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Extremely Low Light Video Enhancement along with No-Reference Video Quality Measurements

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ABSTRACT

Low light video enhancement is a challenge many researchers have been facing. Low illumination is the cause for low light videos. Noise present in the videos adds to the low quality of the low light video. So to improve the quality of videos the noise present in the videos has to be suppressed before enhancement is attempted. This paper addresses Kalman filter to suppress the noise from the extremely low light video. Though entire noise could not be suppressed by this technique a Non local means filter helps to remove the remaining noise after amplification. The Gray World technique is used for amplification. After removing the noise by using NLM filter image enhancement of extremely low light video is carried out.

Key words: Extremely low- light video, Kalman Filter, NLM filter, Gray World.

1. INTRODUCTION

Signal processing is fundamental to video processing. Over the past few decades, there have been phenomenal improvements in image quality of the videos be it digital cameras or other devices. Substantial improvements in resolution and sensitivity are possible due to the prevalence of High Dynamic Range (HDR) videos. However, no great improvements are visible in the area of low light images. The rears on for this state of affairs are (i) the image suffers from a poor dynamic range (ii) low signal to noise ratio. There are different techniques employed to boost the dynamic range of an extremely poor lighting video. Normally used enhancement technique is Dehazing algorithm. But, dehazing algorithm depends on the atmospheric light and its transmission medium. Estimation of transmission term in the hazy image acquisition model by using dehazing algorithm becomes unreliable in extremely lowlight conditions. Wavelet coefficients based video enhancement can also be used for enhancement. But it has very high computational time. Another enhancement technique is tone mapping followed by a Gamma Correction. For obtaining a better video output quality, Histogram Equalization (HE) followed by gamma correction can be used. Several video denoising techniques are used in video processing. Most commonly used video denoising technique is Spatio-temporal filtering and bilateral filtering. Spatio-temporal filter aims merely the videos slightly lower than the normal lighting conditions. Since this method was not originally meant to low-light video enhancement task, some of the steps used, for example optical flow and segmentation, could not provide reliable outcome with low-light videos. Most of the denoising techniques require more computational time. Recently, a three phase processing scheme for denoising and enhancing dark videos was proposed. A modified form of the nonlocal means (NLM) filter for reducing noise in an input video before and after tone-mapping by a logarithmic mapping method. A better denoised output for extremely low-light video is provided by Kalman filter approach. Kalman filtering is based on the prediction and correction of video frames and most of the video noises can be removed by this method. An extremely low-light video can be enhanced efficiently by the use of Gamma correction. Kalman filter and NLM filter can be used to get a better denoised video output.

2. RELATED WORKS

Minjae Kim, Dubok, Park, David K. Han, Hanseok Ko[1] has proposed A Novel Approach for Denoising and Enhancement of Extremely Low-light Video. The methodologies used are: a motion adaptive temporal filtering based on a kalman structure for noise removal. Dynamic range of denoised video is improved by adjustment of RGB histograms using gamma correction through adaptive clipping thresholds. Residual noise is removed using a nonlocal means (NLM).This method exploits color filter array (CFA) raw data for achieving low memory consumption. Histogram adjustment using the gamma correction and the adaptive clipping threshold is also presented to increase the dynamic range of the low-light video. Kim method not effectively work on colour video (Over saturation problem while brightness of the dark region increases) and it is based on uncompressed video.

Xianshu Ding, Hang Lei, Yunbo Rao[2] has proposed Sparse codes fusion for context enhancement of night video surveillance. The methodologies used are Sparse codes fusion (SCF) and Mutual Coherence Learning (MCL) Algorithm. In this method enhancement system is installed on the moving surveillance camera, it is unreliable for fusion with a fixed background and then SCF is not applicable any more. If the moving objects are large and of a great spatial part of the image, SCF will become invalid.

Qing Zhang, Yongwei Nie, Ling Zhang, Chunxia Xiao[3] has proposed Underexposed Video Enhancement via Perception-Driven Progressive Fusion. The methodologies used are Perception driven Progressive Fusion. Spatio-temporal filtering. The result still suffers some noticeable noise artifacts. Patch based spatio temporal filtering may wash out some weak edges. Current progressive fusion cannot work well on videos captured by fast moving cameras since the bidirectional correspondence may fail.

