Objective

In this report, we are analyzing the different algorithms for contrast enhancement of the image. The algorithm includes Brightness Bi-Histogram Equalization (BBHE), Dualistic Sub Image Histogram Equalization (DSIHE), and Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE). Additionally, we including the Histogram Equalization (HE) algorithm. Despite its simplicity, it is one of the core algorithms in the field of image contrast enhancement. We are measuring the performance of each algorithm using different greyscale images to identify which algorithm is best. We are using quantitative measures such as Absolute Mean Brightness Error (AMBE) and the Measure of Enhancement (EME) to compare the result of each algorithm.

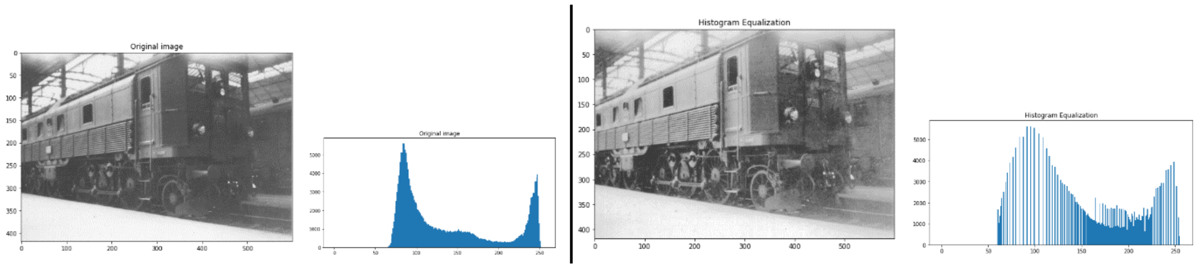
Intoduction

Image Contrast Enhancement process consists of several different techniques. The goal of this process is to improve the quality of the image so it can be possible to analyze by a machine or human. The main objective of the image enhancement process is to improve the specific part of the image or remove the ambiguity of different parts of the image. The image enhancement algorithm is designed in such a manner, so the processed image is more useful in specific applications than the original one. Image Enhancement is useful in many areas such as center-light image analysis, medical image analysis, industrial X-ray image processing and many more.[1]

Brief discussion of each algorithm

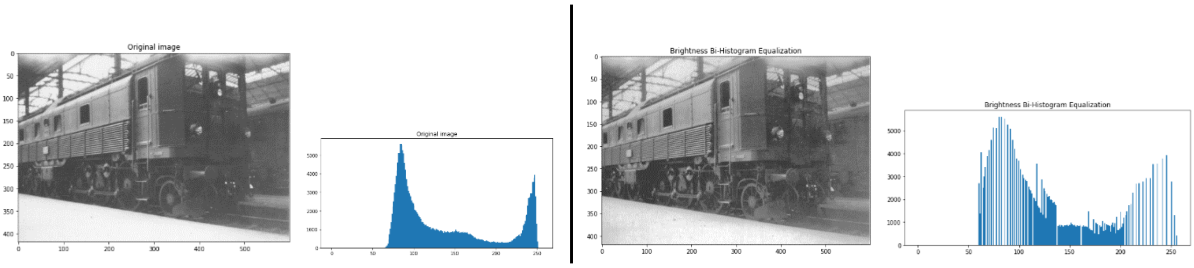
For given all algorith we are choosing image named "algo_img.jpg" which is inside the "algo_img" named folder.

