Differential Illumination Enhancement Technique for a Nighttime Video

G. Abirami and S. Padmavathi

Abstract Video surveillance has become a common security need in the present-world scenario. The nighttime video surveillance becomes more challenging due to the presence of extreme illumination conditions, which is not uniform in a frame. Pedestrian detection would be very difficult under such illumination condition. The system proposes a method to identify and segregate the differently illuminated regions with the help of day-time reference image. Various enhancement techniques are applied on these regions separately and the results are combined to obtain the enhanced frame. Results of these techniques are summarized and appropriate methods are suggested for specific cases.

Keywords Nighttime video enhancement · Video surveillance · Illumination

1 Introduction

A nighttime video lacks the surrounding scene context due to poor illumination and also sensor noise. More background noises are caused by the environmental weather conditions. In high light/dark regions the scene information cannot be seen clearly by the observers. These characteristics increase the necessity of nighttime video enhancement. Nighttime video enhancement will be useful for both visual and machine perception.

Nighttime video enhancement is a crucial step in nighttime video surveillance. Identification of persons, animals in dark regions is a major requirement in the nighttime videos. It helps human monitoring in a better way due to the enhancement

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of the dark regions. The frames are not uniformly dark due to the presence of different light sources ranging from stationary street lights to moving vehicle lights. A global illumination enhancement technique fails in such a scenario. It only degrades the image further. Hence identifying the differently illuminated regions in a frame will lead to precise enhancement of the regions.

Video enhancement improves the visual appearance and produces a better representation for higher level processing such as detection, identification, recognition, and analysis. Video-enhancement technique is categorized into two major groups [1]: Self-enhancement and context-based fusion enhancement. Self-enhancement deals with enhancing the nighttime video without any external reference but context-based fusion enhancement needs external information for enhancement.

Self-enhancement of nighttime video introduces small distortions which produces unrealistic effects. Even though objects are visible, it does not reveal the contour thereby making foreground extraction a difficult task. Due to presence of light sources at few locations, the dark regions lose their actual information. Context-based fusion enhancement is done with the help of daytime image so that the finer image details can be preserved and made visible. The daytime reference video has a rich background context that is almost uniformly illuminated with high brightness values. The lack of nighttime video characteristics can be resolved with a daytime reference video. The real-time application environment for this system would be nighttime surveillance and home security. The paper is structured as follows: Sect. 2 deals with the literature survey, Sect. 3 explains about the proposed work, Sect. 4 depicts experimental results and Sect. 5 concludes the paper.

2 Literature Survey

The existing nighttime video-enhancement techniques are global in nature and perform the enhancement with or without a reference daytime image. The self-enhancement techniques adopt tone mapping, histogram equalization, contrast-based methods, etc., globally for the nighttime frames without the reference frame. These techniques results in small distortions as they are uniformly applied to the bright and the dark regions. The context-based fusion video-enhancement aims to detect, recognize, and track objects (including pedestrians and vehicles) from video/image, while being aware of existing surrounding context from the daytime reference video/image. Various fusion methods are adopted for different illumination enhancement. Context-based fusion enhancement is categorized into three major divisions

1. Color-based method
2. Gradient-based method
3. Intensity-based method

These methods are briefly discussed in the Table 1 with their pros and cons.

Table 1 Comparison between context-based fusion methods

Category	Description	Pros	Cons
Color-based method [2]	Method for applying daytime colors to nighttime imagery in real time can improve situational awareness	The target image need not represent the same scene as the source image	Lack of color constancy
Gradient-based method [3]	Aims to capture the gradient information from the nighttime image/video	Achieves a smooth blend of the input images, preserves their important features	Observable color shift. Difficult to maintain high contrast in single image
Intensity-based method	Background fusion Foreground extraction. Fusion by logical OR operation [4]	Maintain the proper quality of the image	If proper value is not detected then the proper change occurring in the image is not determined
	Hybrid method—high contrast in local part of the image which is stable in the night images [5]	Gives better visibility	It works well with the indoor environment
	Denighting method—Fusion method based on the illumination ratio of daytime background and nighttime background [6]	Maintains intraimage coherence by using the weighting ratio	Due to uneven illumination ratio, the enhanced results will lose illumination information of nighttime videos
	Enhance nighttime background using illumination images of day/night for determining weights. Enhancement performed by a combination of illumination [7]	Maintains high contrast in the image	Works well for nighttime images that are uniformly dark. It can produce false background problem
	Motion detection is carried out by Gaussian mixture model. Illumination is estimated by Retinex theory weighted sum fusion technique is used [8]	Retains information density and helps in high-level behavior analysis and understanding	The important region information in nighttime image may not be maintained

