EBME/CSDS 361/461. Homework 2. Spring.
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Homework: 2D Spatial Noise Reduction Filtering

All homework assignments must be completed individually (no teams/groups).

Your responses to each question to each should include:

- A short discussion of each problem. ***Code/images alone will not suffice.*** A brief description/explanation should accompany each image/algorithm.
- Any processed images
- All MATLAB code used to generate results and images. NOTE: MATLAB/Python code may be randomly tested by TA for functionality!
- Be sure to comment your MATLAB/Python Scripts thoroughly! We need to understand your approach to each problem.

Please submit the following files in Canvas:

- Your responses to each question in PDF format, titled "`[caseID]_HW02.pdf`"
- All generated images, MATLAB/Python code in one zip file titled "`[caseID]_HW02_Code.zip`"

Please read the question descriptions carefully. Be sure to address every question. We try to give you sufficient information to get you successfully started on this simple, but interesting, project.

Images will be provided by the TA. *(note: the .mat file is simply the MATLAB data representation of the corresponding .tif image)*

Images will be provided by the TA.

- Edges.mat, Edges.tif
- Edges_gnoise.mat, Edges_gnoise.tif
- Edges_spnoise.mat, Edges_spnoise.tif

Questions

1. In MATLAB, apply each of the noise smoothing filters below to the test images, (1) Edges_gnoise (edges + gaussian noise) and (2) Edges_spnoise (edges + salt & pepper noise):
    - Averaging filter with 3x3 kernel
    - Averaging filter with 9x9 kernel
    - Median filter with 3x3 kernel

- Built-in function ‘wiener2’. *Please estimate the additive noise power and enter this as a parameter in the call (see https://www.mathworks.com/help/images/ref/wiener2.html)*

Include all of these images in the report. Use them to answer the following questions:

a. Which filter most blurs edges?
b. Which filter most reduces noise?
c. Which filter does the best job with the image containing gaussian noise?
d. Which filter does the best job with the image containing salt and pepper noise?
e. Describe ‘wiener2’.
f. Do you see any advantages with ‘wiener2’?

2. In MATLAB, create a 2D image containing Gaussian noise with a standard deviation of 30 gray-scale values on a flat background of 50.
   a. Filter the image using a 5x5 averaging filter. Show the images before and after. Compute the noise standard deviation and mean before and after filtering. Create a histogram in MATLAB for both images and compare them. Compare your standard deviation result to the theoretical estimate of Gaussian white noise variance after average filtering with a 5x5 kernel, using information given in the lecture.
   b. Take the output image from (a) and filter it again with the 5x5 averaging filter. What is the standard deviation? Compare the result to the theory from (a). Give a rationale for any deviation from the simple theory.
   c. Filter the original image with a 5x5 median. Show the result images before and after. Compute the standard deviation of the noise before and after filtering.
   d. Compare the noise reduction between the averaging filter and the median filter. *At this point, you should easily be able to state what type of filtering works better with Gaussian noise!*
   e. For the two images in a, what are the minimum and maximum values? If you convert the MATLAB images to 8-bit data, what will happen?

3. Use the image Edges_spnoise.
   a. Program a median filter consisting **OF A CROSS (“+”** shape**)** that is 5 pixels wide.
   b. Compare it to a standard 3 x 3 median filter (not cross-shaped). *Determine methods for comparing the filters. You should consider both noise reduction characteristics as well as edge and corner characteristics.*

4. Compare Gaussian filtering to anisotropic diffusion filtering on a clinical image. Use image MRI_brain_sagittal_noisy and its complement without noise.
    a. Please note that when comparing images with and without noise, you must set windo and level appropriately to make a good visual comparison. Same for images before and after noise reduction.
    b. Filter the noisy image with a 3x3 averaging filter.
    c. Filter the noisy image with anisotropic diffusion. Optimize filter parameters to get back to something like the original image. Describe your experience with filter parameter optimization.

Hint for problem 4: To visualize the image "MRI_brain_sagittal_noisy.tif", you need to make appropriate selection on display range of "imshow" function in MATLAB.

Functions of Particular Interest

Useful functions in MATLAB:
imfilter, conv2, fspecial, medfilt2, ordfilt2, weiner2, imshow, imagesc, imdiffusefilt

Useful functions in Python
scipy.ndimage.correlate, **scipy.ndimage.convolve**, **cv2.filter2D, matplotlib.pyplot.imshow (see also the extent kwarg for imshow)**