1. **Histogram Equalization (HE)**
   It is a popular and widely used algorithm in the field of contrast enhancement. People like to use this algorithm because of its simplicity and effectiveness. The algorithm first flattened the histogram of the image. Then it stretches the dynamic range of the grey level by using the "cumulative density function" of the image. One major issue with this algorithm is brightness. Once you apply the algorithm to the image, the brightness will change. Because of that, it is not useful for consumer electronic products.[2]



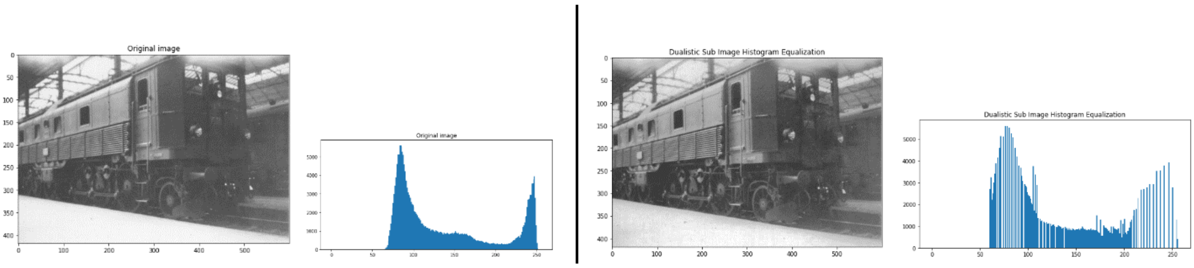
As you can see from the images the output image contrast has been enhanced and its histogram has also been equalized. In other words, the new histogram is stretched over greyscale levels. There is also one thing to note that the overall brightness of the image has been changed.

2. **Brightness Bi-Histogram Equalization (BBHE)**
To over come the problem of HE, BBHE was introduced in 1997. As name suggests its main moto is to preserve the brightness of the image. To do this, first it decompose the original image into the two sub images. It is done by using using the mean of grey-level image. Then apply HE to each sub-images. Generated image is with the value of brightness(mean grey-level) which located in the middel of the mean of the original image. This method is also concider as hybrid method between histogram equalization method and mean brightness preserving histogram equalization methods.[2]



It is clear from the output that this algorithm performs better than the traditional Histogram Equalization (HE) algorithm. This algorithm enhancing the image contrast but at the same time, it also tries to preserve the original brightness of the image.

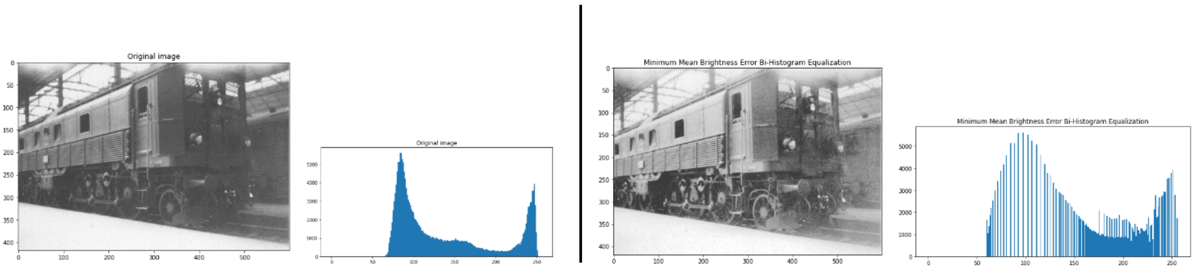
3. **Dualistic Sub Image Histogram Equalization (DSIHE)**
This algoritha is same as the BBHE except one thing. DSIHE choose to seperate the histogram based on gray level inseted of mean as in BBHE. it choose graey level with cumulative probability density which is equal to 0.5. In other word the main aim of DSIHE alorithm is to decompose the image by maximization of the Shannon's entropy of the output image. The overall concept is the original image's grey level probability distribution is decomposed. At the end DSIHE algorithm coposed both images into one image.[2]



As we discussed in the description of DSIHE, the result is almost identical to the BBHE. The noticeable difference can be seen if we put the output images of DSIHE and BBHE side by side. The difference is in the brightness level. The image produce by the BBHE algorithm is a little bit brighter than the one which is produced by the DSIHE algorithm.

