Adaptive Exposure Control Algorithm For Day Night Video Surveillance

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Abstract—An optimum exposure control algorithm is necessary for any camera system to have a better image quality. Night vision requires the camera to make use of the ambient or illuminated IR light for a better image at low lighting conditions which is not desirable during day. A suitable IR cut filter algorithm should be combined with normal exposure control to have a better image quality without much manual intervention. Most of the cameras used for video surveillance require dynamic parameters to set explicitly for working as day night cameras. In this paper an optimal exposure control algorithm for day night video cameras is presented.

Keywords—Exposure; IR cut filter; Day night vision; Image enhancement

I. INTRODUCTION

Quality of the exposure control algorithm decides the acceptability of the video captured. A day night camera is prone to extreme light changes. A high quality video camera used for surveillance requires exclusive sensing elements for detecting various lighting conditions for auto adaptation. This requires explicit use of different sensors like ambient light sensor or IR sensors, which increases the cost. To adapt to those conditions, most of the camera requires various configuration parameters. The parameter which works well for one set of conditions can fail for others. The paper discusses an adaptive exposure control algorithm which works by extracting the scene information. The proposed algorithm is capable of producing images under very low light by automatically switching the IR cut filter.

II. CAMERA IR EFFECTS

Image sensors used for video capture can pickup IR rays and can give a color shift which depends upon sensor characteristics. Most of the image sensors will give peak characteristics at a particular IR wavelength apart from the RGB values. Fig.1 shows the characteristics of IR for a typical CMOS sensor. Apart from the RGB gains under visible spectrum it also gives a particular output value for the IR rays. Fig.2 shows the range of visible light and IR frequency spectrum. The graph on Fig.1 shows the sensor characteristics for IR waves apart from the response for visible light (IR waves near to 800nm).

Objects will show wrong color, when looked through a camera without an IR cut filter. Image on the left of Fig.3 shows the effect of a tree taken under direct sun illumination. The leaves appear to be white because of the IR illumination characteristics of the leaves. It reflects all the IR waves which will be captured by the sensor pixels. Along with the visible green under light it also gives output to red and blue pixels which gives the white effect for the leaves. Image on the right side of Fig.3 shows the correct image of the tree captured with a camera having IR cut filter. This requires an IR cut filter to be placed in front of the camera to avoid the spurious effects of IR rays. On the other hand night vision requires IR rays for visibility under extreme low light conditions. This requires the IR cut filter to be removed under low light conditions.
Fig.4
Fig.4 shows the use of IR for night vision. It’s difficult to identify the objects in the frame with ambient light. At the same time a camera is able to pick the image by the use of ambient IR waves or by an external IR illumination.

III. EXPOSURE ALGORITHM
Exposure is similar to shutter speed in cameras. For the camera’s which doesn’t have a mechanical shutter the term used is ERS or electronic rolling shutter. It refers to how much time the pixels inside the sensor should be turned on for a particular frame. If the exposure time is not proper it will result in over exposed or under exposed images. A proper exposure algorithm controls the exposure time of the camera for generating an image having proper dynamic range.

Fig.5
Image at the extreme left of Fig.5 depicts an underexposed image, the middle one shows the optimum exposed and the extreme left image shows an overexposed image.

A. Exposure algorithm issues for day night cameras
It’s very difficult for a camera to produce the same quality output image during day and night. At night we need special configurations for having a better video quality. The exposure algorithm should be capable of dynamically switching the parameters required for its control. To have a low light sensitivity down to zero lux light intensity, the camera should be able to receive IR rays at night.

IV. PROPOSED ALGORITHM
In the proposed algorithm the video camera will be running under optimum conditions suited for a particular scene.
Along with the normal algorithm to derive optimum target brightness, it will incorporate and auto IR cut filter algorithm which enables the camera to receive IR rays for enhanced visibility during night.

