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Over/Under-Exposed Image Compensation Technique for Real-Time Video Surveillance System

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Abstract—Image clarity is very easily affected by lighting, weather, or equipment used to capture the image. Some of these conditions (inconsistent lighting) lead to under-exposed or over-exposed conditions where an image may suffers from loss of information. This paper presents a new image compensation technique in order to recover the loss of information in the image. This method performs image compensation only on under-exposed or over-exposed regions without affecting those that are correctly exposed. The spatial filter and centre surround approach are used as the sharpen operator for edge enhancement and to minimize the halo effect, respectively. In addition to this, tone mapping is used to remap the dynamic range of an image. Experimental results show that this proposed method improves the quality and clarity of an image and has the capability to process 704×576 pixels sized image in approximately around 0.43 seconds when executed on a conventional personal computer without the need for additional hardware implementation.

INDEX TERMS: Image compensation, under-exposed, over-exposed, tone mapping.

1. INTRODUCTION

Image compensation is widely used to restore information in an image. This technique is normally employed in recognition system, surveillance system, biometric, and machine vision. Video surveillance system for external environment monitoring such as for an auto teller machine (ATM), parking lot, sidewalk, and traffic light are usually exposed to uncontrolled lighting conditions (i.e. day and night, lighting source from vehicle, street lamp, and the weather). These conditions affect the quality of images recorded in the surveillance system. Some of these conditions lead to over-exposed or under-exposed conditions, hence resulting in low quality or clarity in images. Thus, image compensation technique is one of the solutions for restoring information loss. Another alternative would be to use High Dynamic Range (HDR) [1-3] capturing device instead of Standard Dynamic Range (SDR) or combining multiple SDR images [8]. However, this method is highly time consuming. To overcome this disadvantage, Field Programmable Gate Array (FPGA) [4-7] may be implemented but this will increase cost and system complexity.

Initial algorithm towards finding a solution called Retinex has been proposed by Land [9] in 1964. This method relates to the human vision perceiving problem in relation to brightness and colour. It represents a calculating theory, where an object will show different color under different observing conditions. Since then, many algorithms were developed based on Retinex such as Multi Scale Retinex (MSR) [10], Multi Scale Retinex with Wide Dynamic Range (MSRWDR) [11], Multi Scale Retinex with Initial Approximation (MSRRIP) [12], Retinex based Adaptive Filter (RAF)

[13] and Fast Multi Scale Retinex (FMSR) [14]. Although some of the functions work well, their main weakness is computational burden. Another method widely used for image enhancement is Histogram Equalization (HE) [15]. Because of its simplicity, HE method is very fast. However, HE only produces good quality output under certain conditions. Beside that, HE is usually applied globally and as a result, it modifies the initial correct exposed regions. Although some modifications have been made on the original HE such as the Adaptive Histogram Equalization (AHE) [16], Adaptive Height-Modified Histogram Equalization (AHMHE) [23] and Two-Dimensional Histogram Equalization and Contrast Enhancement (2DHE) [24], the problem still exists and usually increases processing time.

In view of the mentioned problems, this study presents a simple and inexpensive solution for under-exposed and over-exposed problems. There is non-necessity for the SDR surveillance camera to be replaced by HDR surveillance camera nor the requirement for additional hardware. This paper proposes a new method for image compensation, which can be deployed in surveillance systems.The output of the capturing device is enhanced through image compensation only on the under-exposed or over-exposed regions, while the correctly exposed portions remain intact. The spatial filteris used as the sharpening operator for edge enhancement and the centre surround approach is used to minimize the halo effect. In addition to that, tone mapping is used to remap the dynamic range of an image. Experimental results demonstrate that the proposed method improves the image quality and clarity based on human observation. This is due to the fact that the proposed method has the ability to increase visibility at the under-exposed and over-exposed region. Image of size 704×576 pixels are rendered in approximately 0.43 seconds when executed on a conventional personal computer, without the need for additional hardware implementation.