4. **Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE)**

   The MMBEBHE is working on the principle, which is the same as the BBHE and DSIHE. The main difference between BBHE and DSIHE and the MMBEBHE is the threshold that decomposes the original image into sub-images. The threshold level selection process is happening in such a way so, the absolute mean brightness error would be minimum. And that's how MMBEBHE preserves the maximum brightness of the original image. Once the original image decomposed in sub-images, the classic HE algorithm applies to both sub-images. Finding threshold by using assumptions and manipulations some time complexity allows the algorithm to obtain the brightness of the output image without producing the output image for each candidate threshold level.[3]



   It is clear from the above image that MMBEBHE is handling brightness very well. It seems like that this algorithm is performing the same as classic HE but you can see the details of the image which did not available in the classic HE algorithm's output image.

Experiments

For Experiment we are choosing image named "exp_img_1.png" and "exp_img_2.jpg" which is inside the "exp_img" named folder.

For the experiment purpose, we are taking two key variables of the output image.

1. **Overall Image Visibility:** It is a very demanding requirement from any Image Enhancement Algorithm. Mostly the images which required enhancement are not completely visible so it is too hard to identify the objects from that image.

2. **Image Details:** The priority goal of any image enhancement algorithms is to produce an image that can be useful for a specific application, and it requires good details enhancement in the image.

For the above experiments, we are taking 2 different images and apply each algorithm to both images in order to analyze the result.

Experiment with Image-1

a. Original Image

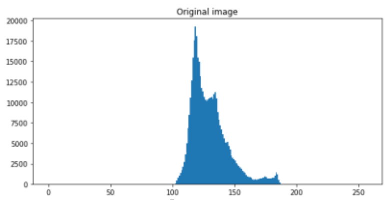
b. HE

c. BBHE

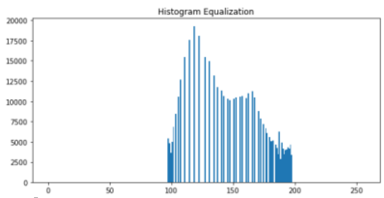
d. DSIHE

e. MMBEBHE

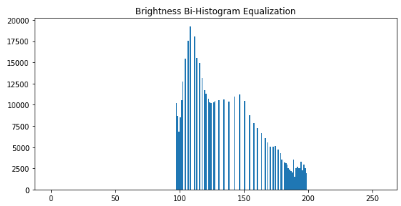
So, here we have the original image and the other four images which is the output of every algorithm. It is very difficult to identify objects like trees in the original image. The image produced by the HE algorithm is a clear image but a little bit overexposed. The image generated by BBHE and DSIHE algorithms is almost identical with little difference in brightness. Whereas the image which is generated by MMBEBHE is significantly different than any other images. For the last image (e. *MMBEBHE*) it is clear that the histogram of this image is more stretched than any other and that is why the dark area looks darker and the light area looks like more light. The overall image visibility and details have also been improved by applying different enhancement algorithms. For example, it is difficult to count the row of trees which is on the right side of the original image. However, that tree row is very clear in every other image.



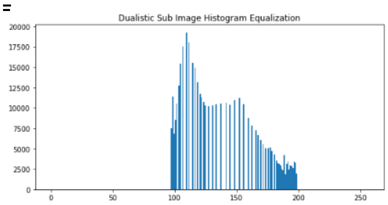
a. Original image Histogram



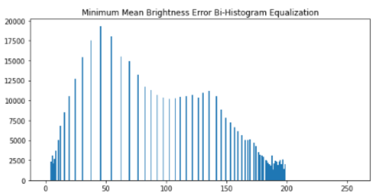
b. HE Histogram



c. BBHE Histogram



g. DSIHE Histogram



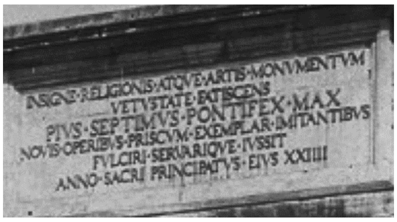
e. MMBEBHE Histogram

So here we have a histogram of all those images. It is clear that every histogram has been stretched on a greyscale level. Although the range is different. For Example, the histogram of MMBEHE is wider than the HE, BBHE, and DSIHE. It is also noticeable that the histogram of HE is slightly different than BBHE and DSIHE. It's because in BBHE and DSIHE we try to preserve the original brightness of the image and that is why its overall shape close to original histogram shape.

