ASSIGNMENT 2

ED6001 – MEDICAL IMAGE ANALYSIS

ED17B022

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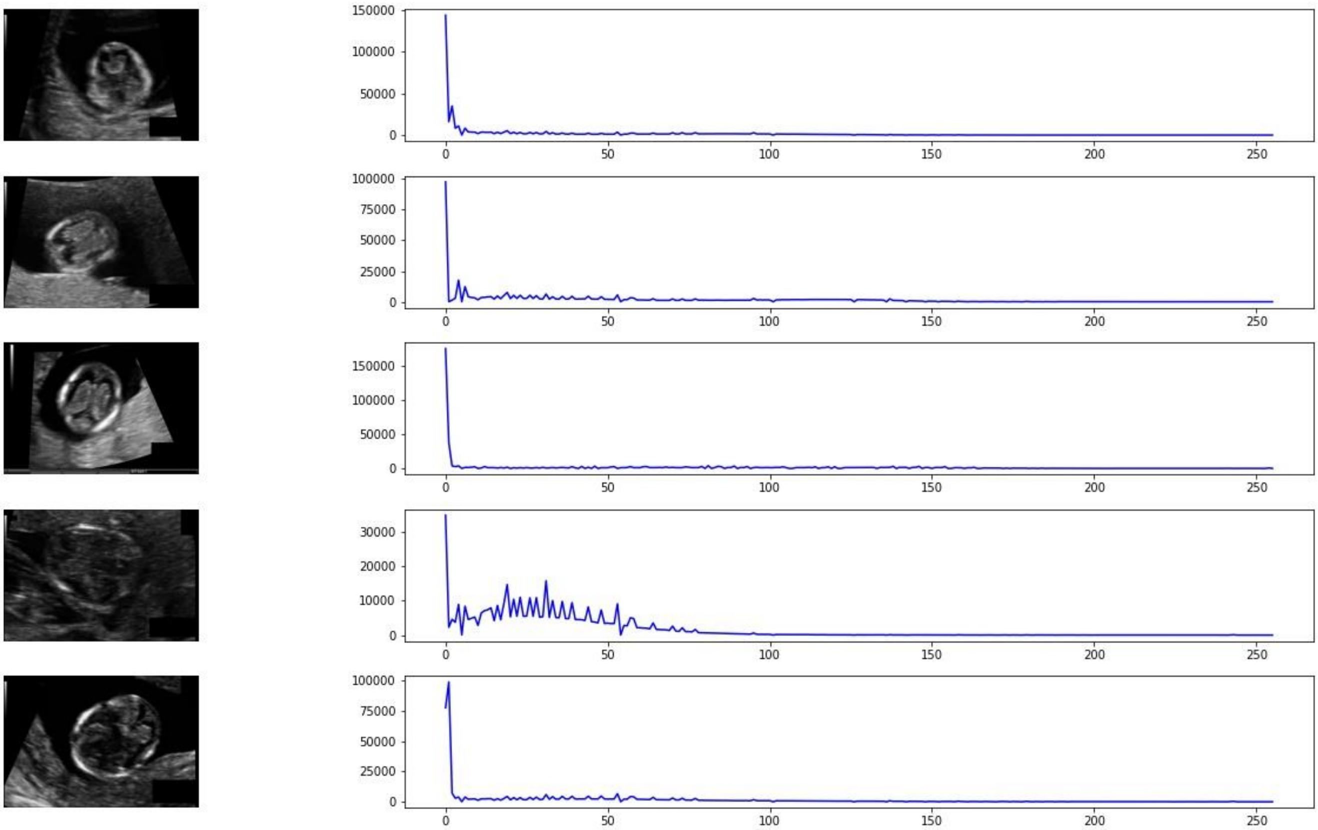
Part 1: Denoising

Prominent noise in the images

Observing the histograms of the images will give an idea on the type of noise in the image.



