Image Enhancement for Surveillance Camera Footage

ECE 4580 Final Project Report

By Sofie Wong and Ayush Shah

Abstract

Nowadays, surveillance cameras are widely used for the purpose of crime detection or home security. Footage from surveillance cameras can be used to identify suspicious activities or record valuable evidence in the event of a crime or an accident. However, the quality of the camera footage is not always desirable. Many surveillance cameras have a very low resolution. On top of that, external factors such as low visibility due to poor weather or dim lighting can further decrease the quality of the footage, which makes it difficult for the footage to be used. The purpose of this project is to perform image enhancement on surveillance camera footage in order to obtain a clearer version of the footage using histogram equalization and multi scale retinex.

I. Introduction

Surveillance camera are prevalently used both domestically and commercially. It can be used for many purposes such as home security or surveillance for stores and private outdoor areas. For the purpose of this project, we will be performing image enhancement for wildlife surveillance cameras at nighttime. These footages are from multiple trail cams and wildlife cameras[1].

These particular camera footages are relatively high quality with not a lot of noise. However, since the footages are taken in forests or mountain areas where there is very limited light source. It can be very difficult to see the animals captured in the footages clearly unless they are positioned at the front and middle of the frame where there is sufficient lightening.

In the light of this, we propose to increase the illuminance of these nighttime camera footage by adaptive histogram equalization and Multiscale Retinex(MSR). These two methods are both useful for increasing illuminance in low light environments. This report will be primarily focusing on MSR since I am responsible for its implementation.

Mutltiscale Retinex[2] is a color correction method that is used to improve local contrast. MSR generally has a better result than traditional histogram equalization methods since the former can improve contrasts and brightness locally while the latter can only do so globally. Because of that, MSR is suitable for our project since the majority of our experimental footage has both brightly lit areas and dimly lit areas. This method allow us to improve the contrast and visibility of dimly lit areas while preserving the brightness of the brightly lit areas.

II. Implementation

A luminance based MSR algorithm[3] is used in our project. The basic idea of the algorithm is to obtain the luminance of the image by standard MSR algorithm from three separated gaussian filter with various sigma and averaging the result.

A. Multiscale Retinex Algorithm

Grayscale images can be split into two components, irradiance and reflectance. These values can be obtained by the equation below:

$$I(x,y) = R(x,y)L(x,y) \tag{1}$$

where R(x,y) is the reflectance at point (x,y) on the surface and L(x,y) is the irradiance falling on point (x,y) on the surface. The two components can be separated by taking the logarithm of the equation as follows:

$$\log\big(I(x,y)\big) = \log\big(R(x,y)\big) + \log\,(L(x,y)) \tag{2}$$

The illuminant component can be obtained by applying a 2D gaussian filter to the image by convolution. For single scale retinex, only the reflectance component is needed. To obtain the value of the reflectance component, the following equation is used:

$$R_{SSR}(x,y) = \log\big(I(x,y)\big) - \log\big(G(x,y) *\ I(x,y)\big) \tag{3}$$

where the gaussian filter G(x,y) is built by the following equation mentioned in the lecture slide.

$$G(x,y) = e^{-\frac{x^2+y^2}{2\pi\sigma^2}} \tag{4}$$

To perform multiscale retinex, three single scale retinex using Eq. (3) is used, the result can be obtained by the equation below

$$R_{MSR}(x,y) = \frac{1}{3}\{\sum_{i=1}^{3} \log I(x,y) - \log[G_i(x,y) *\ I(x,y)]\} \tag{5}$$

where the gaussian filter $G_i(x,y)$ is obtained by Eq (4) with σ_i as following

$$\sigma_1 = 5, \sigma_2 = 20, \sigma_3 = 240$$

The size of σ will determine the output of the single scale retinex. Smaller σ can bring out the finer details, while larger σ can provide color balance.

B. Gain Offset and Preserving Luminence

The next step is to apply a histogram based gain-offset method to R_{MSR} to map the values to a [0, 255] scale. The value of gain G = 150 and offset b = 0.6 are both obtained experimentally with trial and error. Gain corresponds to the contrast of the image, while offset is the brightness of the image. Higher gain will give a sharper and brighter image at the cost of more noises, while higher offset will give a brighter and clearer image at the cost of loss in sharpness. The following equation is used:

$$R_{MSR'}(x,y) = G(R_{MSR}(x,y) + b) \tag{6}$$

The process of MSR can gives a brighter and sharper result for poorly lit areas in the image. However, for brighter regions in the image, using the original pixel values might give a better result. To ensure that the enhanced image have no luminance drop in those areas, the following equation is used:

$$R_{MSR''}(x,y) = \frac{|R_{MSR'}(x,y) - I(x,y)| + R_{MSR'}(x,y) - I(x,y)}{2} + I(x,y) \tag{7}$$

This equation will choose the larger value between $R_{MSR'}(x,y)$ and I(x,y) for each pixel values. Therefore, pixels that are initially bright will have their brightness preserved.