The rest of the paper is organized as follows: Section 2 presents the detailed description of the proposed method. Section 3 shows the results and discussions, and finally, the conclusion is presented in Section 4.

2. DESCRIPTION OF THE PROPOSED METHOD

Figure 1 shows the block diagram of the proposed method. The input image from the capturing device is first converted to $YCbCr$ color space. Instead of RGB colour space, the $YCbCr$ color space is selected for this implementation. This avoids processing of three colour components. This in turn, reduces the complexity and the processing time associated with the algorithm. In $YCbCr$ color space, Y is used to distinguish the luminance. Thus, only the Y component needs to be modified, while both Cb and Cr components remain intact. In this method, the Y component will be passed to the spatial enhancement filter. Subsequently, tone mapping will be implemented on the output of the spatial filtering. Finally, the processed Y component, i.e., Y' is combined with Cb and Cr components and are converted to RGB colour space to produce the final output image.

2.1. Spatial Filter

Spatial filter technique such as unsharp masking filter [15], Sobel [17], and Prewitt [15] are usually used for edge enhancement. After a series of tests conducted in this study, the unsharp masking filter is chosen as the edge sharpening operator.This is implemented as a window based operation. This filter relies on a convolution kernel to perform spatial filtering by using an appropriately defined low pass filter to produce the smoothed version of an image. This is then subtracted from the original image, pixel by pixel, in order to give a description on the image edges. The unsharp masking produces an edge image $f_L(x,y)$ from an input image $f(x,y)$ by using Eq. (1).

$$f_L(x,y) = f(x,y) * L(x,y) \tag{1}$$

where, $f(x,y)$ is the input image and $L(x,y)$ is the negative Laplacian kernel. Lastly, the final sharpen image, $f_s(x,y)$, is obtained from Eq. (2).

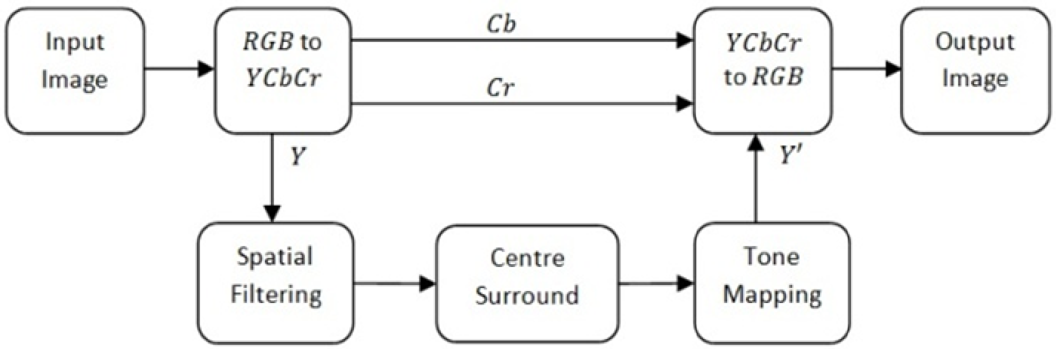

Figure 1: Block diagram of the proposed method

$$f_s(x,y) = f(x,y) - f_L(x,y) \tag{2}$$

where, $f_s(x,y)$ is the sharpen image, $f(x,y)$ is the Y component image, and $f_L(x,y)$ is the convolution output between the Y component and the negative Laplacian kernel.

2.2. Centre Surround Function

Centre surround functions as a mean kernel used in this study to eliminate the unwanted halo effect. The centre surrounds function is defined in the Eq. (3),

$$S_{n,m} = \frac{1}{c^2} \sum_{y=n-\frac{c}{2}}^{n+\frac{c-1}{2}} \sum_{x=m-\frac{c}{2}}^{m+\frac{c-1}{2}} f_s(x,y) \tag{3}$$

where, $S_{n,m}$ is the centre surround output, $f_s(x,y)$ is the output from the spatial filter, c is the size of kernel and n,m is the centre surround point. In the proposed method, c is equal to 21. A higher c value increases the size of the mean kernel. This sometimes results in misrepresentation of the details in the kernel as noise, which reduces the information in the image.