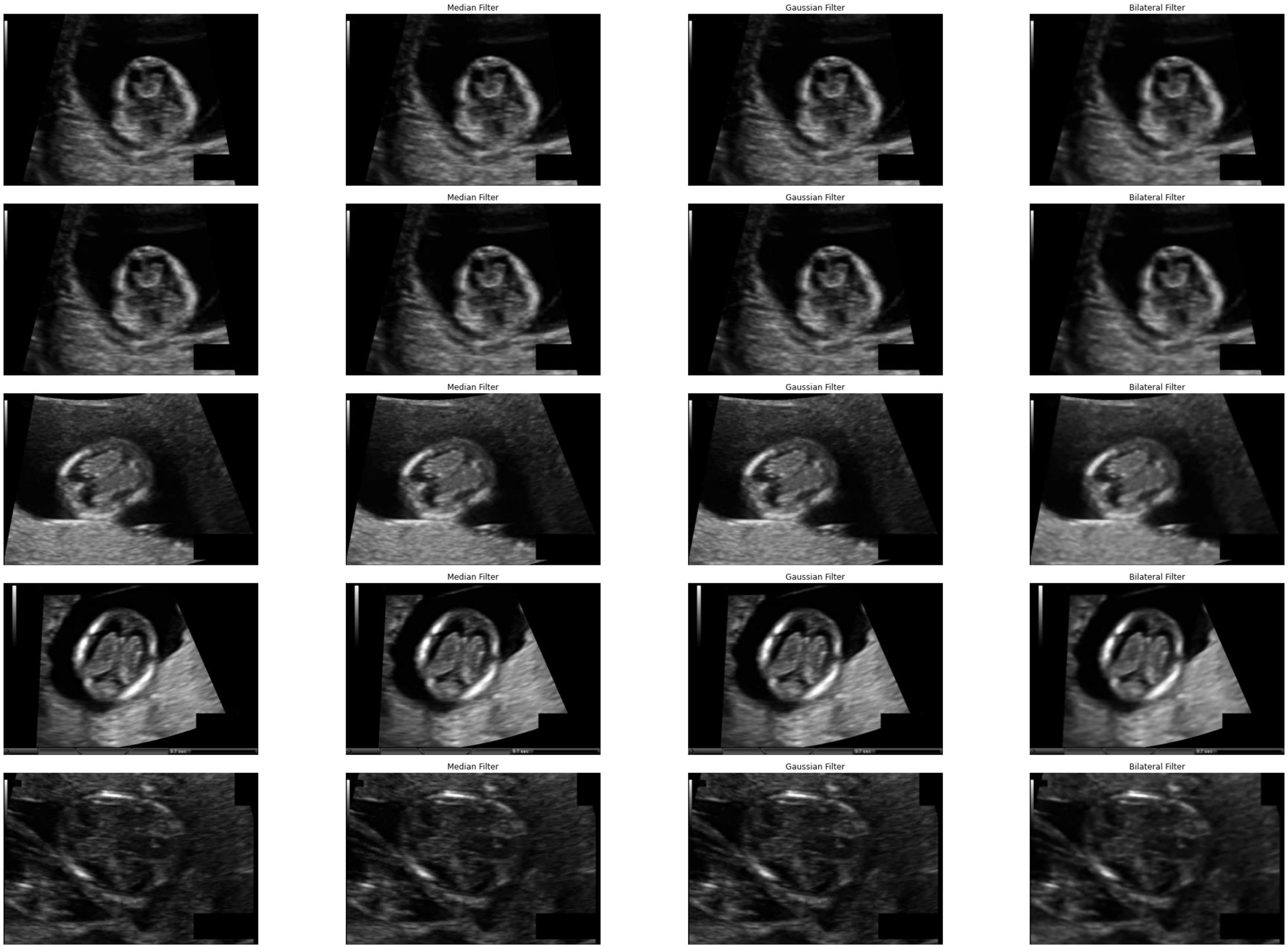
Observations:

- Scan 4 has the most prominent noise compared to others.
- From the profile of the histogram, it can be concluded that it's a combination of gaussian (high) and speckle (low) noise
- The lower intensity pixel are erratic and hence the whites at the edges of the foreground are not clear with respect to the background.
- Scan 3 and 5, especially, have very minimal noise as evident from the images as well. The contrast is pretty good.
- **I added a minimal amount of Gaussian noise to the clean images as well so as to denoise them altogether.**

Filtering out the noise:

- Applied three filters – **Median. Gaussian, Bilateral –** and compared their effects on the histograms and then chose the best that filtered the noise to plot the residuals.

