**Lab3: Image enhancement**

**Student name: Total mark:** / 3

**Student number: TA signature:**

**Instructions**

* Complete all three parts of the lab below.
* Part IV & Part V are optional. It is recommended you complete it on your own.
* Answer all questions using complete sentences in the boxes provided. Answers may be typed or hand-written **legibly**. You may exceed the box size if necessary.
* **Print and bring your lab sheet to the lab in your registered lab session.**

\* See the MATLAB documents of "imfilter", "fft2", "ifft2", "fftshift", "ifftshift", and others in detail at the MathWorks website.

\* To display an image, use “imagesc(im)” or “imshow(im, [ ] )” so that the display intensity range is automatically optimized. Always display the color bar using “colorbar” to verify the intensity range.

**Part I [1 mark]: Averaging mask (spatial domain)**  / 1

1. Download a CT image of your choice. Resize the image smaller if it is bigger than 300 x 300 pixels using “imresize”. If the image data is color, convert it to grayscale using “rgb2gray”. Convert gray to double using “im2double”. Show the image, f(x,y).
2. Add noise signals, given by n(x,y)=0.5sin(0.4πx)+0.5sin(0.4πy), to the image f(x,y). Show the noisy image fn (=f+n).

*Hint: To create n use* [x y] = meshgrid(1:width, 1:height) *to get (x,y) for n(x,y) above.*

Give an example of the type of noise that is being simulated here. Give an example of a different type of noise and an example source (i.e. non-sinusoidal)

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| This noise is additive noise since we added it to the image as a separate signal. A different type of noise is Gaussian noise where random gaussian function is added to the image function to generate the noise. Sources include sensor noise caused by poor illumination and/or high temperature, and/or transmission e.g. electronic circuit noise. |

1. Create an averaging mask h using “ones(k)”, where k is the mask (kernel) size. Remove the noise signals n from fn using h by the convolution mask, g=fn\*h in spatial domain. Convolution mask operation can be performed by “imfilter”. What is the optimal size k? Justify your answer.

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| Optimal k = 5.  Values lower than 5 were sharper but still too noisy and values above 6 started making the image blurry. |

1. Compare and discuss the original image f, noisy image fn, and filtered image g.

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| Original image looked as it should, noisy image has a lot of distortion making it hard to figure out the image, and then the filtered image was similar to the original image but not quite as sharp, had some blur to it even with the optimal value of k. |

**Part II [1 mark]: Low pass filter (frequency domain)**  / 1

1. Apply 2-D Fourier transform “fft2” on the images, f, n and fn, used in Part I. Set the origin of the spectrum (u,v)=(0,0) at the center of the image display using “fftshift”. Display its magnitude using “abs”. You may also take “log” of the magnitude to have a great dynamic range if necessary. Display and compare these spectrums.
2. Create a low pass filter L(u,v) with the same pixel dimension of the image fn using “ones” and “zeros”. You may design the filter with a rectangular (not circular) shape. Display the L(u,v). What are the cut-off frequencies, uc, vc, (pixel numbers) to remove n from fn?

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| uc = \_\_\_50\_\_\_\_ vc = \_\_\_50\_\_\_\_ |

1. In frequency domain, remove the noise n from fn using the low pass filter designed. Display frequency spectrum of the filtered image. Rearrange the filtered complex spectrum data (not the magnitude spectrum data) using “ifftshift”. Then, apply an inverse Fourier transform “ifft2” to reconstruct a spatial domain image. Show the image and compare it with the original image f. What features have change in the resulting image?

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| Yes, it looks very similar to the original image. There is some blurriness and ringing due to loss of high frequency image. |

**Part III [1 mark]: Band limit filter (frequency domain)**  / 1

1. Repeat (2)-(4) with a band limit filter to remove only the noise frequency bands in frequency domain. Compare the reconstructed image with the original image f and the image obtained in Part II (4). Discuss whether the band limit filter more effective at removing noise?

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| It does not look similar to the original image, there is a vague outline but details can’t be made out. |

1. Would a band limit filter be effective at removing thermal noise? Explain your answer.

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| It can be effective in certain scenarios. The amount of thermal noise depends on the temperature. The band limit filter is designed to allow frequencies within a range to pass through, but if the filter's passband includes frequencies within the range of thermal noise, it will not be able to remove that noise from the signal. (Say the circuit for example heats up). |

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**Additional self-study (Do not submit, no marks)**

**Part IV:**

1. Try with a different image having a bigger or smaller pixel dimension.
2. Sharpen the blurred (filtered) image.

**Part V:**

Assume that your image dimension that you downloaded is 200 mm x 200 mm.

1. What are the spatial sampling intervals (mm) along x and y direction, respectively?
2. Show an equation of the averaging mask that you created in Part I-(3)
3. What are the spatial frequency sampling intervals (/mm) along x and y direction, respectively?
4. Show an equation of the low pass filter that you created in II-(2). What are the cut-off frequency (/mm)?

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