2.3. Tone Mapping

Tone mapping is a technique used in image processing and computer graphics to remap the dynamic range of an image. In this paper, the idea for tone mapping function inspired from Vonikakis and Andreadis method [18]. This method divides the intensity of an image into two groups, i.e., for intensity lower than 128 and intensity higher than 128.

$$Y_1' = \frac{(255 + A(S_{n,m})) \cdot Y_{n,m}}{A(S_{n,m}) + Y_{n,m}} \forall S_{n,m} < 128 \tag{4}$$

$$A(S_{n,m}) = [M_{dark} + q(S_{n,m})] \cdot d(S_{n,m}) \forall S_{n,m} < 128 \tag{5}$$

Eq. (4) and Eq. (5) are for intensity, $S_{n,m}$ which is lower than 128, where Y_1' is the output image and Y is the Y component of the input image.

$$Y_2' = \frac{A(S_{n,m}) \cdot Y_{n,m}}{A(S_{n,m}) + 255 - Y_{n,m}} \forall S_{n,m} \geq 128 \tag{6}$$

$$A(S_{n,m}) = [M_{bright} + q(255 - S_{n,m})] \cdot d(255 - S_{n,m}) \forall S_{n,m} \geq 128 \quad (7)$$

Eq. (6) and Eq. (7) are for intensity, $S_{n,m}$ which is equal or higher than 128, where $Y_2^{'}$ is the output image and Y is the Y component of the input image.

Parameters q and d are given by Eq. (8) and Eq. (9), respectively.

$$q(x) = (x)^2/lobe \quad (8)$$

$$d(x) = 128/(128 - x) \quad (9)$$

where, q is the local adaption, d is the correction factor which ensure smooth continuity between $Y_1^{'}$ and $Y_2^{'}$, and $S_{n,m}$ is the centre surround output. M_{dark}, M_{bright} and $lobe$ are shown in Eq. (10), Eq. (11) and Eq. (12), respectively.

$$M_{dark} = \frac{245}{100}(100 - bin_{low}) + 10 \quad (10)$$

$$M_{bright} = \frac{245}{100}(100 - bin_{high}) + 10 \quad (11)$$

$$lobe = \frac{29}{100}(100 - bin_{middle}) + 1 \quad (12)$$

Here, bin_{low} is the percentage of the pixels that belong to the interval [0,85), bin_{middle} is the percentage of the pixels that belong to the interval [85,170), and bin_{high} is the percentage of the pixels that belong to the interval [170,255].The final output of processed Y component is given by Eq. (13).

$$Y^{'} = Y_1^{'} + Y_2^{'} \quad (13)$$

where, $Y^{'}$ is the final value of luminance component, $Y_1^{'}$ and $Y_2^{'}$ are the output from Eq. (4) and Eq. (6), respectively.

3. RESULTS AND DISCUSSIONS

In this section, the final parameter used in the proposed method is discussed. Section 3.1 discusses the spatial filtering which is found to be the most suitable to be implemented in the proposed method. Section 3.2 discusses the best c value for centre surround function and Section 3.3 shows the performance of the proposed method compared to other existing methods.

All tests are implemented on MATLAB and executed by an Intel Quo 2 Duo at 2 GHz, under Window XP. Entropy value is used to compare the results with other methods. In information theory, Shannon entropy [14] or information entropy is a measure of the uncertainty associated with a random variable. This measurement is generally used to measure the level of enhancement obtained using a given enhancement algorithm and enhancement parameter. Subsequently, it is a measure of the informativeness of the distribution, which exhibits higher information if the entropy is higher.