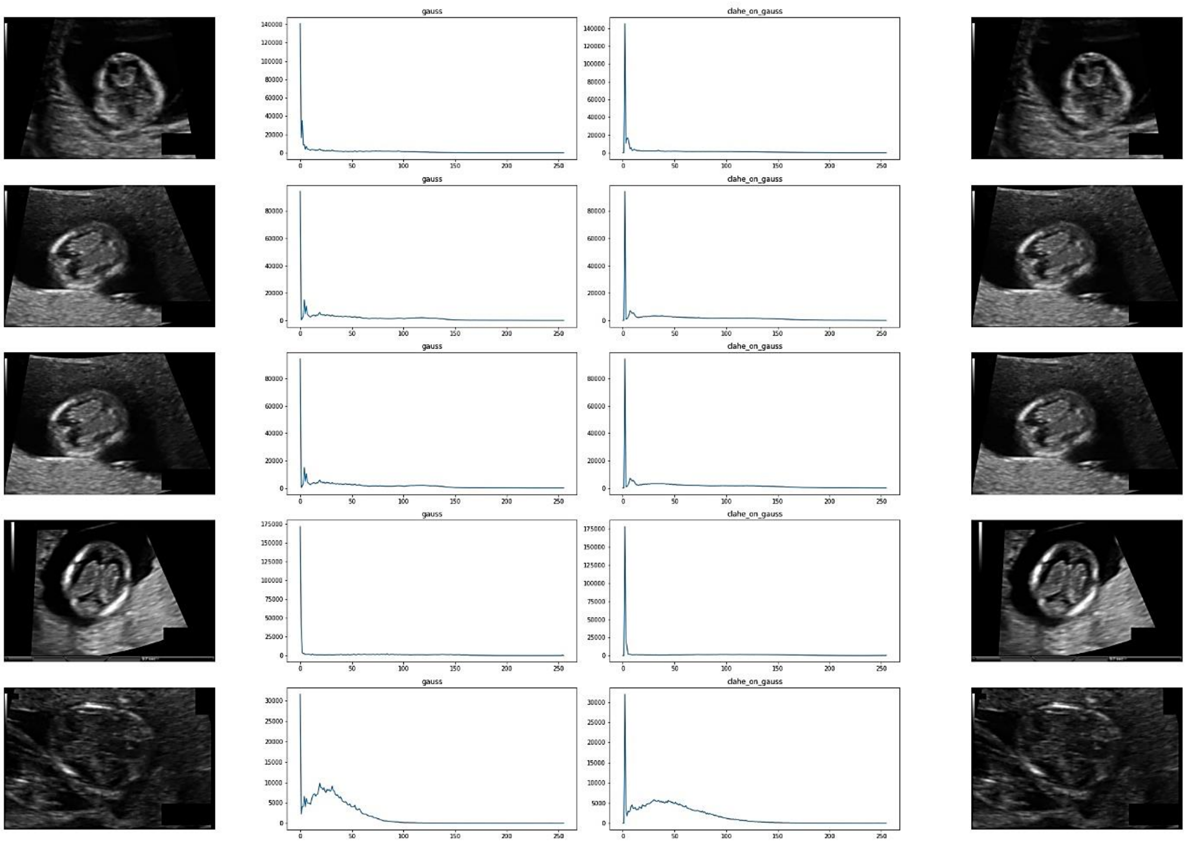

Original
Median Filter
Gaussian Filter
Bilateral Filter
Original
Median Filter
Gaussian Filter
Bilateral Filter
Original
Median Filter
Gaussian Filter
Bilateral Filter
Original
Median Filter
Gaussian Filter
Bilateral Filter
Original
Median Filter
Gaussian Filter
Bilateral Filter


Median Filter
Gaussian Filter
Bilateral Filter
Median Filter
Gaussian Filter
Bilateral Filter
Median Filter
Gaussian Filter
Bilateral Filter
Median Filter
Gaussian Filter
Bilateral Filter
Median Filter
Gaussian Filter
Bilateral Filter

	Median filter	Gaussian filter	**Bilateral filter**
Scan 1	44.024311	52.331790	**59.669491**
Scan 2	44.024311	52.331790	**59.669491**
Scan 3	48.377891	53.985339	**62.937237**
Scan 4	48.620719	56.221666	**62.309024**
Scan 5	51.077094	55.337732	**64.104512**

Observations:

- As expected and evident in the histograms, the median filter did not denoise the images much as it is best used to filter Salt and Pepper noise.
- Although the histograms show a strong competition between Gaussian filtered images and Bilateral filtered images, the PSNR values clearly show that bilateral filtering is the more efficient one.
- This filtering smoothens out the edges and makes it easier to equalise the histogram locally so as to improve the image contrast and subsequently detect edges.
- For the sake of curiosity, I tried applying the CLAHE technique (Assignment 1) on Gaussian filtered scan and **compared it** with the contrast enhanced using White Top-hat Transform on Bilateral filtered ones **for contrast enhancement**.



Part 2. Contrast enhancement / Feature Extraction:

WHITE TOP-HAT TRANSFORM ON BILATER FILTERED SCANS

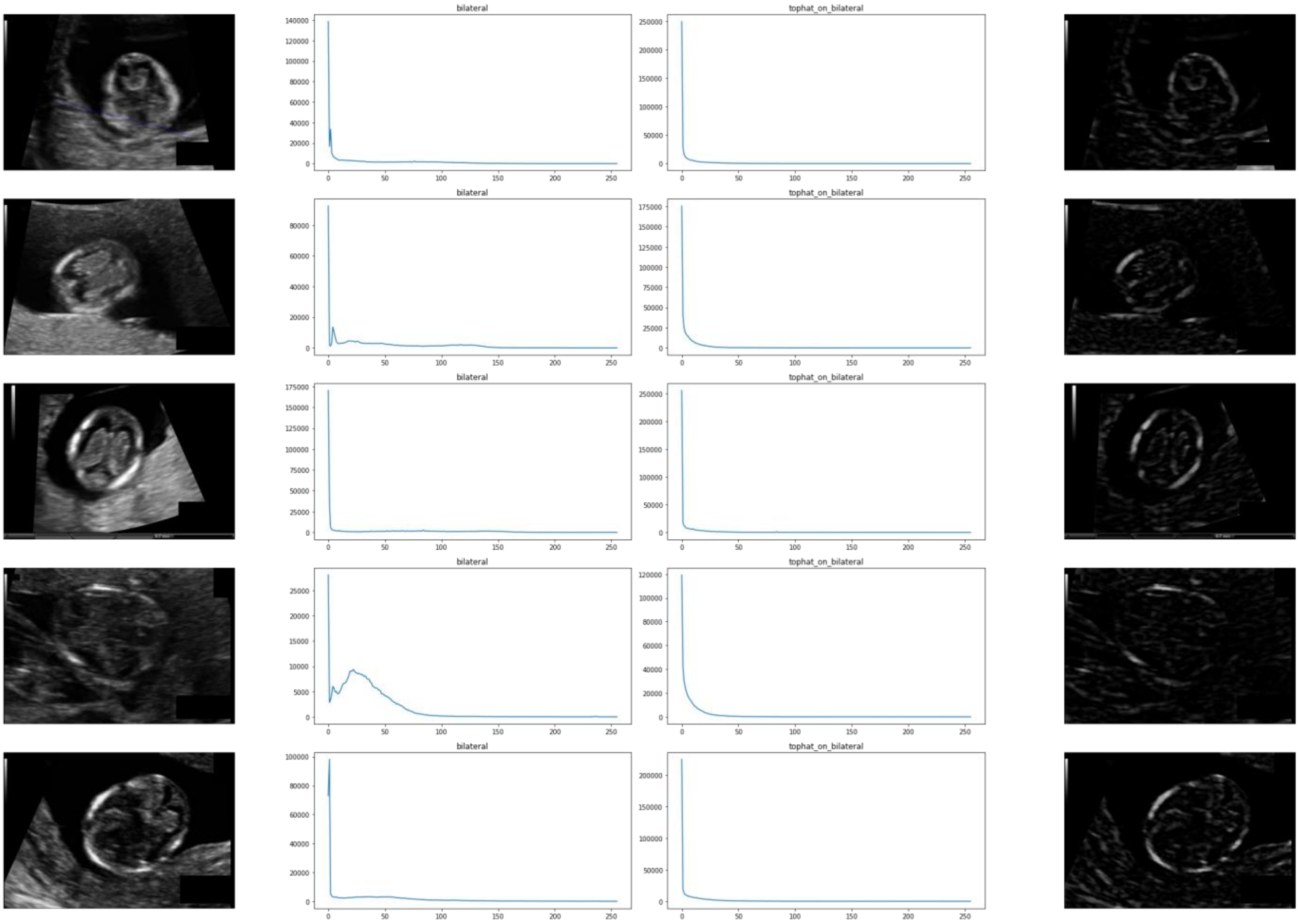


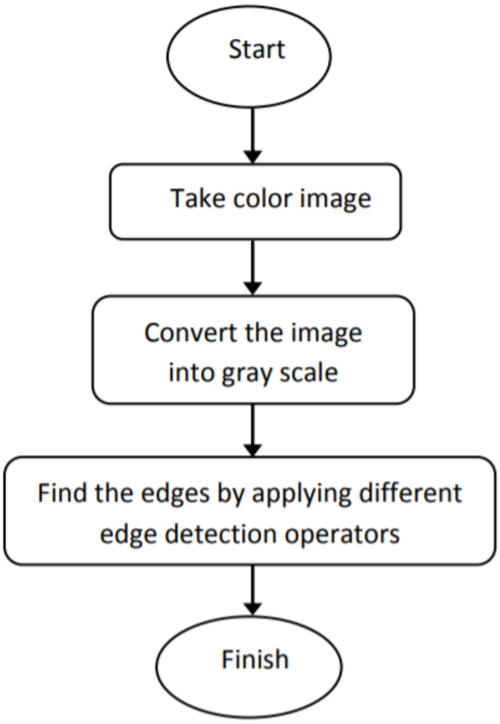
Figure 1

Observations:

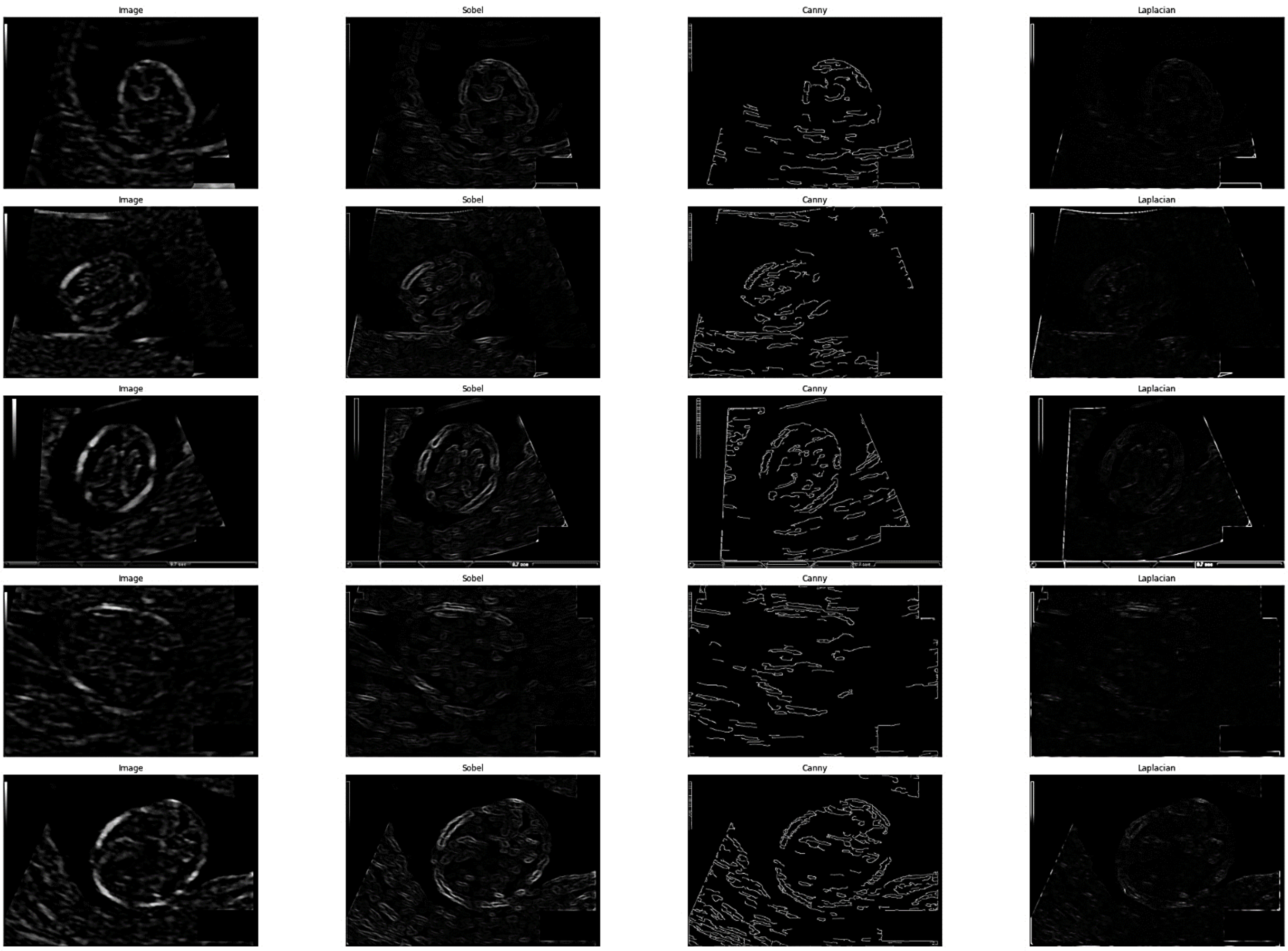
- Although CLAHE seems promising on certain scans (3 and 4), it did not enhance the fetal head on scan 1 and 5.
- On the other hand, the white Top-hat transform has in fact made the fetal head circumference very evident with respect to the background.
- The histograms have also been flattened and equalized appropriately which thereby **reduced the high frequency of low intensities** that were part of the background.
- Hence the feature extraction/contrast enhancement by histogram equalization has been performed very well by the top-hat transform when compared with CLAHE technique.