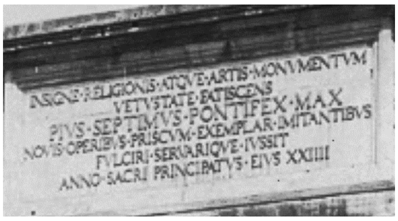
Experiment with Image-2

In this experiment, we are using a slightly different approach. First, we apply the algorithm to the "archTitus1880_ALB.jpg" image from the test dataset. You can find all images which are produced by the algorithm in the "*exp_img*" folder. Here we only focus on one part of the image in order to get a better understanding that how exactly every algorithm performs on Image Detailings.

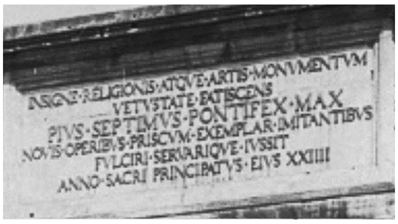
a. Original Image



b. HE



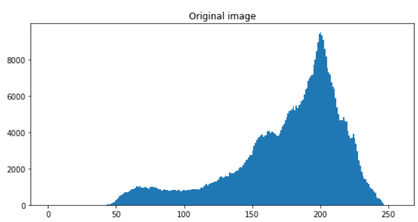
c. BBHE



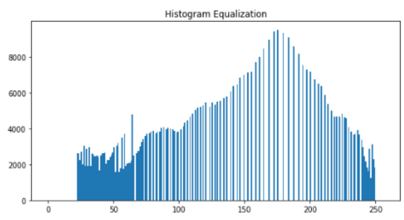
d. DSIHE

e. MMBEBHE

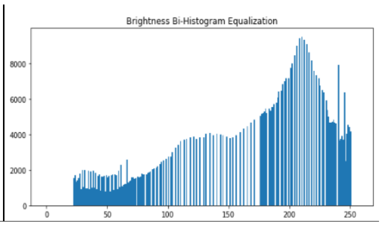
So based on the above images we can see that some algorithm performs well whereas some perform partially good. The "Image a" is an original image and it is very difficult to read the text in that image. We can observe almost the same output in "Image e" because MMBHE is trying to preserve as much as brightness of the original image and that affects the detailings of the image. Whereas the other three HE, BBHE, DSIHE did well on detaining enhancement. DSIHE outperforms every other algorithm in order to preserve details of the image.



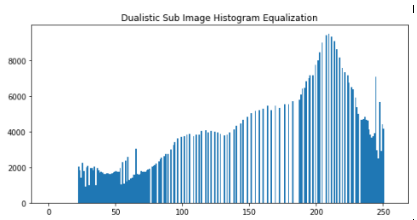
a. Original image Histogram



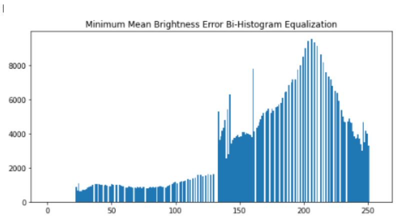
c. HE Histogram



b. BBHE Histogram



e. DSIHE Histogram



d. MMBEBHE Histogram

Quantitative analysis

1. Absolute Mean Brightness Error (AMBE):

The main objective of AMBE is to show the performance of the algorithm in preserving the original brightness. In other words, it is the absolute mean of input and output image.[4]

The lower value of AMBE indicates that the brightness is preserved better. In short, brightness is close to the original image's brightness.

Below we have a table that shows the AMBE performance of different algorithms on Image-1 and image-2.