III. EXPERIMENTAL RESULT AND DISCUSSIONS

This section shows the experimental result of applying the MSR method to several screenshots of the wildlife surveillance camera footage as mentioned above. Our goal is to improve the brightness level and sharpness of the darker areas of the image while preserving brightness on brighter areas. After MSR is applied, the details in the images, such as animals and trees, can be seen more clearly.

All experimental image results are shown below:

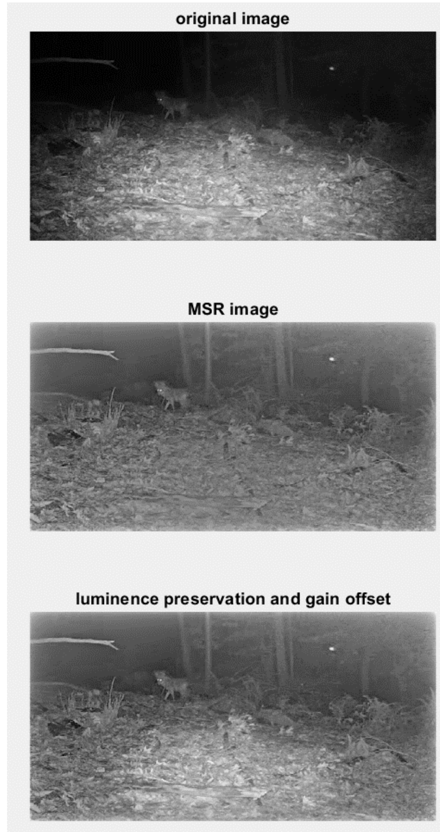

Figure 1: Experimental image with fox

In Figure 1, the original image is bright in the middle and dark everywhere else. This is most likely due to the camera footage being illuminated by a single light source pointing to the middle of the frame. A fox is present at the upper left corner of the image. However, the fox is barely visible since it is located at the darker part of the image, which is not a well illuminated area.

The middle image shows the result of applying MSR on the original image. As we can see, the image is a lot brighter and clearer and the fox can be seen clearly. However, the image appeared washed out, especially at the middle part where it is supposedly illuminated.

The bottom image shows the result after applying histogram gain-offset method and preserving luminance by comparing the pixel values of the original image and MSR image. It is clear that the dark part of the image is now enhanced, while the brighter parts remains unchanged and the luminance of those parts are preserved.

Figure 2: Experimental image with armadillo

In Figure 2, the original image is bright in the middle and dark everywhere else similar to Figure 1. An armadillo is present at the center of the image. In this case, the armadillo can be seen easily since it is located in a brightly lit area. However, the details on the armadillo are slightly blurry.

The middle image shows the result of applying MSR on the original image. In this case, the resulting image does not necessarily have a desirable effect. Although the tree in the background is much clearer. The armadillo has significantly lower contrast than the original image.

The bottom image shows the result after applying histogram gain-offset method and preserving luminance by comparing the pixel values of the original image and MSR image. Now the image is much closer to our expected result, since the details of the image can be seen more clearly, such as the trees and tail of the armadillo, while the luminance of brighter areas can be preserved, such as the body of the armadillo.

Figure 3: Original Image (top), Adaptive Histogram Equalization Result (bottom)

Figure 3 shows the result of adaptive histogram equalization implemented by Ayush. As shown in the image, the resulting image has a higher contrast and is more detailed.

IV. CONCLUSION

In conclusion, the MSR method proposed can successfully increase brightness, contrast and sharpness in dimly lit areas while preserving the brightness of brightly lit areas. This algorithm also works well in our goal of performing image enhancement on wildlife surveillance cameras, which often produces images and footages in unevenly lit areas. Overall, this method performs very well in our experimental footage with dark backgrounds and is illuminated by a single light source. The adaptive histogram equalization also works as expected.

REFERENCES

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[3] L. Tao and V. K. Asari, "Modified luminance based MSR for fast and efficient Image enhancement," AIPR Proc IEE, pp. 174-179, 2003.