3 Proposed Work

In this paper, a nonglobal method for enhancing the nighttime video with the daytime reference image is proposed. The differentially lighted regions in the video frames are segregated using illumination segmentation method. The luminance values of these regions are adjusted to with the help of daytime reference image.

The segregation of differentially lighted regions is based on the assumption that the luminance value of the dark regions is less than the daytime reference. The regions of the nighttime video frames that are illuminated by street lights, vehicle lights, etc., have a higher luminance value than that of a daytime reference image.

3.1 Methodology

3.1.1 Illumination Segmentation

Based on the assumption, the pixels in a nighttime video frame is said to be part of region under street light or head light of a vehicle based on the following condition

$$\begin{aligned}&\mathrm{If}(\mathrm{Nt}\,(x,y) > \mathrm{DB}(x,y))\\&\mathrm{Nt}(x,y) = 1;\\&\mathrm{Else}\,\mathrm{N}(x,y) = 0;\\&\mathrm{end}\end{aligned}$$

Nt(x,y)—intensity image of nighttime video frame
DB(x,y)—intensity image of daytime background image.

We obtain a binary image BDB with dark regions represented by 0 and high light regions are represented by 1. These regions are treated separately by various enhancement techniques.

3.1.2 Illumination Adjustment

The illumination segmentation module yields the output as a binary image BDB of the particular nighttime frame which represents both highlight regions and dark regions. The bright regions are segmented and a homomorphic filtering is applied to it. Histogram equalization technique is applied to the dark regions. The results are then combined to give the enhanced frame.

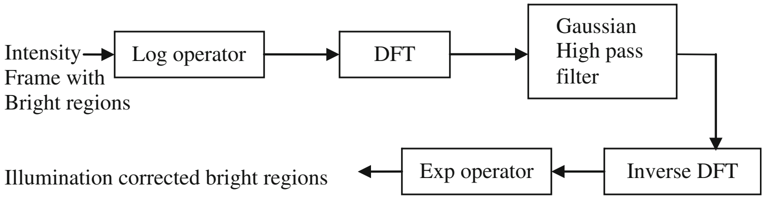

Fig. 1 Design of homomorphic filter

3.2 Bright Regions

3.2.1 Illumination adjustment using homomorphic filtering

Homomorphic filtering [9] is a technique for removing multiplicative noise and most commonly used for correcting illumination effect in images; it assumes that illumination is uniform and illumination varies slowly across the image as compared to reflectance. Reflectance changes abruptly at object edges. The homomorphic filtering is explained with the block diagram given in Fig. 1.

The bright regions segmented from the binary image BDB is given to Log operator to convert the multiplicative noise to additive noise. Discrete Fourier transform (DFT) is applied to convert the frame to frequency domain. The Gaussian high-pass filter function as given in Eq. (1) is applied to enhance the bright regions. Then inverse DFT and exponential operator are applied on the filtered frame to obtain the illumination corrected bright regions.

The filter function is represented as follows:

$$H(u,v) = (\gamma H - \gamma L)\left[1 - \exp\left(-c^* D^2(u,v)/D^2\right)\right] + \gamma L. \tag{1}$$

$$D(u,v) = \left[(u - P/2)^2 + (v - Q/2)^2\right]^{(1/2)}. \tag{2}$$

$D(u, v)$ is the distance between the point (u, v) in the frequency domain and the centre of frequency rectangle.