Edge Detection:

The contrast enhanced scans were then passed through various edge detectors – Sobel and Canny (Gradient methods) & Laplacian operators (Zero Crossing Method).



Col 1 – Enhanced image | Col 2 – Sobel | Col 3 - Canny | Col 4 - Laplacian



SCAN 1

METRICS	PSNR	MSE –Mean Sq. Error	Entropy
Sobel	34.945832	201.837083	3.223775
Canny	33.806979	1093.742516	0.117662
Laplacian	34.189748	380.708542	2.049680

SCAN 2

METRICS	PSNR	MSE –Mean Sq. Error	Entropy
Sobel	34.087365	223.232699	3.943252
Canny	32.683128	1486.021757	0.156916
Laplacian	33.275765	490.174600	2.498261

SCAN 3

METRICS	PSNR	MSE –Mean Sq. Error	Entropy
Sobel	34.052933	382.414801	3.394499
Canny	33.233112	1898.845049	0.189539
Laplacian	33.508104	789.818116	2.279392

SCAN 4

METRICS	PSNR	MSE –Mean Sq. Error	Entropy
Sobel	33.306902	177.978030	4.330429
Canny	31.699208	1595.489127	0.165555
Laplacian	32.370970	447.373829	2.701470

SCAN 5

METRICS	PSNR	MSE –Mean Sq. Error	Entropy
Sobel	33.218998	316.261146	3.864812
Canny	32.311400	2372.225924	0.227405
Laplacian	32.692258	531.156426	2.527612

Observations:

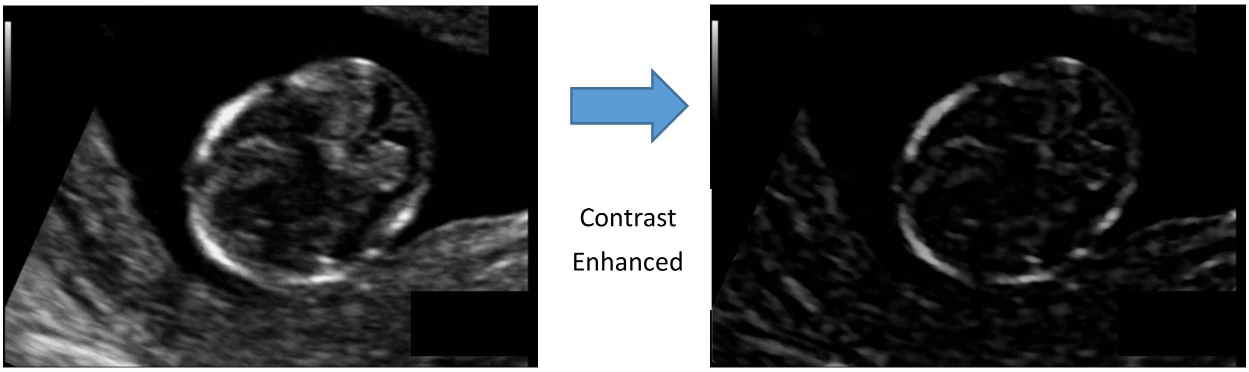
- It has been observed that the Canny edge detector produces higher accuracy in detection of object edges with higher entropy, PSNR and MSE compared with Sobel and Laplacian operators (zero crossing).

- Sobel and Canny detectors seem to capture the ROI (fetal head) pretty well.
- Laplacian detected the scan background better than ROI and hence is a bad fit.