A. Video subsystem
For the system to implement exposure method a typical video capture SOC is being used. The system is having a sensor interface which captures the images on real time and will be encoded for streaming. The SOC supports hardware modules which in turn captures the scene brightness as RGB values. An application can read these RGB values to implement a proper exposure method.

Fig.6
As shown in the Fig.6 the chip supports an AE (Auto Exposure engine) engine which reads the value directly related to scene brightness. As a subsequent stage processing the processor also supports basic image processing blocks such as color correction gamma correction etc. The RGB values are directly read by the AE engine which can be used to evaluate the scene brightness for the algorithm. The values read from AE engine is used to evaluate the scene which in turn is used by the algorithm to control various factors like IR cut filter, exposure, gain etc.

B. Exposure algorithm
A simple exposure algorithm is used to control the basic exposure of the camera. The parameters used are
• Sensor analog and digital gains (S gain)
• Image processor gain (I gain)
• Sensor exposure
• Edge enhancer configuration
• Luminance Y
The Y value can be calculated directly from the standard equation for using RGB
RGB Luminance value $= 0.3R + 0.59G + 0.11B$
or it can be calculated by directly taking the G value as brightness because human eyes are more sensitive to green than any other color. This also avoids some complexity in calculation.
Upon start, the algorithm initializes all the parameters to their default base values (Fig.7). The method will continuously evaluate the frames to measure the scene luminance (Y). It will try to achieve a scene target brightness level which will be defined between a maximum and minimum.

**Ymin < Y < Ymax**

If this is not achieved upon analysis it will try to increase different control parameters one after the other. The order of the parameters is important as the first one is less prone to noise. It should be in the order such that exposure comes first then sensor gain (S gain) and then the processor gain (I gain).

Under extreme dark conditions the value of the digital and analog gains are such that the noise content in the video will be that high. The most prominent noise will be the color noise. To avoid such a condition and to provide a better visibility during night the algorithm will convert the video to black and white as an enhancement (Fig.8).

On the other hand if the target brightness is greater than the target luminance then the algorithm will try for a decrease routine indicated by D in Fig.7.

To have a more pleasing video the exposure algorithm also can use the edge enhancer support from the processing chip.

The algorithm adjusts dynamically the edge enhancer parameters to adapt to various situations.

The changes made by the algorithm will be effected from the next frame itself. After calculation and parameter variation the routine will be operating from the start indicated by S (Fig.7). All of the routines are specifically tuned for adapting to low light conditions.

**C. Auto IR cut filter algorithm**

As a night mode enhancement the exposure algorithm should make use of the ambient IR to produce a better image at night and subsequently to work as a day night camera. This requires the IR cut filter to be removed automatically.

Most of the IR cut algorithm requires extreme manual configuration such as switching threshold to work properly avoiding unwanted oscillations in case of a strong external IR illumination.

The proposed algorithm explicitly detects an oscillation condition and goes into a special frame check routine R1 (Fig. 9) in case of an oscillation. It also detects an increase or decrease in IR and goes back into normal routine which suits the condition.

For Fig.9 and Fig.10, S represents start condition. R0 represents the routine to be followed for normal auto IR cut filter functionality. R1 is the routine to be followed for auto IR cut filter method in case of strong IR illumination. Both the routine analyzes the video frame by frame.

The architecture of the IR cut filter is such that control for the IR cut filter will be connected to the GPIO or PWM modules.
Whenever we remove IR cut filter from the camera the sensor can give a color cast, which will be red for most of the cases. To prevent this unwanted color cast the algorithm will switch the video to black and white which removes the color cast and also the noise as a result of increasing gain under low light conditions.

V. CONCLUSIONS AND FUTURE WORK

The proposed method implements an adaptive exposure algorithm for a day night camera. It utilizes the ambient or illuminated IR light to enhance the visibility during a low light condition. The method tries to avoid an oscillation due to IR inrush by allowing the filter to go back once and then retaining a stable condition. Instead it can be avoided using a separate IR sensor or any other detection mechanism which avoids a onetime switch. The low light performance can be further improved by configuring the processor image processing support modules like noise filters.

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