P, Q is the size of the image.

exp(.) is the exponential function.

c is the constant which controls the slope between the transitions of γL and γH.

D is the cut off frequency.

3.3 Dark Regions

The dark regions are enhanced using histogram equalization [9] which stretches the intensity levels to fit the dynamic range 0–255. This converts the low-contrast dark image into the high-contrast image and further the distribution of pixels is not too far from uniform.

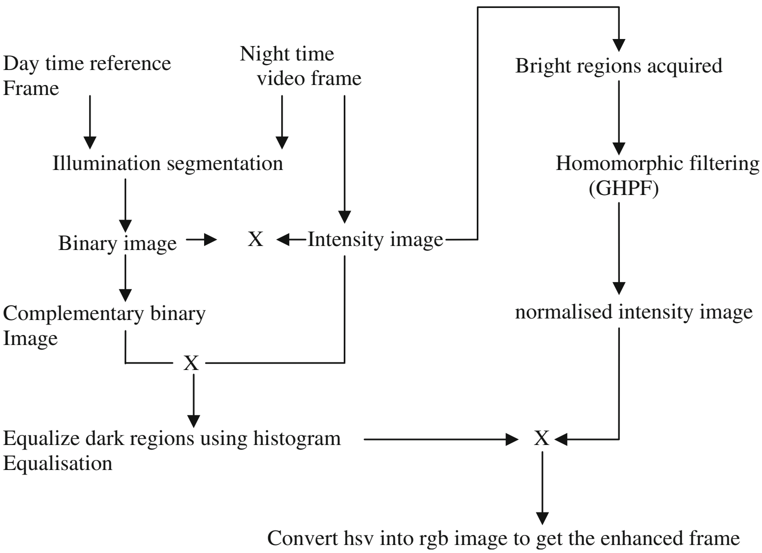

Fig. 2 Overall flow diagram of illumination segmentation and adjustment for the differentially illuminated areas of the nighttime video

The probability of occurrence of the intensity level rk in the image is approximated by

$$\Pr(\mathrm{rk}) = \mathrm{nk}/\mathrm{MN}. \quad k = 0, 1, 2\ldots.L - 1 \tag{3}$$

where MN is the total number of pixels in the image.

nk is the number of pixels that have intensity rk.

L is the number of possible intensity levels in the image (e.g., 256 for an 8-bit image).

Fig. 2 explains the differential illumination-enhancement method. Here the binary image that indicates the bright and dark region is obtained as specified in Sect. 3.1.1. Once the differential regions are segmented in the intensity frame, enhancement methods are performed accordingly as specified in the Sect. 3.1.2. The regions after enhancement are combined and normalized to fit into the range of 0–255. The enhanced intensity frame is concatenated with hue, saturation components of the nighttime frame, which is converted back to an enhanced RGB video frame.

4 Experimental Results

The Experimental dataset includes an indoor video which is collected from the website: http://web.media.mit.edu/~raskar/NPAR04/. The video has a person walking from one place to another in indoor environment. Two outdoor surveillance videos are collected from the Amrita Vishwa Vidyapeetham University campus for a day, is also considered for experimentation. Videos taken in Amrita Vishwa

Table 2 List of several night and daytime videos among the dataset

Name of the video	Day/night	Category	Time in min	No. of frames	Frame rate (fps)
Nite_outdoor.avi	Night	Outdoor	60	89,982	25
Nite_indoor.avi	Night	Indoor	5 s	154	29
Nite_outdoor1.avi	Night	Outdoor	30	43,293	25
day_outdoor2.avi	Day	Outdoor	60	89,982	25

Vidyapeetham is freely available for Amrita students and staff for the research purpose and is approved by the University heads. The outdoor video datasets are taken from same view point, same location but at different times such as day and night without manipulating camera parameters. The camera specification is as follows: Common CCD Outdoor Camera, Vari Focal lens (2.8–12 mm) (2 mega pix), Horizontal Resolution 700 TV Lines, 36 IR LED, IR Distance-20 m. The outdoor videos have huge number of pedestrians and vehicles crossing the security post. These videos are cut to 1 h videos for experimentation which are listed in Table 2. Among the videos the nighttime videos are used for testing the algorithm. A daytime image is considered as a background reference frame for computing the bright and dark regions. The implementation is performed on MATLAB R2013a platform.