Anwaar Ulhaq , Xiaoxia Yin , Jing He , Yanchun Zhang[4] has proposed FACE: Fully Automated Context Enhancement for night-time video sequences. The methodologies used are A color night vision system, named FACE (Fully Automated Context Enhancement). Median filter for noise removal. A glare-free video fusion unit which is responsible for efficient fusion and false-colorization using RGB color channel fusion. Source color image selection based on contextual. Colour features with deep-KNN and color value imputation. It is designed to deal with a stationary camera environment under which background scene does not change.

Tunc¸ Ozan Aydın, Nikolce Stefanoski, Simone Croci, Markus Gross, Aljoscha Smolic[5] has proposed, Temporally Coherent Local Tone Mapping of HDR Video. The methodologies used are HDR video tone mapping operator (TMO), EdgeAwareFiltering. In this method artifacts are suppressed only to a reasonable level. Only a basic means of controlling Chrominance in the form of saturation slider.

Seungwon Lee, Nahyun Kim, Joonki Paik[6] has proposed Adaptively Partitioned block-based contrast enhancement and its application to low light-level video surveillance. The methodologies used are Divides the image into dark and background regions using adaptively partitioned blocks by two optimal threshold values computed by fuzzy C-means clustering in the V channel of the HSV color space. Contrast stretching method is performed only in the detected dark area. This method take long computational time .Sensitivity to the initial guess (speed, local minima) .Sensitivity to noise and One expects low (or even no) membership degree for outliers (noisy points).

R.G Hirulkar, P U Giri[7] has proposed Video enhancement for Low Light Environment. The methodologies used are Illumination Segmentation, Illumination Adjustment, Homomorphic filtering, Histogram equalization. Illumination enhancement method reduces the luminance levels around the bright regions but did not expose the details in the darker region. Illumination equivalent to the daytime could not be achieved.

Dr. P. Ashok Babu [8] has proposed Approximate Binary Plane Technique for Super Resolution Image Reconstruction in Transform Domain (ABPTSRIRTD). Leelavathy N, V.Kusuma Kumari, JyotsnaK, P Nagamani, B NKishore [9] This paper presents a comparative study on various methods for underwater image enhancement and restoration

3. METHODOLOGY

3.1. Framework

The purpose of extremely low light video enhancement is to improve brightness and contrast of low light video. This paper proposes a new approach for enhancing videos taken under luminance value less than 0.1 is dealt with in the paper. Figure 1 shows the flow diagram of proposed work. Kalman Filter removes temporal noise by comparing adjacent frame. Colour consistency gray world correction technique is used to enhance the dynamic range of such video. Non local mean denoising filter reduces the spatial noise.

3.2 . Temporal Noise Reduction

The difference frame is used for the temporal noise reduction of the frames. The Kalman filter has two steps predictions and the correction steps. In the prediction step the noise level in the images were estimated by the computation of the weight matrix. The predicted noise level was then updated and the gain of the method is calculated. From the predicted images the new difference matrices are formed. The new difference matrices spot the noise locality in the images more accurately compared to the previous difference frames. The kalman gain was useful in the estimation of the temporal noises from the images. The correction step removes temporal noises from the images. The approach followed for temporal filtering is to modify Kalman filter. Then, the dynamic range of the demised signal is widened by Gamma correction of each of the RGB histogram by suitably clipping the low and high intensity levels by taking appropriate thresholds. Any left out noise from the above steps is filtered using spatial noise reduction method. As it is clear that visual components in the improved video are more standard than those in the underlying info video, the patch-based nonlocal implies channel can expel the left over disorder viably while protecting edges. Consider uneven procedures X(n) and Y(n) such that in Equation 1.

$$\left.\begin{aligned} Xn+1 &= AnXn + Wn \\ Yn &= HnXn + Nn \end{aligned}\right\} \quad \ldots\ldots (1)$$