3.1. Spatial Filtering Results

Several spatial filter operators exist for edge enhancement, namely unsharp filter, Prewitt and Sobel. For the first experimental result, operator which is the most suitable to be implemented in this work is shown. In the experiment, YaleB01_P00 [15] is used as the sample images. In this database, there are 65 images whereby each image has different lighting condition. The size of the image is 640 × 480. It is assume that this database has the following surveillance system condition, i.e., lighting is unbalanced, a variety of lighting direction, also under-exposed and over-exposed spots. The results are shown in Figure 2 and Figure 3 for entropy and time comparison, respectively. Table 1 shows the summary for all test results.

From Table 1, it is observed that the highest entropy is produced when the Sobel filter is used. However, since the objective of the study is to have a fast computational algorithm, the Sobel filter is not the best choice as it is slower compared to the other similar filters. Based on the results in Table 1, it can be concluded that unsharp masking filter is suitable to be used as the spatial filtering operator. This is due to its faster computational time and the entropy result is almost atpar with Sobel filter.

Table 1: Spatial filtering results

Method	Averaged values from 65 samples	
	Entropy	Time (*s*)
Unsharp	6.9022	0.1828
Prewitt	6.9220	0.1975
Sobel	6.9275	0.1987

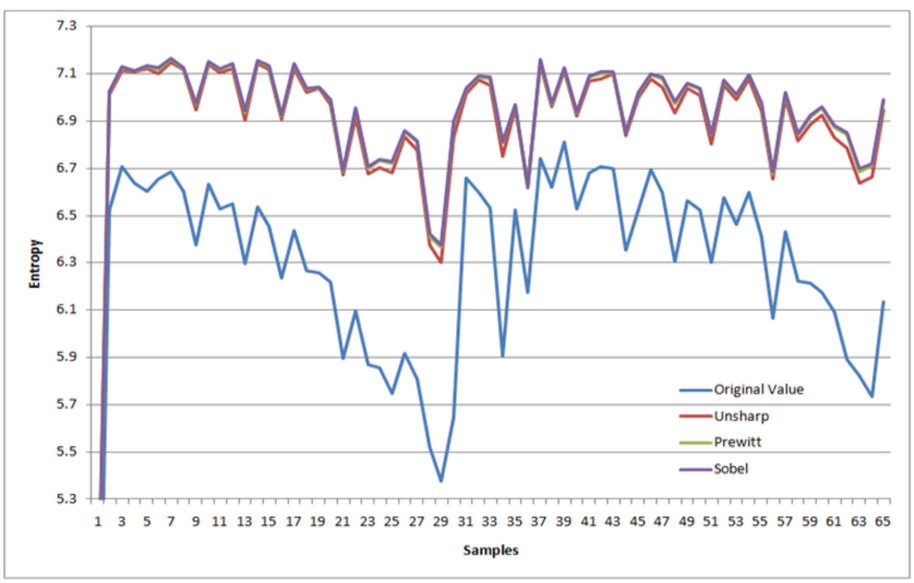

Figure 2: Comparison between spatial filtering in terms of entropy

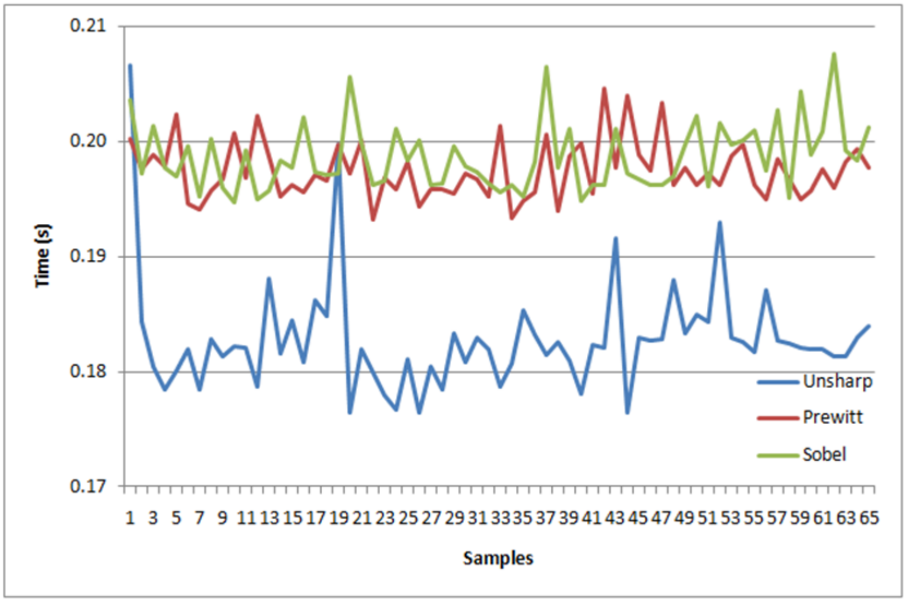

Figure 3: Comparison between spatial filtering in terms of processing time

3.2. Centre Surround Function Results

Eq. (3) shows the centre surround function, which is a simple averaging equation. However, it is necessary to determine the appropriate size of the kernel, c, the main factor fore liminating the halo effect. Figure 4 shows the results of multiple c values.

