# ECE-435 Homework 1 - Imaging Fundamentals

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**Abstract**

The purpose of this homework assignment was to experiment with different imaging techniques used in medical imaging. Image processing is a tool us engineers can use to help radiologists identify important information from obtained scans.

## 1 Introduction

To briefly summarize, the concepts of: noise, blurring, filtering, and edge detection will be employed on a set of obtained CT scans of the thorax made available by Mulrecon. It is the first scan on their webpage: http://www.castlemountain.dk/atlas/index.php?page=mulrecon

## 2 Slicing

Three images of different slices of the thorax will be presented based on the lateral x and y components and the axial z component. Careful analysis of the images shows all important features of the thorax such as the spine and its disks. Furthermore, the dimensions of the lateral scans are 512x237 while each axial scan is 512x512. Each pixel is considered a rectangle in three dimensions where the length of a pixel in the x and y directions are 0.703mm which implies lateral scans are 0.3584m x 0.3584m. Furthermore, the spacing between slices is 0.625mm which means along the z-axis, the total depth is 0.1481m.

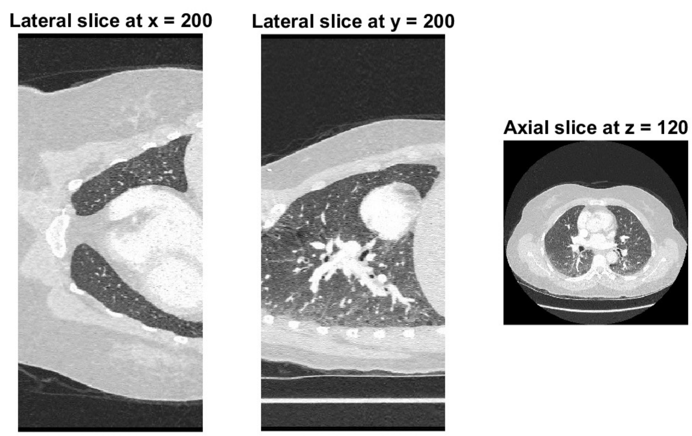


fig 1. Slices of different axes of the thorax

## 3 Salt and Pepper Speckle Noise in Image Processing

**Motivation:** Salt and pepper noise is common in CT scans and includes noise in the form of white or dark pixels (the very high or very low intensity pixels). Given a 3x3 kernel, these spurious pixels values can skew the mean of local pixel values upward or downward **while not affecting the median**.

### 3.1 Mean and Median Filtering Using a 3x3 and 5x5 Kernel

We will now examine the effect of median and mean filtering on the images using a 3x3 and 5x5 neighborhood around each center pixel. The noticeable effect as kernel size increases is that the image becomes more blurred with increasing size. This can be attributed to including a wider range of pixel values to "consider". In the extreme case, if our kernel was the size of the entire image and we averaged over every pixel with this size, the it should be obvious that the mean/median will be the same in each case which is equivalent to letting every pixel take on that same value. In essence, the larger the window, the less noticeable changes in pixel frequency will be, thus leading to greater smoothing effects.