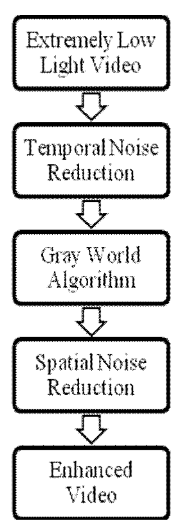

Figure 1: Proposed Frame Work

Wn and Nn are independent Gaussian processes and independent of X. Though, Xn is a Markov process Yn is a Hidden Markov process. To get best estimate of X from the observations Y, one has to estimate conditional probabilities p (Xn| Yn). This can be accomplished with the help of forward recursion algorithm. When there is a large motion around a pixel, sum of squared distance (SSD) of its patch becomes large and its weight decreases. This means contribution of previous estimate is to be reduced to prevent motion blurs. Towards this prediction and update equations of Kalman filter estimation are modified as shown in Figure 2.

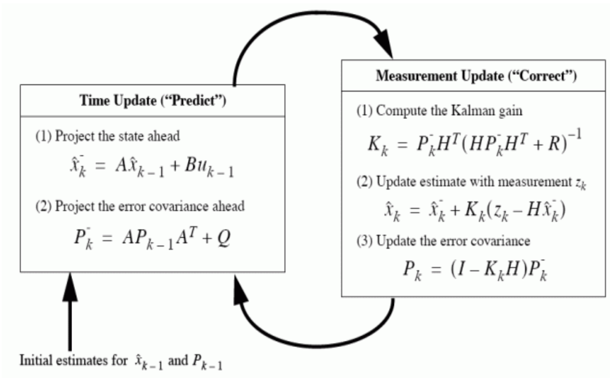

Figure 2: Kalman Filter

3.3 . Gray World Correction

Grey world algorithm is very widely used algorithm to attain color constancy. This is based on the assumption that average reflectance of surfaces is an achromatic. Being a simple algorithm its computational cost is low.

- To solve the colour constancy first step is to estimate the colour of the prevailing light. Then, at the second stage, remove it.
- Gray World assumes that for any scene, the average intensity of the Red, Green and Blue channels should be same.
- If all the three colours have equal intensity image satisfies the Gray world assumption.
- If they are different then keep the Green channel unchanged, and define the gain for Red and Blue channels as shown in Equation. 2 and Equation. 3.

$$\alpha = \frac{Gavg}{Ravg} \text{ and } \beta = Gavg/Bavg \quad \ldots\ldots\ldots \quad (2)$$

Adjust the Red and Blue pixels by

$$Ir(x,y) = \propto Ir(x,y) \text{ and } Ib(x,y) = \beta Ib(x,y) \quad \ldots. \quad (3)$$

3.4 . Spatial Noise Reduction

Non Local Means filter is employed to remove spatial noise in the gray world tone mapped image. The first step is to estimate the overall means of the difference between the gray world images. When stopping condition is arrived at then the solution to NLM method emerges. Convergence provides the solution to identify the local means of the neighbor and removes the unwanted pixels in the images. Color of an image is represented by controlling colors red (R), green (G), and blue (B). So a colour image is referred to as an RGB image and R, G, B component are called color channels. Tone mapping can be done to all three color channels independently by performing the same operation three times. This method is widely used for global tone mapping and results in good color rendition. Pixels resembling to a given pixel need not necessarily be close to the pixel. Periodic pattern or the elongated edges appear in many images. The task of demising pixels which resemble the pixel in question is very tedious and one has to scan a vast portion of images to identify such pixels for elimination. On the other hand an NLM method as shown in Equation. 4 enable one to identify the portion of images to be searched for elimination. The classical Bayer pattern CFA image, first task is NLM demising filter is modified for to smoothen pixels of each colour channel by using a modified Gaussian mask. This alleviate the adverse effect of the amplified noise which may be prevent while measuring the similarity between neighboring and reference patch. Only neighboring patches with same pattern as the reference patch are considered to prevent any faulty inter-color similarity. In Equation 4. for a pixel i, the estimated weight is computed using $W_{k,i}$ and normalize the value by using $w_k(i,j)$.