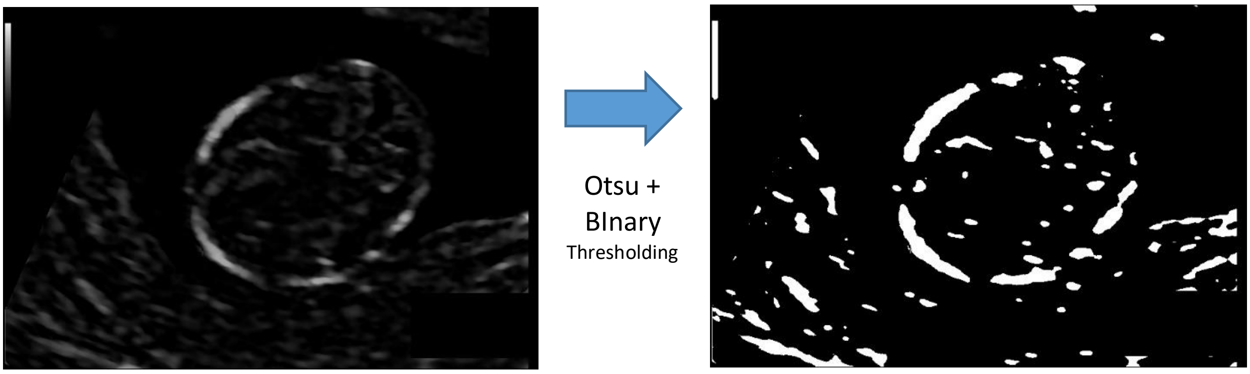
Part 3: Application of Hough Transform

Let's walkthrough the ROI detection using Hough Transforms for a single scan first.

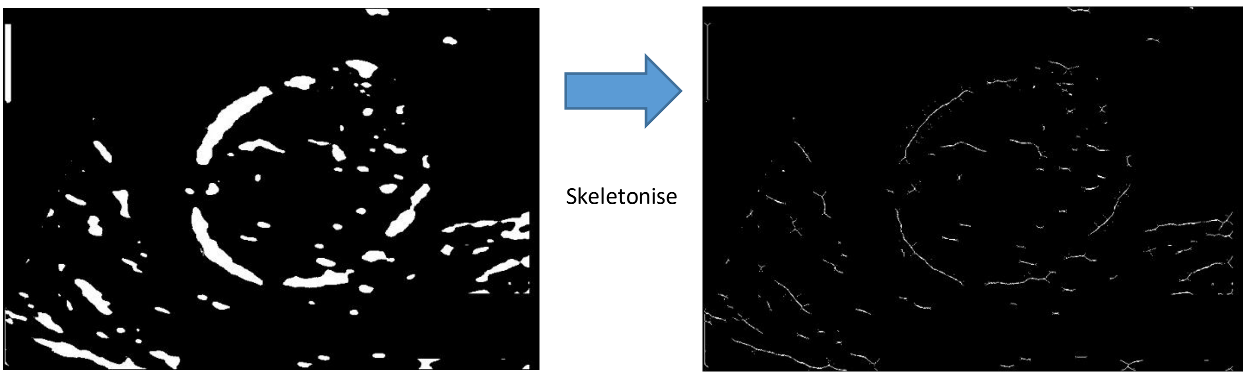
Step 1:



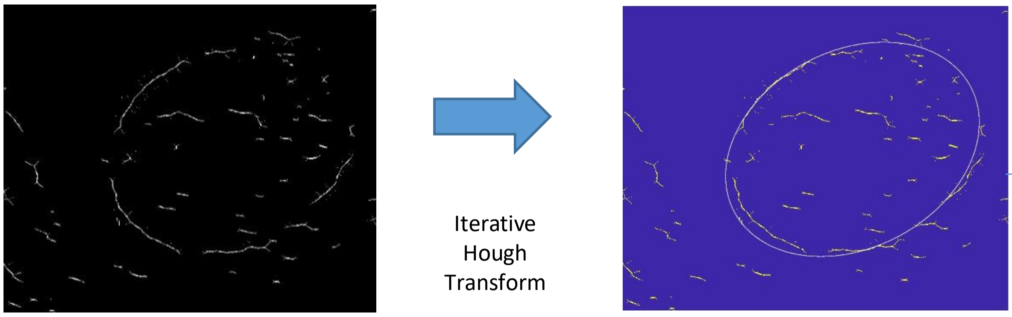
Step 2:



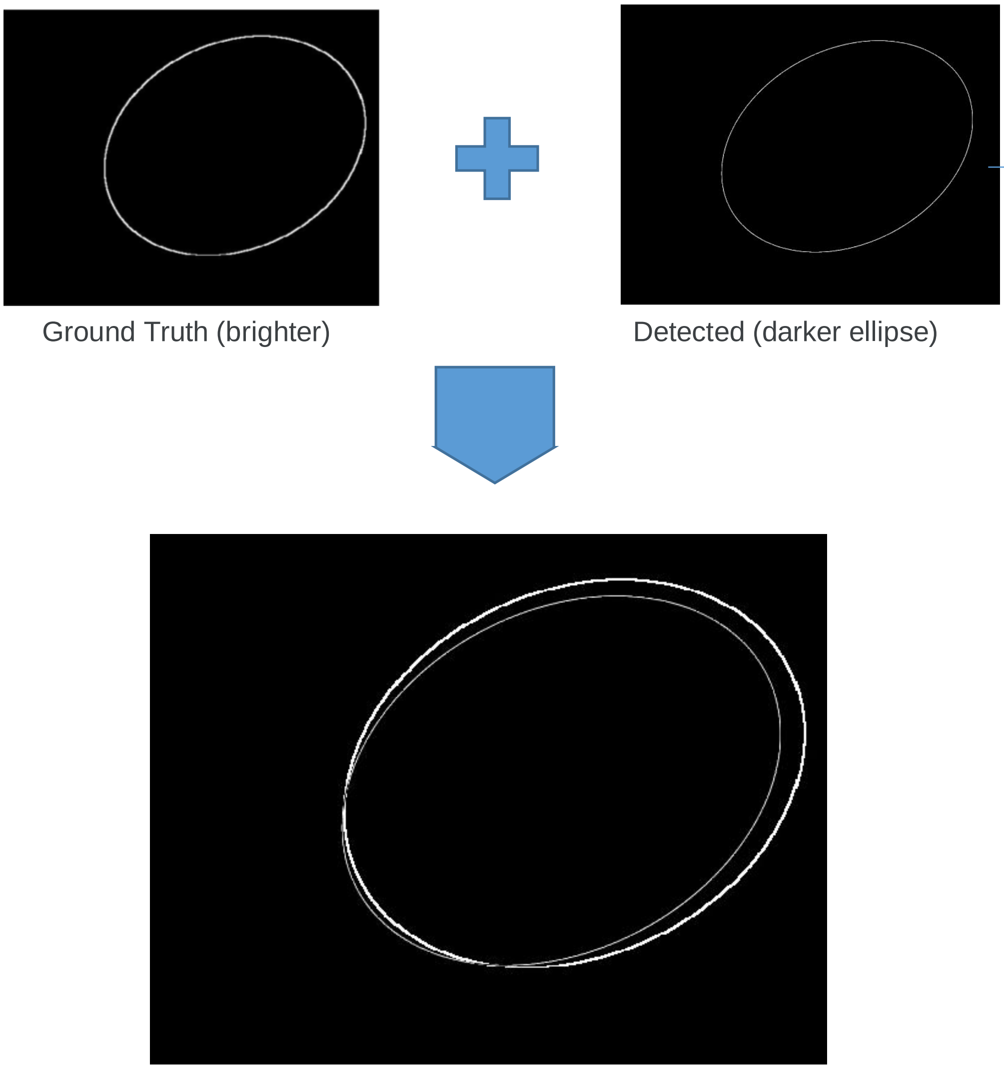
Step 3:



Step 4: (since the ROI is fairly centered in most images and to remove the scan boundary, let trim the edges)



Step 5: (Plotting only the ellipse on the blank image of the same size as the scan and comparing with ground truth)



The same algorithm was used for all the scans and have been shown below.

(Brighter ellipse – Ground Truth | Darker Ellipse – Detected)

