Data Science: Image Processing Report

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Introduction:

The task at hand was to design a program to fix images generated by a faulty x-ray scanner. The images: contained Salt and Pepper noise, contained Gaussian noise, were warped, and had a hole missing, had issues with brightness and contrast, and had imbalanced colour channels. This will report will cover my solution to this problem.

Solution Design:

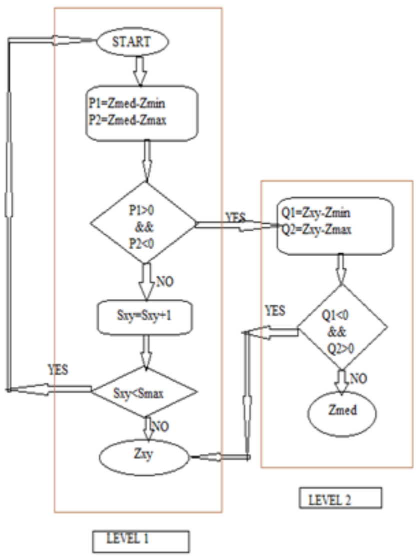
Warping and noise reduction:

The first major issue with the images is that they are warped against a black background. All the images are warped in the same way. This means that we can use the same coordinates to warp every image, I selected these coordinates by identifying the midpoint where the image corners blend into the background. Doing so provided the highest accuracy.

For noise reduction I opted to go with 3 different filters: A conservative blur, adaptive median blur, and non-local means noise reduction.

My conservative blur was based on the implementation described in lectures. I go over an n-by-n neighbourhood of pixels and get the min/max values of the neighbourhood excluding the central pixel. I then bind the brightness of the pixel to the min/max values.

I implemented adaptive median filtering based on this paper[i]. It starts with a minimum search area and applies 2 checks to decide whether to apply a median filter. Level 1 checks whether the current pixel is above/below the min/max values of the neighbourhood and level 2 checks whether the pixel is different from the median. The algorithm works by performing the level 1 check and expanding the search area if it fails.



Flowchart for the Adaptive Median Filter

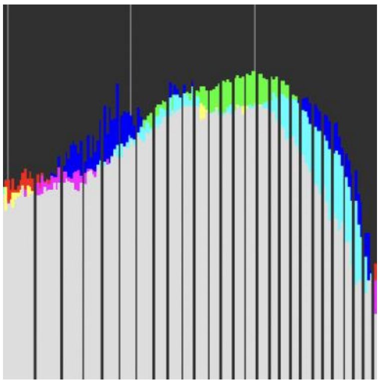
My final image processing step is to apply non-local means filtering to the image to remove gaussian noise, resulting in a relatively noise free image.

Histogram equalisation:

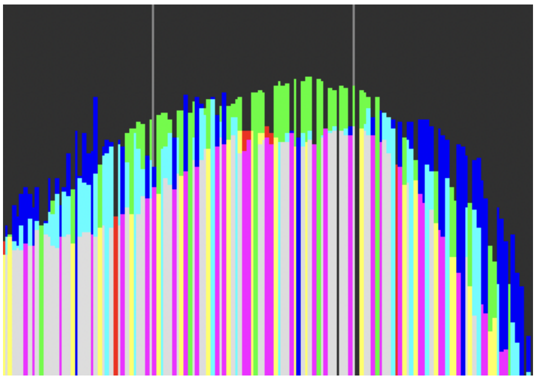
I used a variation of the histogram equalisation shown in lectures called contrast limited equalisation. It operates on an n-by-n grid in the image and ensures no bin of the histogram goes past a clip limit.

Colour balancing:

I changed the brightness and contrast by adjusting gamma. I made these choices based on the histogram of a denoised test image in GIMP and by eye. First, I adjusted the gamma in each colour channel to darken the image, as even after histogram equalization, my images remained overexposed. I darkened the images until fine details in the dark red areas, specifically the lower red part in image 001, became visible. I then adjusted the colour balance by changing the gamma per colour to align the peaks in the histogram.



Before Gamma adjustment



After Gamma adjustment

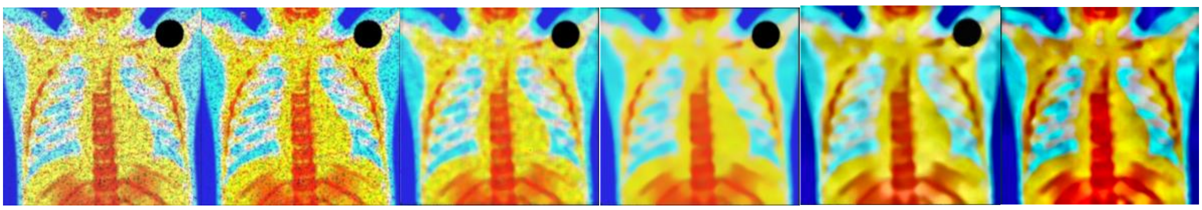
I also applied white balancing based on GIMP's implementation, where each channel is stretched to 255 while keeping the same histogram distribution. Making the image brighter without losing contrast. This also ensures that there is no clipping with my histogram.

Masking/Inpainting:

For my masking/inpainting I applied Navier-Stokes inpainting with thresholding to detect the hole in the image with one key difference. To address issues with pixels not meeting the threshold, I diluted the mask by a couple pixel to ensure full coverage of the hole. Resulting in an almost unnoticeable inpaint.

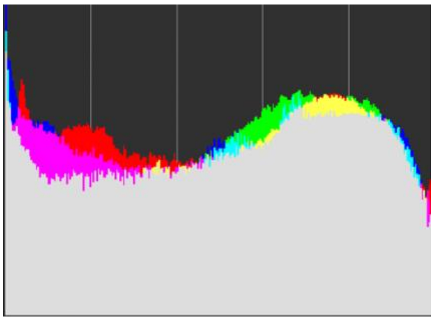
Analysis of performance:

To analyse performance, I made incremental changes to each parameter for denoising, mask threshold and CLA Histogram equalisation clip limit and tile size, balancing image quality with classifier performance until I reached a level of noise reduction and detail retention I was satisfied with while classifier performance remained high.



The step-by-step process can be seen above, it is as follows: Warping, Applying conservative smoothing, adaptive median filtering, non-local means filtering, CLA Histogram equalisation and colour adjustment. This process yields a 94% accuracy, while balancing detail retention. The image looks like the guideline images while maintaining high classification accuracy. This took a lot of trial and error as a lot of things can boost accuracy while producing an image where, visually, it is hard to tell if a patient has pneumonia.

This is the histogram for one of my final images, we can see that the histogram distribution is smooth, showing even distribution of colours with a well-defined and balanced peak across colour channels spread across the whole range from 0-255.



Histogram displaying colour distribution.

The final metric I used for performance evaluation is the peak signal-to-noise ratio, where comparing an unprocessed image to a processed one resulted in a value of 28.1 dB. A value above 25-30dB is a significant improvement. Given that the original images are extremely corrupted; A value of 28.1dB would be considered a good improvement.

[i]

[i] [Image Restoration using Adaptive Median Filtering]