$$\hat{x}_k(i) = \frac{1}{W_{k,i}} \sum_{j \in \tau(i)} w_k(i,j) y_k(j)$$

Where $W_{k,i} = \sum_{j \in \tau(i)} w_k(i,j)$ and

$$w_k(i,j) = \exp\left\{ -\frac{\|y_{k,i} - y_{k,j}\|^2}{2\sigma_y^2} - \frac{d(i,j)^2}{2\sigma_d^2} \right\} \quad \ldots\ldots\ldots (4)$$

3.5 . Proposed Algorithm

Input : Extremely Low light Video

Output: Enhanced Video Frames

Steps:

Level-1: Extract frame -Video shot V which is an array of frames $V[fr_0 ... fr_n]$

Level-2: Kalman Filter (Temporal Noise Reduction)

1. $\forall V[fr_0 ... fr_n]$
2. Compute Frame Difference to identify the noise
3. Apply Prediction process

   $$X = A_{x_{k-1}} + Bu_{K-1}$$

   $$p = APA^T + Q$$

4. Apply Correction process to reduce temporal noise
   - Compute Kalman gain

     $$K = pH^T (HpH^T + R)^{-1}$$

   - Update the image prediction

     $$x_k = X + K(z - HX)$$

   - Update the variance estimate:

     $$P_{x_k} = (I - KH)p$$

Level-3: Gray World (Tone Mapping)

1. Compute the average intensity value of Red, Green and Blue channel in a frame (R_{avg}, G_{avg} & B_{avg})
2. If the three intensity values($I_r(x,y)$, $I_g(x,y)$, $I_b(x,y)$) are identical then
3. the image satisfies the Gray world assumption

4. Else

   Keep $I_g(x,y)$ channel unchanged and define the gain for Red and Blue channel and adjust the $\mathbf{Ir(x,y)} = \propto \mathbf{Ir(x,y)}$ and $\mathbf{Ib(x,y)} = \beta \mathbf{Ib(x,y)}$ pixels

End if

Level-4: Non Local Mean Filter (Spatial Noise Reduction)

1. For Size of the frame[$fr_0 \ldots fr_n$]
2. For window row size
3. For window column size
4. For a pixel i, the estimated value is computed as $\mathbf{W_k(i,j)y_k(j)}$
5. Compute the cumulate sum $\sum_{j \in r(i)} \mathbf{w_k}\,(\mathbf{i,j})\mathbf{y_k}(\mathbf{j})$
6. End for
7. Calculate and cumulate the weight of the pixel within the search window
8. End for
9. Normalize the restored value to the sum of the weights

$$\mathbf{w_k(i,j) = \exp\{-\frac{\|y_{k,i} - y_{k,j}\|^2}{2\sigma_y^2}\}}$$

10. End for

Level-5: Enhanced Frame

4. EXPERIMENTAL RESULTS

The proposed method was tested on low light outdoor videos and also on the real low light video captured at night. The result of proposed methods is depicted in Figure 7 and Figure 8 Enhancement factors were effected by trial and error on the proposed algorithms. Gray world is among the simplest estimation methods. The main idea is that in a normal well color balanced photo, the average of all the three colors is neutral gray. As a result, we can estimate the illuminant color cast by looking at the average color and comparing it to gray. It is important to remove all intensity values from the image while preserving color values and it is also useful to remove shadows or lighting changes on same color pixels. The quality of video delivered by proposed system is much better in comparison with Kim[1] method. The proposed method eliminates the most of noise from input video frames delivered better quality output as compare to Kim[1] method.

The performance evaluation of the process is measured by the No- reference technique NIQE and GCF.

NIQE (Naturalness Image Quality Evaluator): It is a blind image quality assessment (IQA) model which assesses image quality without the knowledge of anticipated distortions. The quality of distorted image is expressed as a simple distance metric between the model statistic and those of distorted image. Smaller value of NIQE is a measure of better quality of the image.

GCF (Global Contrast Factor): A greater GCF is a measure of higher perceived contrast of the image. Generally HDR and less blurry images have higher GCF.