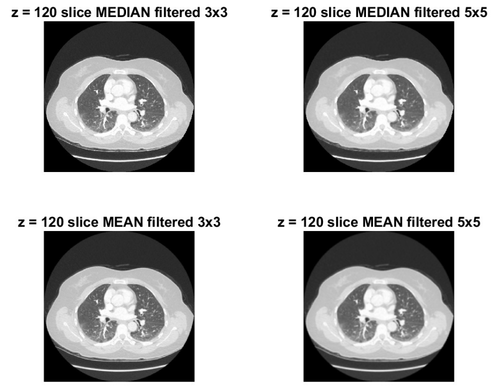


fig 2. Mean and median filtered slices at depth 120mm

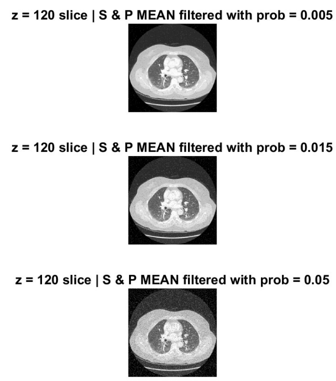


fig 3. Mean filtered slice with added salt and pepper noise

### 3.2 Filtering With Added Salt and Pepper noise

Now we analyze mean and median filtering techniques on images with added salt and pepper noise. The idea here is to increase the frequency of high and low intensity pixel values within each neighborhood. We assign a (low) probability p to replace a pixel in our image with either a light or dark pixel value.

```
%% Functions Created
% Function that takes in an image and determines whether or not to add salt
% & pepper noise to each pixel based on a probability p
function outputImage = saltandpepper(image, p)
    % Function takes input p - as the probability of choosing black or white pixel
    q = 1 - 2*p;        % Probability of leaving pixel alone
    % Determine number of rows and columns of input image:
    [rows, columns] = size(image);

    % Preallocate output image:
    outputImage = zeros(rows, columns);
    for i = 1:rows
        for j = 1:columns
            pixel = randsample([0 255 image(i,j)], 1, true, [p p q]);
            % Replace pixel in image with the randomly chosen one:
            outputImage(i,j) = pixel;
        end
    end
end
```

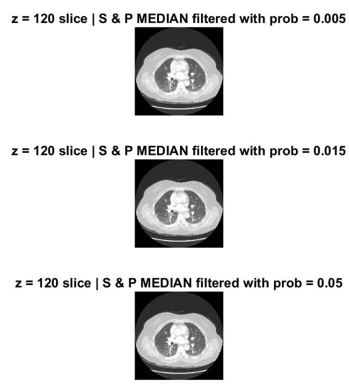


fig 4. Median filtered slice with added salt and pepper noise

# 4 Gaussian Image Processing

To simulate thermal effects of hardware on image measurement schemes, additive white Gaussian noise will be added to a sample image to show the need for Gaussian filtering on these images. There was a noticeable trend in the value chosen for the standard deviation of the Gaussian filter employed: the lower the standard deviation, the sharper the image quality. One interpretation of these results is that the smaller the standard deviation, the narrower the Gaussian curve, meaning that when filtering the image with this tighter Gaussian, the output will low pass the low-intensity pixels while suppressing the spurious high-intensity pixels introduced from AWGN.

