# **COE 4TN4 Course Project 1:**
Restoration of Poorly Exposed Images

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## 1 Image Quality Degradation Issue

Image equality degradation are usually caused by lighting conditions with high dynamic range. Digital cameras attempt to match the human visual systems in adapting to lighting strength but due to the limitations of semiconductor imaging sensors, it becomes difficult. As a result, digital cameras frequently generate underexposed and overexposed patches in the areas that have low and high illumination. Some other causes include environmental conditions such as haze and fog. The image contrast decreases because the aerosol particles in the haze and fog cause light to scatter toward the sensor and reflected by the terrain. Veiling glare and ambient light reflection can significantly degrade the quality of an image on a display device. The light diffuses due to the light reflection and the ambient light enters a display surface and return at random emission angles.

To solve the ill exposure problem, many traditional methods have been used for image enhancements. These methods include contrast stretching, histogram equalization, and tone mapping. In this paper, the histogram equalization method is implemented and is compared to a different image enhancement method, the Retinex algorithm.

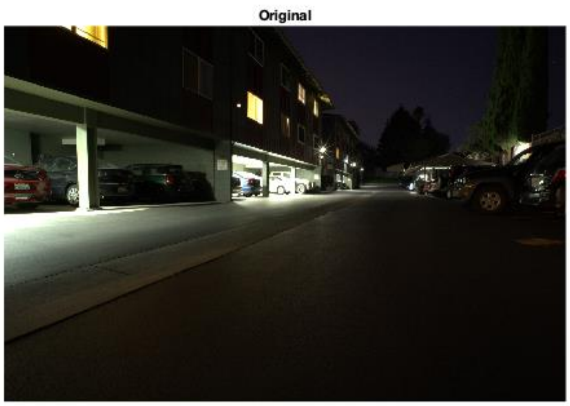
## 2 Histogram Equalization

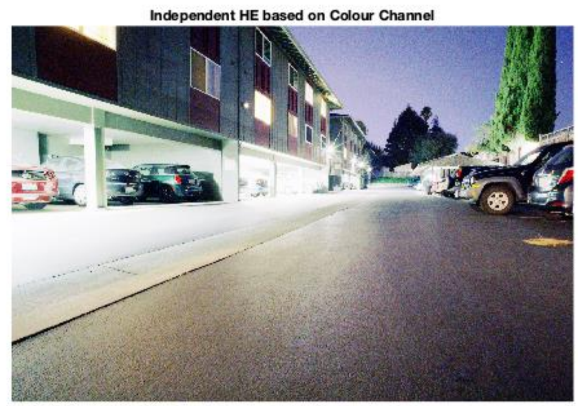
Histogram equalization is a method of contrast adjustment where the image's histogram is used to distribute the intensities. The method utilizes the probability distribution to stretch the areas of high intensities and compress the areas with low intensities. It modifies the intensity values such that the histogram of the image is flattened and equalized. An advantage of this method is that it is effective in spreading out the most frequency intensity values. However, it is ineffective in recovering subtle details corrupted by the A/D quantization due to nonlinearity and non-invertible during the quantization operation. As a result, there could be an increase contrast of background noise and decrease of usable signal.

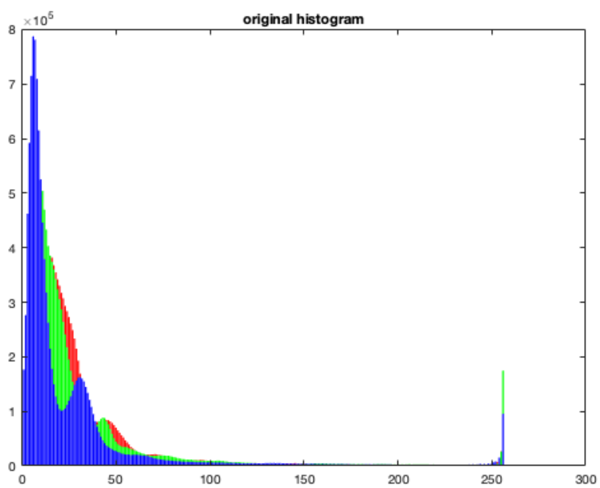
Three ways have been used to implement histogram equalization on an RGB image:

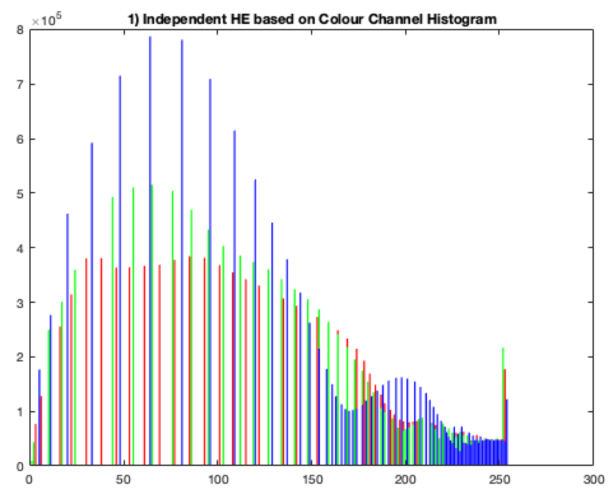
1. *Independent histogram equalization based on colour channel*

   Algorithm: split image into R, G, B channels. For each channel, find the frequency occurrence of each pixel, calculate pdf, then find cumulative histogram of each pixel. HE maps the input image into entire dynamic range by using cdf. The results are shown below:



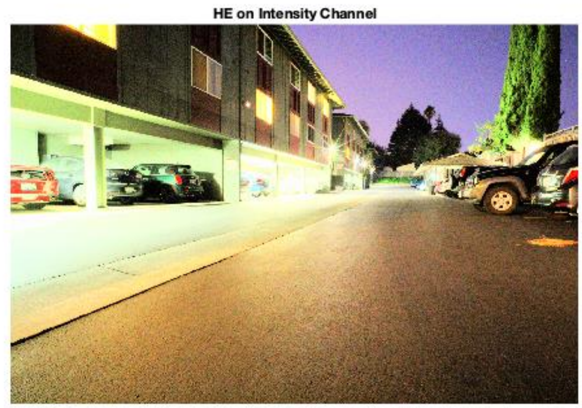



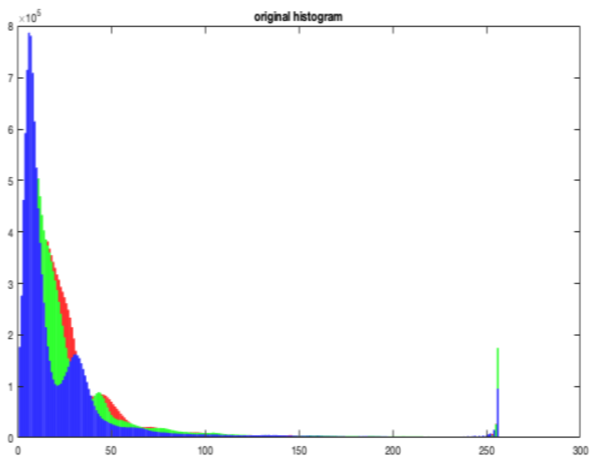



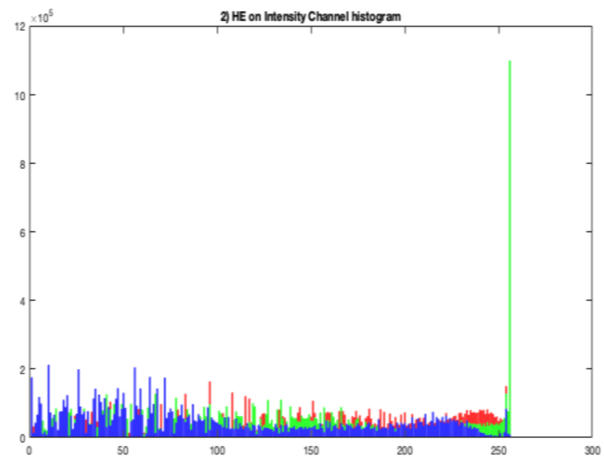

   Advantages: Fast processing
   Disadvantages: It doesn't consider the relative distribution between the R, G, and B channels which leads to distortions of the image's colour. Due