From Figure 4, increment of c value also increases the edges thickness in the image. In centre surround function, the value of centre surround depends on the neighbourhood pixels, which usually produces a lower intensity value compared to the original because of the averaging function. For instance, in Fig. 4, when $c = 11$, the edge is clearer or sharper compared to the image with a higher c value. Note that, when $c = 61$, the edge is spread which in turn affects the object appearance.

3.3. Proposed Method Results

To evaluate and benchmark the proposed method between other existing similar works, the proposed method is compared with histogram equalization [15], Retinex method based on Frankle and McCann algorithm [21], Vonikakis and Andreadis [18], and the commercial software, Photoflair [22]. These methods implement the compensation technique without using additional hardware such as the HDR camera. Three data sets are used in this experiments; Yale face database B with size 640×480, surveillance footage (database) whereby each frame is of size 704×576, and a randomized environment database.

Figures 5 to 10 depict some of the results from the Yale face database B, surveillance database and randomized environment database. From the results, the effectiveness of the proposed method can be observed whereby the output contains more information compared to the original image. By implementing the proposed method, the under-exposed and over-exposed regions have been reduced as displayed in the red-circled area. For the output image, it can be observed that the proposed method has the ability to compensate under/over exposed regions while the correctly exposed ones remain intact.

In Figure 5, the proposed method and Vonikakis and Andreadis [18] method actually improve

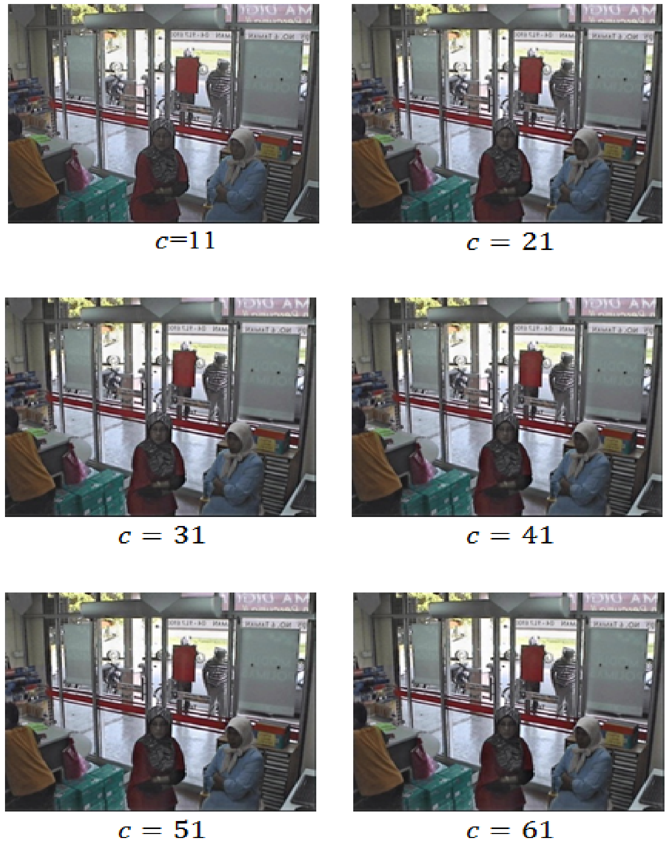

Figure 4: Effect of c value in centre surround function

the visibility in the circled area while the histogram equalization produces an over exposed output, Retinex produces 'washed out' appearance and Photoflair failed to improve the right eye region.