Indoor environment
Figure 3 shows a sample of indoor nighttime frame with the person and daytime background image. Figure 4 depicts the enhanced frame corresponding to Fig. 3. Another enhanced night frame without the person is shown in Fig. 5.

Outdoor environment
Figures 6 and 8 show a sample of outdoor nighttime frame and the daytime background image taken as reference. Illumination segmentation algorithm as specified in Sect. 3.1.1 is applied to Fig. 6 which gives the mask with light regions specified in white and dark

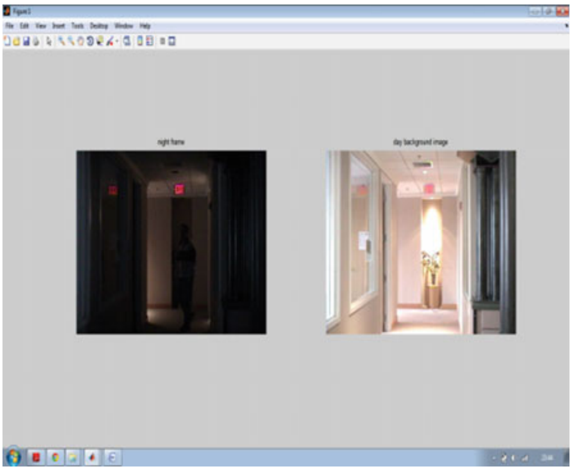

Fig. 3 Nighttime frame and daytime background image

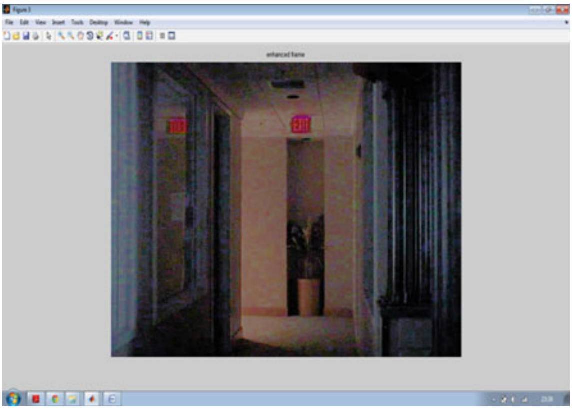

Fig. 4 Enhanced nighttime frame

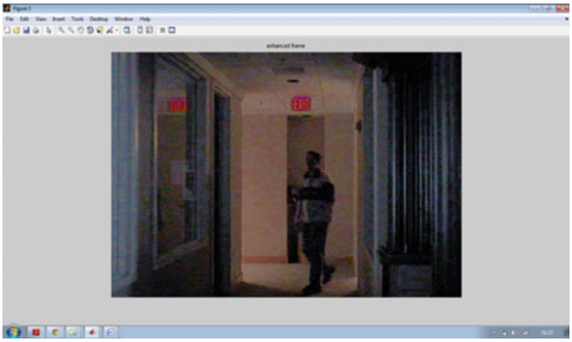

Fig. 5 Enhanced frame with the presence of person

regions specified in black as in Fig. 7. Figure 8 depicts the corresponding enhanced frame, obtained through the algorithm as specified in the Sect. 3.1.2.

The proposed illumination enhancement method reduces the luminance levels around the bright regions but did not expose the details in the darker region (Fig. 9).

