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State of the Art Analysis of Low Light Video Noise and Various Environmental Conditions for Enhancement

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Abstract: ***Noise present in the digital videos sequence during acquisition, coding, transmission and processing can be effectively removed only with a previous knowledge of noise origin. Hence we have to review the origin of noise in videos/images is a pre requisite to denoise the same. Videos have been captured under controlled or uncontrolled environment. Many researchers who are fervently engaged in enhancing of video images quality taken under different situations like low light ambience, sunny, rainy, snow, camera shake etc have come up with various technical ideas to improve the image quality. The scope of this paper is to make an analysis of the proposals to overcome video noise. An attempt is made to study the presently available algorithms widely used to enhance video images taken under different light condition.***

Keywords: Environment, Lighting condition, Lowlight, Noise.

I. INTRODUCTION

Noise is an inevitable part of the signal when images are captured in perceived light. When images are captured under low light conditions Signal-to-Noise Ratio (SNR) is bound to be low. Such noise can be broadly categorized as either Temporal Noise or Fixed Pattern Noise. Temporal noise is generated by the semiconductor devices used in the hardware. As we all know that the semiconductor devices generate more current through movement of micro electrons when temperature rises and this current being not part of the signals captured such currents cause unwanted signals which we term as noise. Temporal noise is one such signal. There is a definite relationship between the absolute temperature and temporal noise. On the other hand fixed pattern noise is due to variation of spatial property between pixels close to each other.

Impact of noise is that it greatly affects the image discrimination capability. It causes to enlarge the data size and results in difficulties when compression of image is attempted. Noise compromises transmission and storage efficiency. Surveillance cameras as installed to capture images under low light environment, noise reduction assumes paramount importance in transmission and storage of such video images. There are bound to be a large number of images captured under low light conditions in everyday life and work. Such images may be due to performance limitations of photography equipment as well. In both case noise reduction is absolutely necessary. The sure shot solution to such situations is to enhance low light images. Such enhancement improves visual effect and visual information of the images. Comparing to gray scale images, colour images contain a lot more information and the processing algorithm for colour image become more complex.

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II. LOW LIGHT CONDITIONS

Enhancing visibility of images captured under low light conditions is the prime pre requisite. The important parameters to be addressed of the camera used for such conditions are (i) ISO sensitivity (ii) aperture settings (iii) shutter speed. These elements decide visibility. ISO sensitivity is an algorithmic value which shows the image sensor's sensitivity to light. When the lighting of video is increased there is bound to be a proportionate increase in the light captured by the camera and this in turn increases noise as well. It is well known characteristic that low light video has large noise and low dynamic range. To reduce noise we have to address different sources of noise.

III. ORIGIN OF NOISE IN VIDEO FRAMES

Unwanted signals which creep in the image during acquisition or transmission of video images are defined as noise. One major cause for the induction of noise is corruption of pixels in the image. More this number more is the noise. We can list the various ways in which noise find its place in the video as:

- Deterioration of the quality of the imaging sensor due to environmental deterioration or variation at the time of image acquisition.
- Poor light levels also cause induction of noise. Sensors are sensitive to temperature. So when temperature raises sensor also produce excess electrons which results as noise because the signal due to electrons increase due to temperature is not from the image.
- When other signal interferes in the transmission channel noise is introduced.
- Sources of dust are yet another cause. When fine dust is present on sensor screen then that becomes another source of noise.

IV. CLASSIFICATION OF NOISE

A noisy video frame to be indicated as:

$$g(x,y) = f(x,y) + \xi(x,y)$$

Here *f(x, y)* stands for original video frame pixel, *x(x, y)* is the noise term and *g(x, y)* is the resultant which looks noisy

Fig 1. Original Video Frame

Noise in image sensor [1] [2] are referred as

- Random (Temporal) noise.
- Pattern noise.

A. Random Noise

Random noise is the main noise to be tackled. It is temporally random. By its name random means noise varies from frame to frame without any steady feature. By averaging successive frames it can be reduced. It follows statistical distribution laws.

B. Pattern Noise

Pattern noise is effectively a spatial noise. Pattern noise on the other hand is spatial noise and it does not vary drastically from frame to frame. So frame averaging technique for reducing this noise cannot be resorted to. Main sources of noise here are mismatch of in-pixel or column level transistors and dark current produced inside the pixel. Pattern noise has two major elements

- Fixed Pattern Noise (FPN)
- Photo-ResponseNon-uniformity noise (PRNU)

FPN is the factor of pattern noise calculated in the absence of illumination. PRNU is the component of pattern noise that depends on the illumination. The different video noises are shown in Table I.

The cause for FPN on images is due to the mismatch present in the manufacturing of in pixel transistors. Other sources of noise are threshold voltage variation of the reset transistor, the input gate of the source follower amplifier, charge insection from the reset transistor to floating diffusion. These random and fixed pattern noise include

C. Photon shot Noise

This arises due to natural variation of light (photon). It is found that photon collected from CCD (Charge Coupled Device) follow Poisson distribution pattern. So that we call the light fluctuations on the video frame is Photon shot Noise. Histogram of this noise follows Gaussian distribution. Variations of photon count from pixel to pixel are entirely uncorrelated with respect to spatial variation. So photon shot noise is known as white noise with a uniform appearance without any pattern.