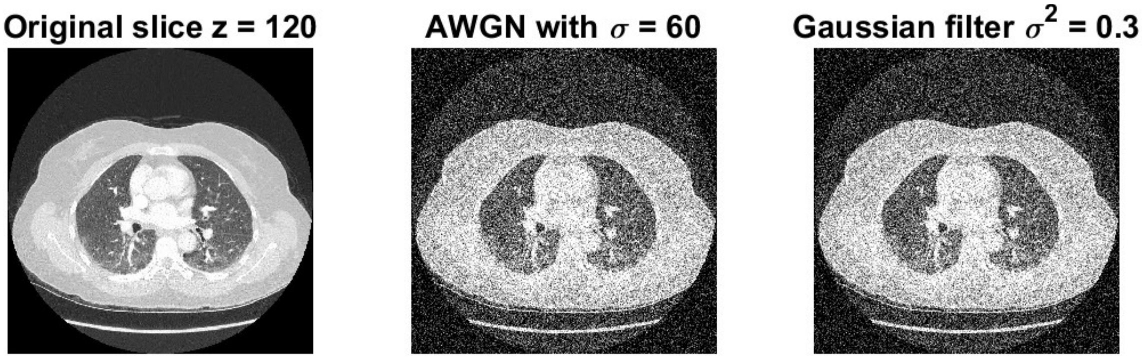


fig 5. Gaussian Filtered slices with present AWGN

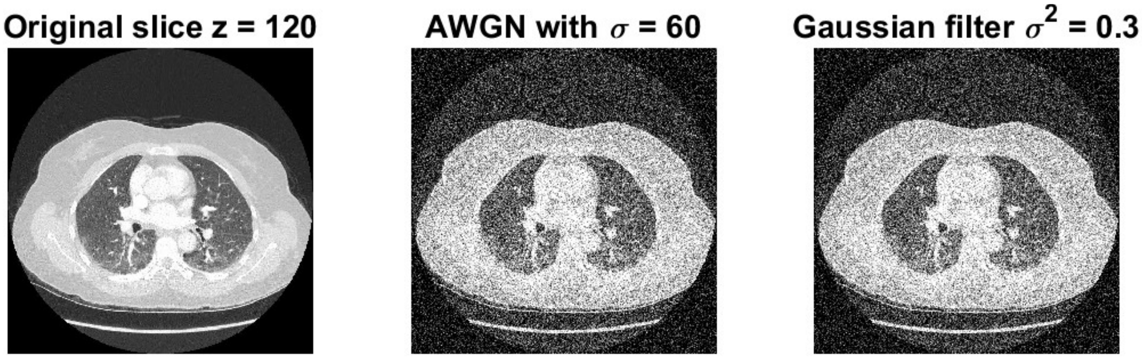


fig 6. Gaussian Filtered slices with present AWGN

## 4.1 Gaussian Blurring

The motivation behind blurring is that when we convolve an image with some point spread function, equivalently the impulse response of our system, blurring can be observed. In the case of Gaussian blurring, we will use an anisotropic 3D Gaussian volume PSF to convolve with our images (in reality we will consider only a 2D effect on an image since we are dealing with 2 dimensional slices).

$$f(x, y, z) = \frac{1}{\sqrt{2\pi}\sigma_x\sigma_y\sigma_z} e^{-\left(\frac{x^2}{2\sigma_x^2} + fracy^2 2\sigma_y^2 + \frac{z^2}{2\sigma_z^2}\right)}$$

This formula can simply be thought of as a Gaussian in a 3D volume such that the distribution "moves" in all directions. Additionally, the term in front of the exponential is a normalization constant to ensure that integration of the PSF is equal to unity across space.

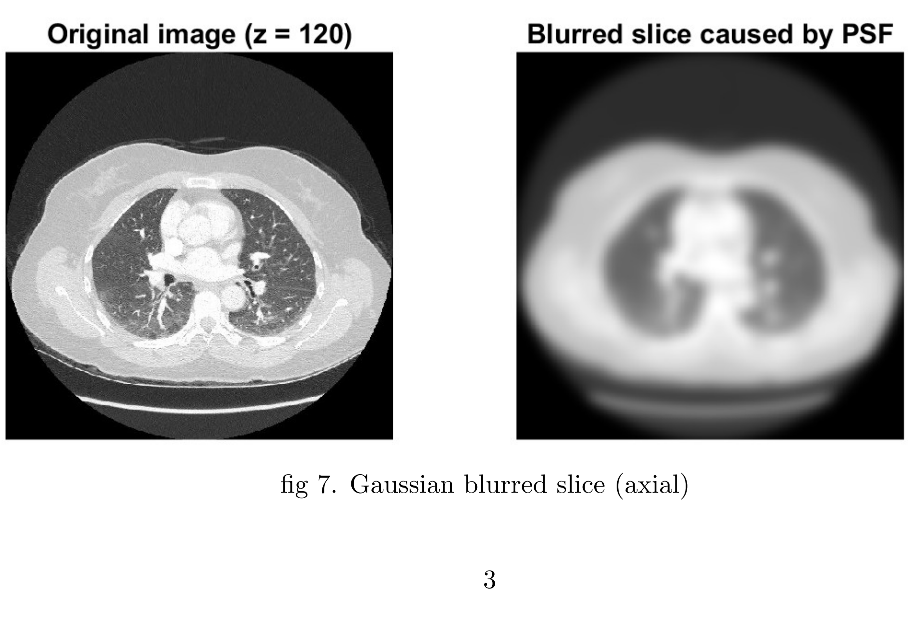


fig 7. Gaussian blurred slice (axial)