Fig. 6 Screen shot of nighttime video

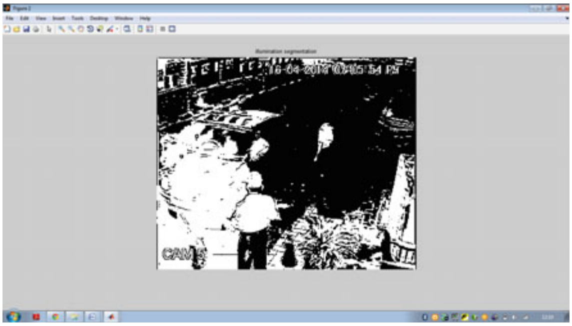

Fig. 7 Illumination segmentation mask for a frame

Fig. 8 Daytime reference background image

To exhibit those details, methods like histogram equalization, contrast-enhancement functions like log, exponential operators, and also histogram matching, homomorphic filtering for both dark and bright regions were experimented and

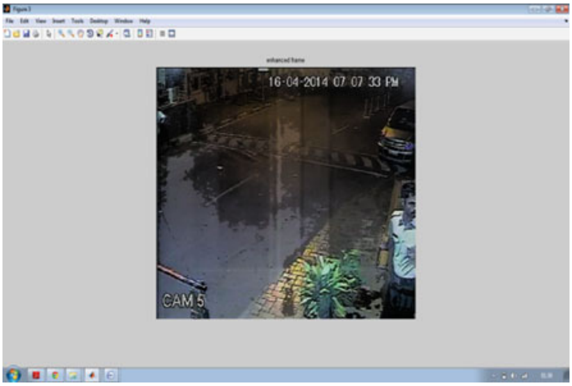

Fig. 9 Enhanced nighttime frame obtained from the proposed work

Table 3 Experimentation on different illumination methods for the differential regions

Method	Region segments	Output result	Inference
Histogram equalization-worked on intensity image alone	For dark region		Dark regions enhanced
	For bright region		Bright regions not fully discovered
	Both combined	Combined intensity on taking inverse 	Sharpness reduced, and bright regions can still be reduced

(continued)

Table 3 (continued)

Method	Region segments	Output result	Inference
Contrast enhancement	Using log and exp operator		Dark regions log operator better. Bright regions exp operator better. Whole image exp operator comparatively better but bright light not suppressed
Histogram match	For dark region-match saturation and intensity		Slight increase in dark regions
	For bright region-match Intensity alone		Light around the vehicle lights reduced but complete bright regions not exposed

(continued)

Table 3 (continued)

Method	Region segments	Output result	Inference
	Both regions		Comparatively better enhancement

summarized in Table 3. The daytime reference background image and illumination segmentation are similar to the previous method.

Observation
From the experimental analysis, it could be seen that certain techniques produce better result for the bright regions and certain other techniques are better for dark regions. These are summarized in the following paragraph.

For bright regions Homomorphic filter reduces the effect of luminance values with γ^L as 0.25 and γ^H as 1. Histogram matching reduces the intensities around the bright light areas. Exponential operator when used to enhance the image, the regions around the head lights was darkened.

For dark regions Enhancing the dark regions with log operator produces a better result than histogram equalization and histogram matching.

These methods work better on the individual regions. The quality of the combined image after the independent enhancement of the regions was poor. Histogram matching when applied on the regions independently and the results when combined give a better result than the above-specified methods. The regions from the daytime reference frame are considered for matching the histogram of the nighttime regions.

5 Conclusion and Future Work

Nighttime video enhancement is required to identify people, object in the dark regions. It is a challenging task due to the presence of different illumination sources. In this paper, the highly illuminated areas are identified and segregated with the help of daytime reference image. Various enhancement techniques are experimented on the bright areas and dark areas separately, whose results are combined to get the enhanced frames. After a detailed experimentation, it could be summarized that homomorphic filtering, and exponential filters enhance the bright regions; log filters enhance the dark regions and histogram matching for the combined regions are found better than the other methods.

Histogram matching between the nighttime regions and daytime regions is performed with various combinations of HSV and RGB components. It can be concluded that matching between intensity and saturation component provides better-enhanced image than others. The effect of the headlights in the surrounding regions is reduced and the darker regions are enhanced to see the finer details present there. But the illumination equivalent to the daytime could not be achieved.

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