Figure 6 shows the surveillance database at 6 P.M. For the database, proposed method gives good results as shown in the circled region while other methods are unable to reduce the under-exposed region especially for the subject's face (blue shirt lady).

Figure 7 depicts the result for 8 P.M database. In this database, the under-exposed or over-exposed region is minimal due to favourable lighting condition (light is turn on). As a result, most of the methods do not have any effect on the image. However, the proposed method and Vonikakis and Andreadis method further improve the image output appearance especially in the red circled region.

Figure 8 and Figure 9 show the surveillance database at 10 A.M and 11 A.M, respectively. The images at this hour has under-exposed (indoor) and over-exposed (outdoor) conditions. The proposed method and Vonikakis and Andreadis method are able to compensate for most of the regions in the image especially for the circled region. Retinex also able to compensate the object, however it failed to produce good result on the right side of the image. Photoflair and histogram equalization are ineffective as both method are not able to improve the image condition, i.e., the subject remain dark and unclear.

Figure 10 shows one image from the randomized environment database whereby the image suffers from under-exposed and over-exposed regions. For this particular image, the proposed method provides good results in which the method is able to reduce the under exposed region as in the red circled area and reduces the over exposed region as in the blue circled area. Vonikakis and

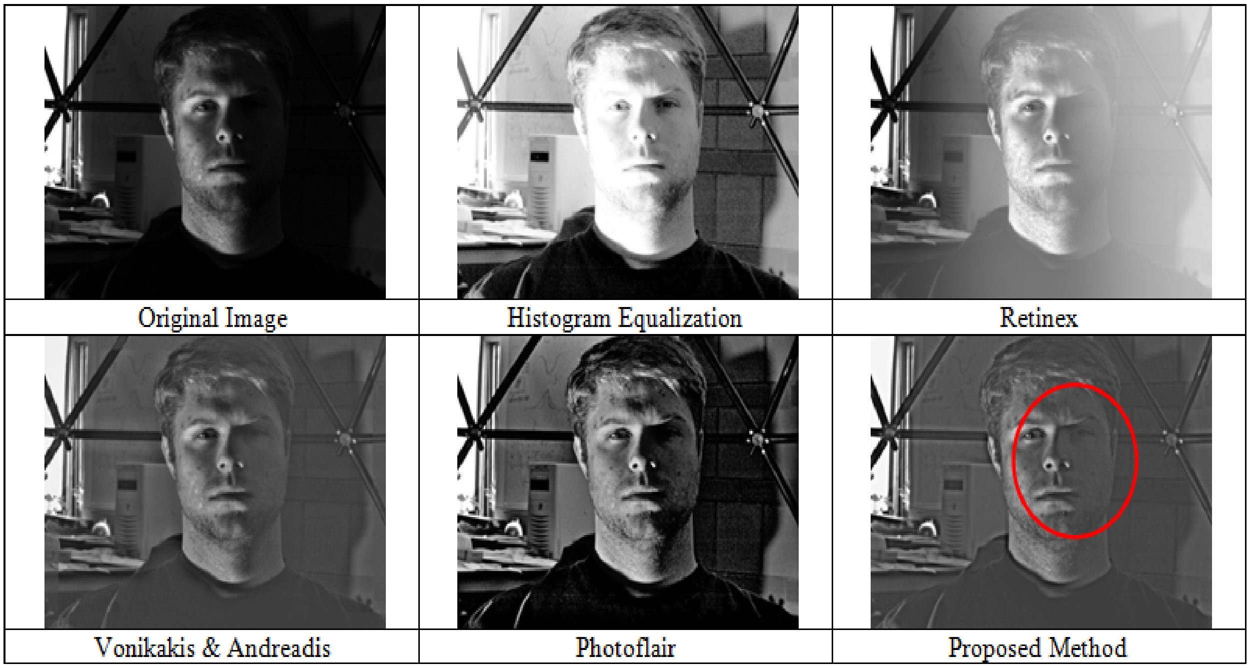

Figure 5: Yale face database B

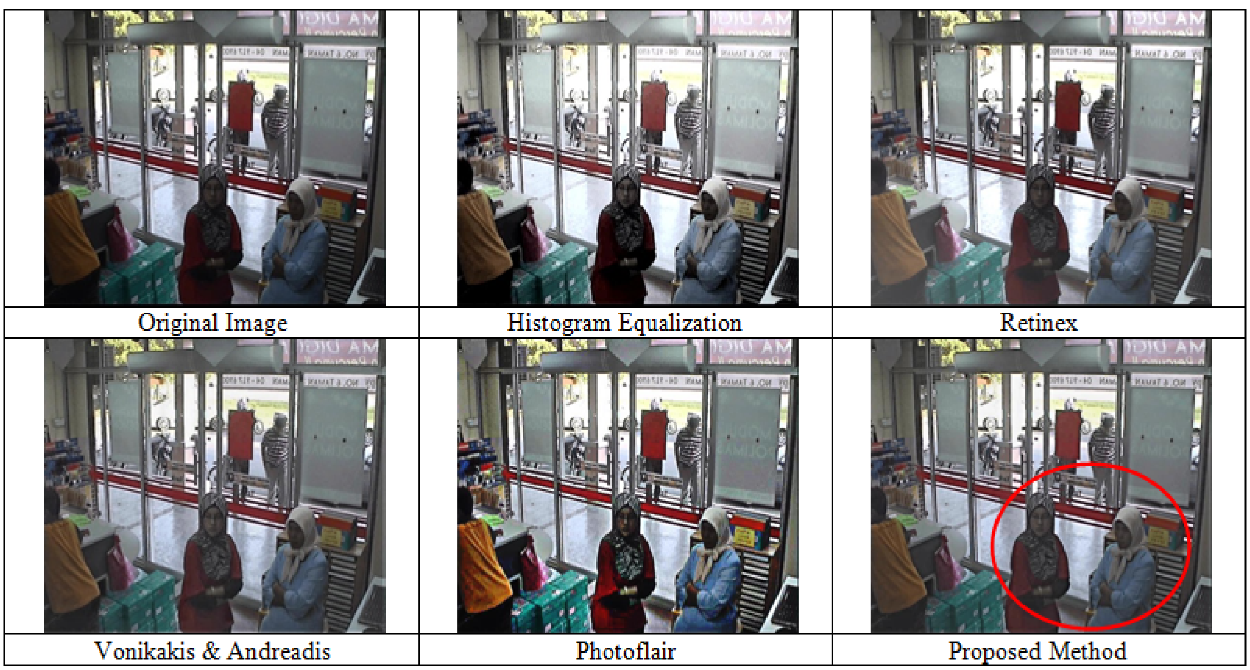

Figure 6: Surveillance database at 6 P.M.

Andreadis method gives almost the same results as the proposed method. However, the drawback is that the over-exposed region has turned into greyish colour. The other methods are unable to compensate both for the under-exposed and over-exposed regions. On the other hand,the proposed

Figure 7: Surveillance database at 8 P.M.

Figure 8: Surveillance database at 10 A.M.

method works exceptionally well.

From all of the experimental results, it can be concluded that the proposed method is able to compensate for the over-exposed or under-exposed regions. This method, which transpired from

Figure 9: Surveillance database at 11 A.M.