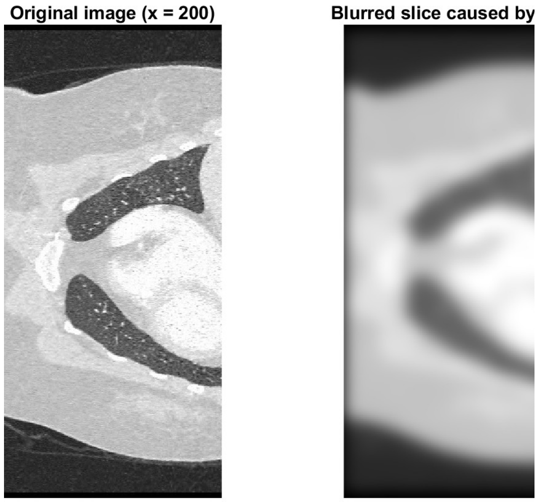


fig 8. Gaussian blurred slice (lateral)

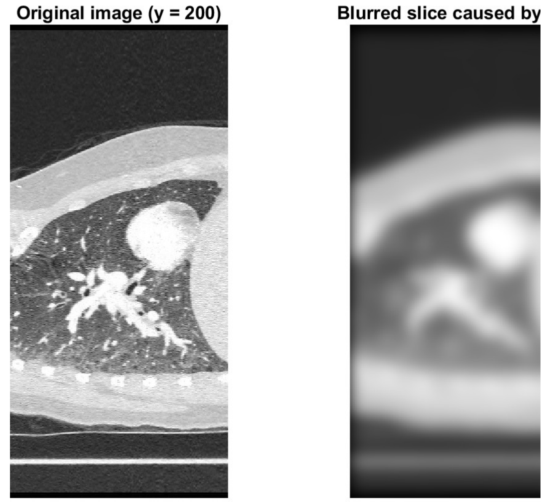


fig 9. Gaussian blurred slice (lateral)

# 5 Canny Edge Detection

The last part of this documentation will highlight Canny edge detection for the different filtered images obtained in previous sections. Results will be shown for: the 3x3 median-filtered image, the 2D Gaussian filter via the 3D volume PSF, the image corrupted with AWGN alone, and for an image filtered by a Gaussian filter with standard deviation $\sigma = 3$ pixels in both directions.