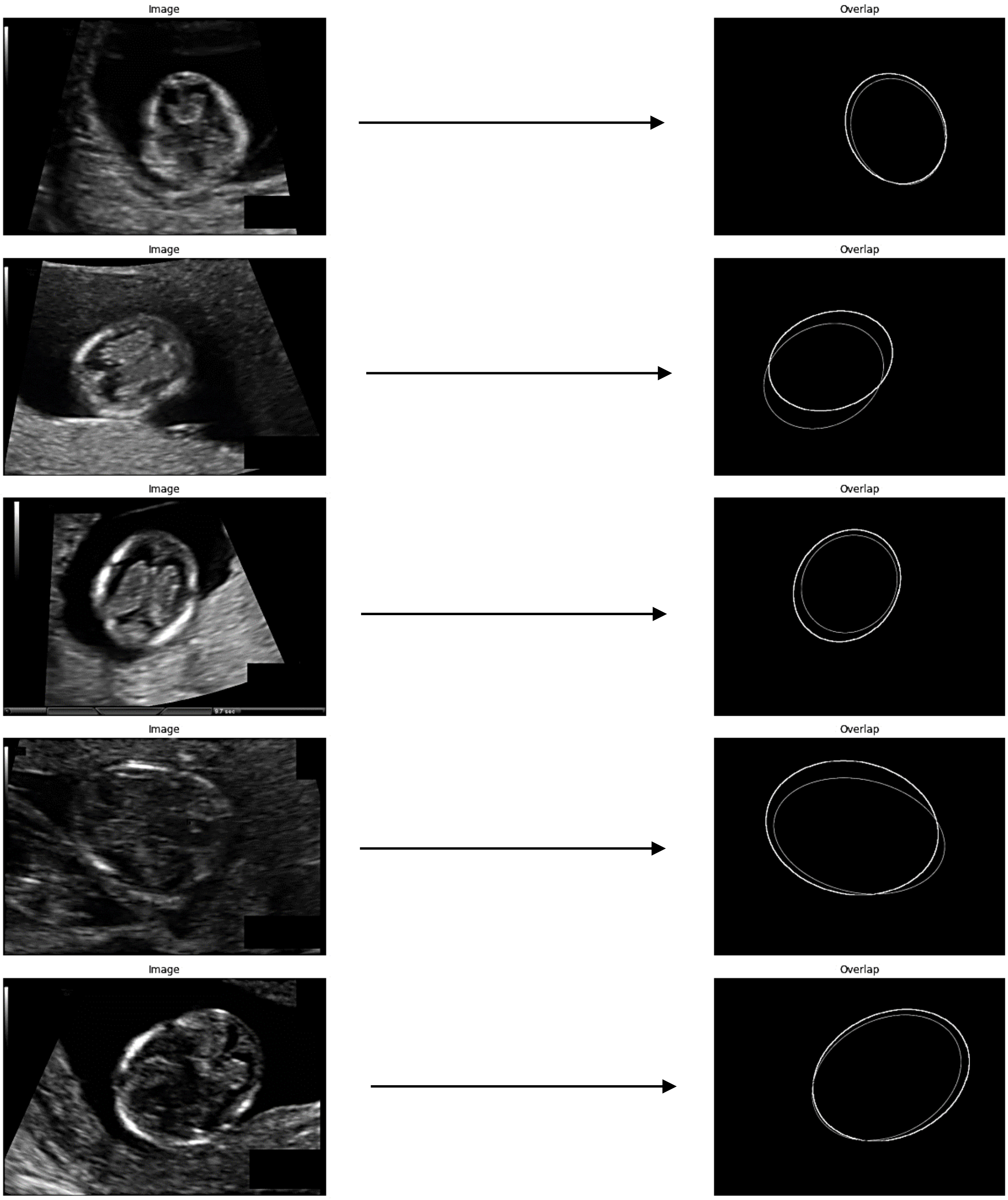


Figure 2

METRICS	Hausdorff Distance	Relative absolute surface difference	Average surface distance	Dice coefficient
Scan 1	12.041594578792	0.3036342321	2.870972301822	0.9735083758
Scan 2	38.842624427843	0.2255517963	18.40139962055	0.9631561261
Scan 3	22.022715545545	0.3146724598	7.829823910553	0.9651529817
Scan 4	43.460325577600	0.1227540606	17.05258916212	0.9525357719
Scan 5	16.124515496597	0.1215791834	6.490292695160	0.9691647862

Observations:

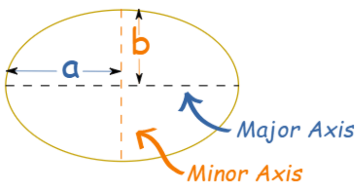
- The metrics show the comparison between the ground truth and detected fetal head circumference.
- From a basic outlook of the overlapped images, Scans 1 and 5 show the most promise.
- Hausdorff Distance – As expected, the Hausdorff Distance is least for Scan 1 and 5 and relatively large for Scan 4 showing the farthest away from ground truth.
- Relative absolute surface difference - This implementation does not check, whether the two supplied arrays are of the same size and hence, Scan 1 shows a higher difference relative to Scan 5.
- Average surface distance – ASD values are very low for Scan 1 and 5, as well as Scan 3 since the detected ellipse is almost enclosed by the ground Truth.
- Dice coefficient – As the values get closer to 1, the overlap gets better. Most of our values are close to 1, with highest for Scans 1 and 5.

Below is the comparison of circumferences of the fetal head scans from the Hough transforms algorithm using absolute difference metric.

Major axis (*2*a*) and minor axis (*2*b*) lengths measured from the plots detected:

	*2*a (in pixels)*	*2*b (in pixels)*
Scan 1	283.5363	222.4385
Scan 2	301.6369	258.0478
Scan 3	254.1441	224.1480
Scan 4	385.7825	370.1430
Scan 5	379.9067	303.9660

Perimeter/Circumference of Ellipse



$$p \approx 2\pi \sqrt{\frac{a^2 + b^2}{2}}$$

	Circumference in pixels (calculated)	Pixel to mm conversion values	Circumference in mm	Ground truth in mm	Absolute error (%)
Scan 1	797.68322689	0.087755845	70.001365	72.09	2.90%
Scan 2	880.48430593	0.085636069	75.401214	73.96	1.95%
Scan 3	752.03840341	0.092240975	69.368755	78.5	11.63%
Scan 4	1187.53206733	0.060673679	72.051939	71.9	0.21%
Scan 5	1077.5388503	0.065501081	70.579959	72.8	3.05%

Observations:

- Detected values are fairly accurate with respect to the ground truth.
- Scan 3 has the highest error in measurement. As can be observed in Fig.2, the detected ellipse is overlapped by the ground truth ellipse and hence the error.
- Scan 4 has the least error in measurement, but it has a large offset as observed in Fig.2.

References:

- Xu, Rong & Ohya, Jun & Zhang, Bo & Sato, Yoshinobu & Fujie, Masakatsu. (2011). Automatic Fetal Head Detection on Ultrasound Images by An Improved Iterative Randomized Hough Transform.
- https://loli.github.io/medpy/_modules/medpy/metric/binary.html
- https://in.mathworks.com/matlabcentral/fileexchange/33970-ellipse-detection-using-1d-hough-transform
- https://www.mathworks.com/matlabcentral/fileexchange/289-ellipse-m

README

- All codes are written in Jupyter Notebook (.ipynb).
- All folders and code necessary to run in Google Collab are here
- https://drive.google.com/drive/folders/1yBFNXS7AC-1TR2jAa-SQpsfEq0_jAfYS?usp=sharing
- The MATLAB folder is only to run the Iterative Hough Transform and fit the ellipse as it is very slow in python.
  - Run **<scan{1-5}.m>** files in MATLAB to fit the ellipse on the scans.
  - Ensure **<ellipseDetection.m>** and **<ellipse.m>** are also in the same directory.
- Make sure all the files and folders in 'Open Me' folder are in the collab directory as well.
- If any issues, I'm always ready to run the code in my laptop anytime.