB), I want the first convolution layer to have 16 5x5 filters. How many filter coefficients (parameters) does the layer need to learn? Explain your reasoning.

   A single filter operates across all channels of the input image, so the dimensions of each filter: 5 *5 *3 = 75 parameters / filter.

   For 16 filters in the first layer, the total # of parameters: 16 × 75 = 1200

6. Given a second convolution layer on the same network (first layer has 16 filters), we want the second layer to have 32 3x3 filters. How many filter coefficients (parameters) does the second layer need to learn? Explain your reasoning.

   The input to the second layer comes from the output of the first layer, which has 16 feature maps, so the filter dimensions: 3×3×16 = 144 parameters / filter

   Since there are 32 filters in the second layer, the total # of parameters: 32×144=4608 parameters.