	HE	**BBHE**	**DSIHE**	**MMBEBHE**
Image-1	16.32	3.80	6.06	30.73
Image-2	40.75	8.63	15.41	1.18

Image-1 and *Image-2* are the images that we used in "*Experiment with Image-1" and* "*Experiment with Image-2" respectively*.

Here we can observe that BBHE performs best on Image-1 for preserving the brightness. In image-2 MMBEBHE has the lowest value of AMBE so MMBEBHE performs best on image-2 for preserving the original brightness. But in terms of detailing DSIHE performs best on image-2. Here one odd thing to notice that there is a large difference between the MMBEBHE value of image-1 and image-2. The reason is the input images. Input *image-1* is a greyscale image whereas the input *image-2* is a kind of yellowish image and that results in a huge gap of AMBE value for algorithm MMBEBHE.

2. Measure of Enhancement (EME)

EME estimate the overall contrast of image by divideing the image in to the blocks. Final resut defines by maximum and minimum pixel intenensity values of each block and averaging those values. Larger value shows the better enhancement of image.[5]

Below we have a table that shows the EME performance of different algorithms on Image-1 and image-2.

	HE	**BBHE**	**DSIHE**	**MMBEBHE**
Image-1	1.11	1.06	1.07	5.27
Image-2	4.48	4.11	4.33	3.20

Image-1 and *Image-2* are the images that we used in "*Experiment with Image-1" and* "*Experiment with Image-2" respectively*.

Here we can observe that MMBEBHE performs outstandingly on image-1. Other algorithm's performance is almost the same with little difference. In image-2 the result shows a completely different flow of values and it's because of the yellowish input-image. From the numbers, HE performs best on image-2.

Analzing the Time Complexity of Different Images

For Time Complexity we are choosing images "test_img_1.jpg" to "test_img_8.jpg" which is inside the "test_img" named folder.

Here we are checking the time complexity of different algorithms using 5 different images. The results are in below table. All values are in seconds.

	HE	**BBHE**	**DSIHE**	**MMBEBHE**
test_img_1	1.93	3.62	3.53	3.66
test_img_2	9.61	17.27	18.22	16.87
test_img_3	10.16	18.59	24.79	19.09
test_img_4	1.56	2.72	2.73	2.70
test_img_5	3.83	6.51	6.39	6.98
test_img_6	1.63	2.94	2.90	2.94
test_img_7	4.60	8.14	8.12	8.27
test_img_8	1.60	2.92	2.88	2.98

All values are in seconds.

Some Diffuclties in Processing Images

During the whole process, I did not face any major difficulties in processing images except one that I discussed above.

- When the input image is different from the pure greyscale level the algorithms perform a little bit awkwardly. You can analyze this in "*Experiment with Image-2"*

Conclusion

It is clear that these techniques are good enough for Enhancing the Image. But it is hardly useful on commercial bases because of its limitations such as changes in brightness.

REFERENCES

[1] Vijay A. Kotkar and Sanjay S. Gharde, "Review of Various Image Contrast Enhancement Techniques", International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 7, July 2013

[2] Vinay Kumar and HimaniBansal, "Performance Evaluation of Contrast Enhancement Techniques for Digital Images", International Journal of Computer Science and Technology, Vol. 2, No. 1, pp.23-27, 2011.

[3] Soong Der Chen and RahmanRamli, "Minimum Mean Brightness Error Bi-Histogram Equalization in Contrast Enhancement", IEEE Transactions on Consumer Electronics, Vol. 49, No. 4, pp.1310-1319, 2003.

[4] Omid Rahbar, (2 Apr 2016), "How can I compute AMBE?" Retrived from https://www.lib.sfu.ca/help/cite-write/citation-style-guides/apa/websites.

[5] Ismail A. Humied and Fatma E.Z. Abou-Chadi, "Image Contrast Enhancement Techniques: A Comparative Study of Performance", International Journal of Computer Applications (0975 – 8887), Volume 137 – No.13, March 2016