to the nonlinearity of the process, mapping colours between colour spaces may involve huge computation load.

2. *Histogram Equalization based on HSV Colour Space*

   Algorithm: the image is converted to HSV colour space and HE is only applied to the intensity/luminance channel – keeping the hue and saturation of the image the same. The results are shown below:

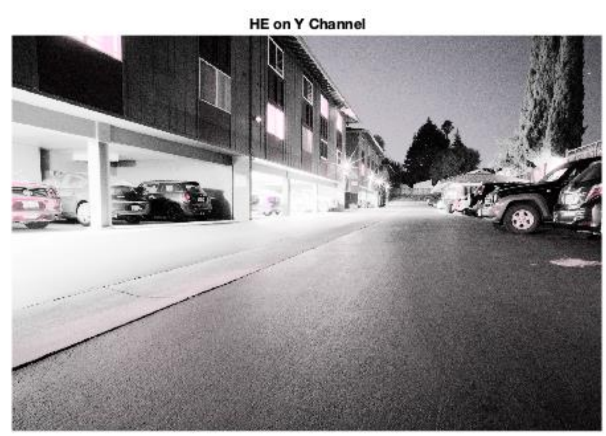



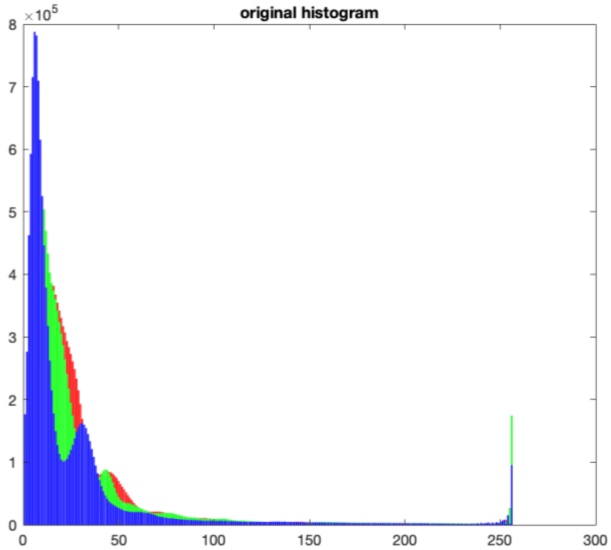



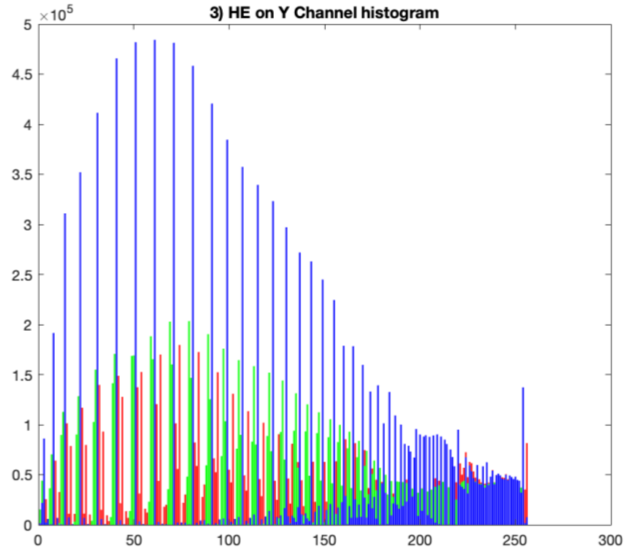




Advantages: Fast process, Colour is restored
Disadvantages: Noisy

3. *Histogram Equalization based on YUV Colour Space*




Advantages: Fast process
Disadvantages: Colour is off, noisy.