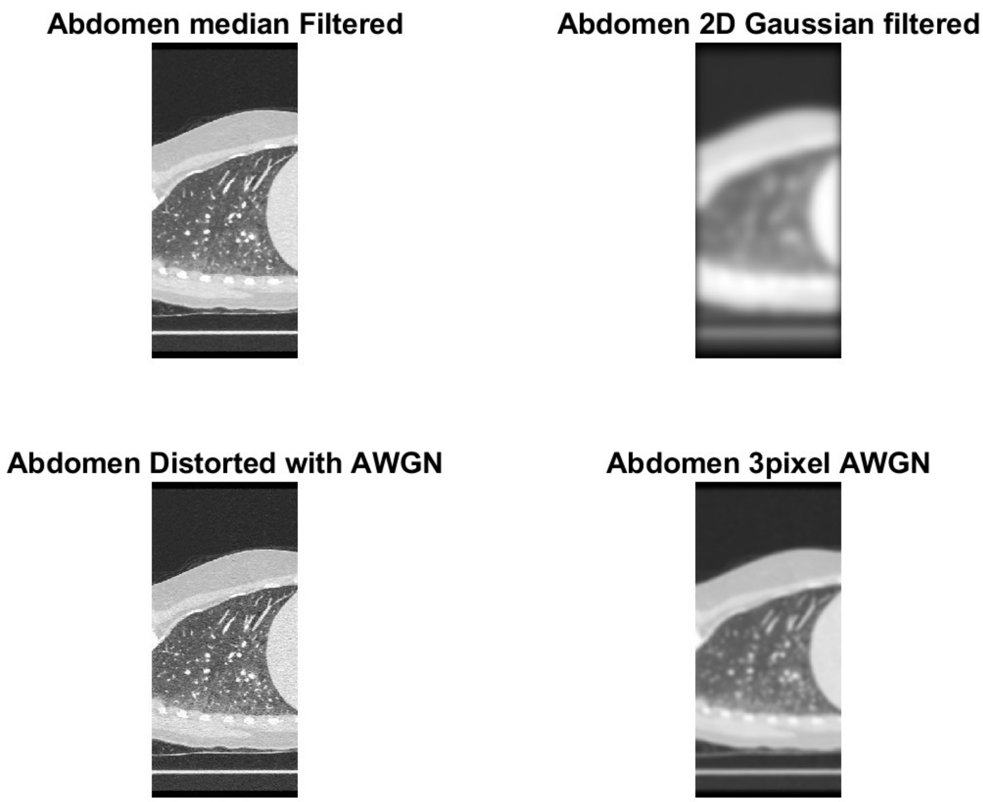


fig 10b. Distorted Abdomen Images Before Edge Detection

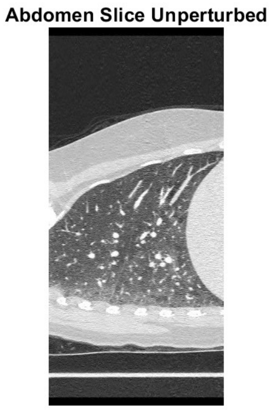


fig 10a. Unharmed Abdomen image (lateral slice)

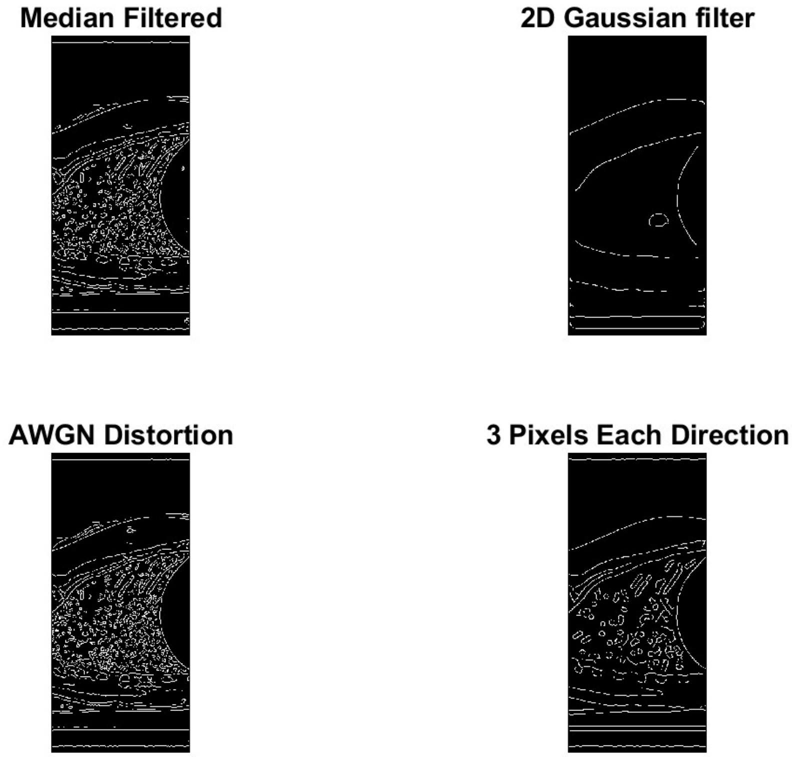


fig 11. Distorted Abdomen Images Before Edge Detection