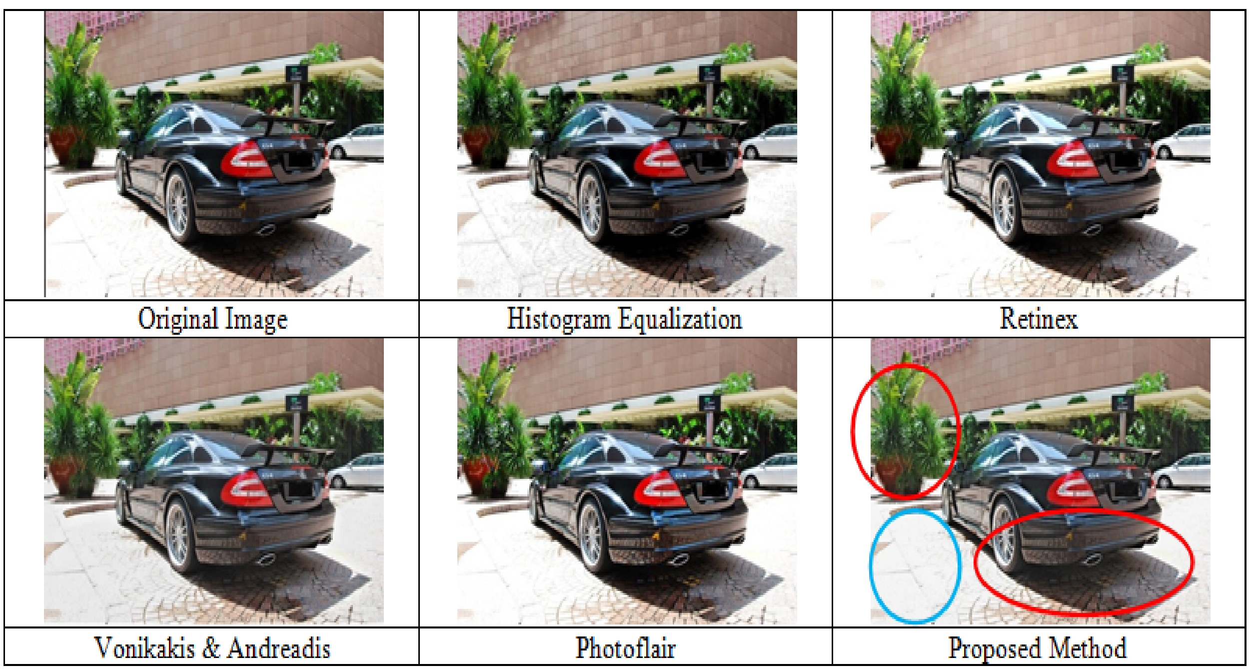

Figure 10: Environment database

Vonikakis, and Andreadis[18] method have been redesigned for simplicity and less computational time. The unsharp filter has replaced the orientation map introduced in their method where the function of the filter is almost the same as the orientation map. Centre surround function which is required to compute two centres surround for Y and orientation map components, has been reduced to only one centre surround in the proposed method. These improvements tremendously reduce the computational time. Despite these modifications it can be noted that the output from the proposed method is atpar with the Vonikakis and Andreadis[18] method albeit with faster processing time for real-time surveillance system.

4. CONCLUSION

A new method for fast image compensation for surveillance system has been presented in this paper. The main objective for the study is to compensate only the under-exposed or over-exposed regions of the input image while the correctly exposed region should not be affected. The proposed method utilizes spatial filtering in order to sharpen the image and also a tone mapping function. The tone mapping function is inspired by the shunting characteristic of the centre surround cells of the spatial filter output image. The function is modulated differently for every pixel according to its surrounding. The experimental results demonstrate that the proposed method has the ability to improve the information and quality of the image while reducing the execution time. No direct hardware implementation is required in the proposed method. For future work, quantitative analyses of the proposed method compared to other methods will be pursued. The method would also be implemented for real-world testing and efforts will be given to further reduce the processing time.

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