## 3 Retinex Algorithm

Another method that has been designed for image enhancement is the Retinex algorithm. The retinex theory was developed by Land and McCann and was aimed at explaining human colour perception but its derivation over the years has led to efficient algorithms in enhancing local image contrast. Researchers has described the Multiscale Retinex algorithm as the most successful center-surround image filter. In this section, an improved image formation of the MSR model is explored as well as a colour image enhancement model is experimented.

In the retinex model, one or both of the illumination and the reflection is first estimated, the estimated terms are next enhanced, and the output image is obtained by combining enhanced term. The algorithm is summarized below:

1. Gaussian-form linear LPF to the input image. The Matlab built-in function was used to create the Gaussian function. Gaussian function is a key function that can denoise images.

$$F(x, y) = C \exp[-(x^2 + y^2)/2\sigma^2]$$

where sigma is the standard deviation that controls the amount of spatial detail which is retained. C is a normalization factor such that:

$$\int F(x, y)dxdy = 1.$$

2. The log signal of the reflectance is estimated by subtracting the log signal of the estimated illumination from the log signal of the input image

$$R_{MSR_i} = \sum_{n=1}^{N} w_n R_{n_i} = \sum_{n=1}^{N} w_n \left[\log I_i(x, y) - \log(F_n(x, y) * I_i(x, y))\right]$$

   Where N is the number of scales and w is the weight of each scale.

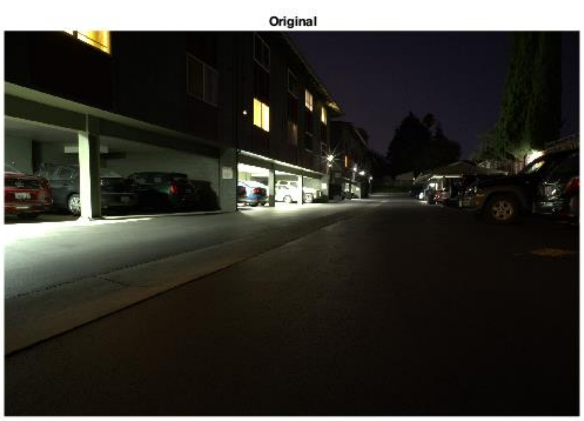
3. The estimated reflectance in log domain is used as the output image
4. A gain/offset correct is applied to adjust brightness range of the output image

The ideal parameters that Jobson et al. suggested is:

| constant | N | $\sigma_1$ | $\sigma_2$ | $\sigma_3$ | $\alpha$ | $\beta$ | $w_n$ | G | b |
|---|---|---|---|---|---|---|---|---|---|
| value | 3 | 15 | 80 | 250 | 125 | 46 | 1/3 | 192 | -30 |

Table 1

The output of the MSR algorithm applied on an RGB image is as shown:





As a result, the MSR algorithm brightened up the image. However, it is noticeable that the image is a bit grayish and has decreased the colour saturation. To solve the problem, Jobson proposed a colour restoration step.

The chromaticity coordinates are computed:

$$I'_i(x, y) = \frac{I_i(x, y)}{\sum_{j=1}^{S} I_j(x, y)}$$

where S is the number of channels, in this case it is 3 for RGB colour space. The restored colour MSR is given by:

$$R_{MSRCR_i}(x, y) = C_i(x, y) R_{MSR_i}(x, y)$$

where:

$$C_i(x, y) = \beta \log[\alpha I'_i(x, y)]$$

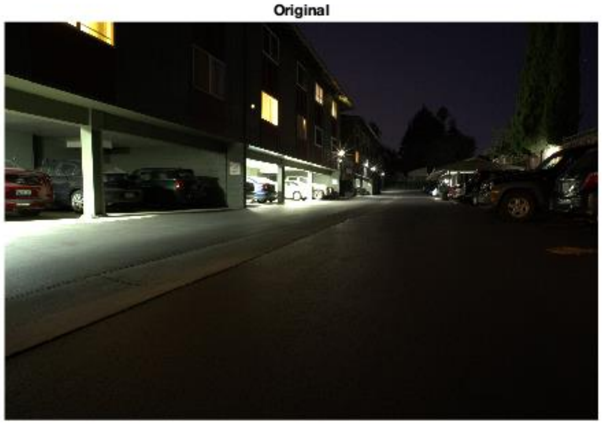
And Beta is a gain constant and alpha controls the strength of the nonlinearity. The suggested parameters are shown in Table 1 above. The output is shown below:



As a result, the MSRCR algorithm has attempted to fix the colour. However, the colour seems a bit off. In attempt to improve colour image enhancements even more, a proposed method is to convert the RGB image into HSI/HSV colour first. The H and S component remain the same and only the MSRCR algorithm is applied onto the luminance channel (V component).

The output is shown below:

Original



MSRCR

After several steps, the output shown above is the best in terms of brightening, contrast, and noise. We can see the retinex algorithm is less noisy than the HE method.

## 5 Conclusion

In conclusion, many traditional methods have been used in attempt to solve the image quality degradation problem. Some of these traditional methods include contrast stretching, histogram equalization and tone mapping. In this paper, histogram equalization method has been experimented and has been compared to an improved image enhancement method, the Retinex Algorithm, specifically the Multi-Scale Retinex method. Modifications have been applied to this method in terms of adding a colour correction and how the algorithm is applied onto the image (i.e., in RGB colour space or HSV colour space). As a result, we can see that MSRCR applied in the V channel in the HSV colour space provides the best image enhancement out of all the methods implemented in this paper.

## 6 References

A. Petro, C. Sbert, and J. Morel, “Multiscale Retinex,” Image Process on Line, 2014, pp. 71-88, doi: 10.52201/ipol.2014.107

C. Liu and X. Wu, “Single-exposure HDR Imaging with Concurrent Neural.”

D. H. Choi, I. H. Jang, M. H. Kim and N. C. Kim, "Color image enhancement using single-scale retinex based on an improved image formation model," 2008 16th European Signal Processing Conference, Lausanne, Switzerland, 2008, pp. 1-5.

D. J. Jobson, Z. Rahman and G. A. Woodell, "A multiscale retinex for bridging the gap between color images and the human observation of scenes," in IEEE Transactions on Image Processing, vol. 6, no. 7, pp. 965-976, July 1997, doi: 10.1109/83.597272.

D. J. Jobson, Z. Rahman and G. A. Woodell, "Properties and performance of a center/surround retinex," in IEEE Transactions on Image Processing, vol. 6, no. 3, pp. 451-462, March 1997, doi: 10.1109/83.557356.

J. Wu, W. Lin and G. Shi, "Image Quality Assessment with Degradation on Spatial Structure," in IEEE Signal Processing Letters, vol. 21, no. 4, pp. 437-440, April 2014, doi: 10.1109/LSP.2014.2304714.

V. Yadav, M. Verma and V. D. Kaushik, "Comparative Analysis of Contrast Enhancement Techniques of Different Image," 2016 Second International Conference on Computational Intelligence & Communication Technology (CICT), Ghaziabad, India, 2016, pp. 76-81, doi: 10.1109/CICT.2016.24.

P. Wang, Z. Wang, D. Lv, C. Zhang, and Y. Wang, “Low Illumination Color Image Enhancement Based on Improved Retinex Theory.” 2020 4th International Conference on Electronic Information Technology and Computer Engineering, 2020, pp. 334-339, doi: 10.1145/3443467.3443777.