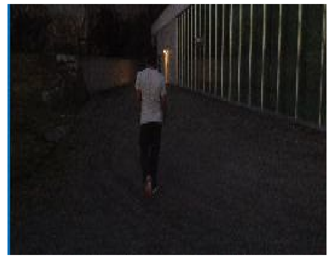

Figure 3: Video 1 (Luminance : 0.1 lux)

Figure 4: Video 2 (Luminance : 0.0221 lux)

GCF and NIQE value for Figure 7 and Figure 8 are given in Table 2, and charted in Figure 9 and Figure 10, it is clear that proposed method is superior to the other method for enhancing outdoor dark video in extremely poor lighting.

Table 1: Input Videos Properties

	Video 1: Luminance :0.105 lux	Video 2: Luminance:0.0221lux
Total No.of Frames	100	133
Width	1920	1920
Height	1080	1080
BitsPerPixel	24	24
VideoFormat	RGB24	RGB24
FrameRate	24	24
Duration	4.2500	5.6200

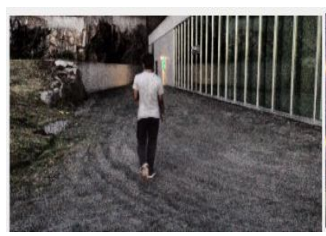

Figure 5:

Figure 6:

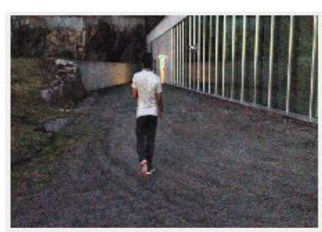

Figure 7:

Figure 8:

Figure 5, 6: Outcome using the Kim[1] for Video 1 and video 2
Figure 5, 6: Outcome of proposed method-Video 1 and video 2

Table 2: Performance comparison based on no reference objective metrics

	Metric	Input	M.Kim	Proposed
Video 1 Luminance 0.1 lux	NIQE	5.3262	3.4878	3.142
	GCF	2.8117	5.4916	6.5254
Video 2 Luminance 0.0221 lux	NIQE	8.9012	4.9616	4.5196
	GCF	1.6093	5.9839	6.4496

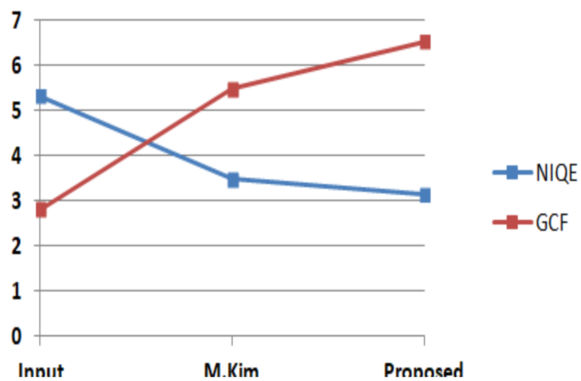

Figure 9: Video 1-No Reference Measures

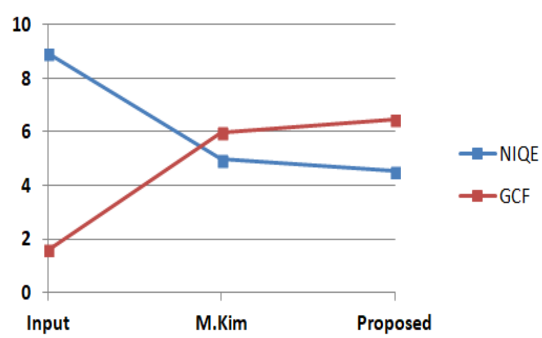

Figure 10: Video 2-No Reference Measures

5. CONCLUSION

In this work, we used an effective framework to enhance an extremely low light video. Kalman filter to remove temporal noise by comparing adjacent frames. Colour consistency gray world correction technique is used to enhance the dynamic range of video. Non local mean denoising filter reduces the spatial noise. The proposed algorithm is implemented using MATLAB R2016a. The objective analysis of NIQE and GCF indicate improved quality of video frame and high dynamic range. The possibility of denoising in frequency domain can also be tested in future research.

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