D. Read out Noise

CCD captures the video signal and quantifies the same. The uncertainty introduces during this process is called Read out Noise. In the chain from capturing video signal by CCD and amplifying the signal there are many electronic devices such as sensel (Photosensitive part of a pixel or sensor element) readout, ISO gain, and digitization. All these semiconductor devices additional current due to change in temperature and the same is converted in to voltage an unwanted signal and it is called noise. The fluctuations in signal is proportional to the photon count. This noise is called read noise of the sensor. This read out noise is dominant under low light conditions. The noise histogram resembles Gaussian distribution.

E. Dark Current Noise/Thermal Noise

The silicon devices used in CCD when subjected to thermal variations produces electronics signal not relevant to the video is generated. This is called dark current noise. Dark current generated at a given temperature has a pattern resembling to Poisson distribution. Some pixels may have higher dark currents and produces fixed pattern noise. Spectral subtraction is used to eliminate FPN.

F. Quantization Noise

When the analog signal from sensor is digitized, the digitized value is rounded off to the nearest integer the resultant value differs from the actual signal and this error in the value is nomenclature as quantization error. Pattern of the histogram of this noise closely resembles Gaussian distribution.

V. LOW LIGHT ISSUES

The various problems related to low-light conditions are

- Video noise: This noise increases when ever gain of the amplifier increases.
- Streaking: If a bright spot caused by a candle, reflections, panning or zooming are present under low light setting they leads to streaks because the after-image of the bright spot lingers on the image.
- Blurred motion: If the shutter speed was reduced to overcome the low lighting it will result in blurred image in the video. Same is the fate if any motion like camera movement takes place.
- Poor focus: It is a challenge to focus under low light situations and camera's auto focus may also miss to correctly focus on the object.
- Spotlight look: when on-board spotlight is used by a video grapher to overcome low-light condition, it may prove beneficial if no other light is present. On the other hand if any other light is present it will project circles of light with sharp edge which may look annoying.

VI. HOW TO AVOID NOISE?

Table- I: Different Video Noise

	Noise	
Random Noise/Temporal Noise	Photon Shot Noise	
	Readout Noise	
	Dark Current/Thermal Noise	
	Quantization Noise	
Fixed Pattern noise		

Following are the ways to reduce noise:

Lower ISO: Higher ISOs increases noise levels. By maintaining right level of exposure lower ISO can give good result. A higher ISO can give low noise if DSLR cameras are used. DSLR cameras use high quality sensors

Larger Sensor: The quality of final image and degree of noise in the image are attributes of the size of camera's sensor. Sensor of camera is made of millions of photosites or light sensitive spots. These micro elements gather and record information captured in the camera lens. So a laser sensor is better suited to gather more information. It is seen that when the camera sensor is large we get a vastly improved quality image.

Expose Properly: Right exposure of camera captures the image totally and avoids unwanted objects resulting in the required signals. This reduces noise.

VII. ENVIRONMENTAL SCENARIO

There is video variation in the light due to various environmental factors [3]. Bright sun light may appear due to appearance of clouds in the sky, the light may dim at as the sun sets. The lighting conditions change during night due to flickering fluorescent lamps, frequently switching of bulbs or due to switching on and off of car lights etc. These changes cause very wide changes in the lighting pattern. Videos taken under such conditions vastly differ in quality. A detailed study on the video images was undertaken by varying the levels of illumination and environment both under indoor and outdoor conditions. For indoor experiment illumination was varied through either artificial lighting allowing sunlight in controlled way through windows or doors. In the outdoor the source of lighting is sunlight. Hence illumination of the images is affected by such environmental conditions. The illumination of the images is also affected to some extend by the quality of capturing system. Table II shows the video frames taken under different environmental conditions.

Out-door:

Outdoor condition is unpredictable. Poor visibility in view of changing weather situation adds to the woes of a video grapher when the equipment used like the camera is of interior quality. Poor illumination, low contrast, presence of noise, poor saturation and hue, disorderly detailing of objects, occurrence of shadows, irregular distribution of light, uneven brightness etc., are a few of the problems an outdoor video grapher often faces. If the video systems, camera etc are of superior quality to take images/videos in all weather conditions like dark night, rain, heavy snow and fog the images can be straight away used. Enhancement techniques outdoor image/video captured by camera as widely used in criminal investigation, sports analysis et al.

Indoor:

The major issues in indoor environment pertain to varying lights irregular lighting, glare, and reflections from objects etc. Main application of capturing indoor image is in film making, in medical applications. Imaging of internal organs with proper contrast is vital for diagnosis. It is also used in surveillance systems for face detection.

Images taken under lowlight indoor conditions details can be improved by blending the background. A drawback of indoor imaging is the noise introduced due to overhead lighting used. Algorithms are used to enhance resolution. Resolution reveals close details even in motion. In order to present images with high dynamic range retinex and to manage over exposure

Table- II: Name of the Table that justify the values

	Environmental outline	Frames	Issues take place	Illumination	Enhancement process	Description
Outdoor	Sunny		Shadow	Bright	Smoothing	To reduce sharp and bright section
	Cloudy		Dullness	Dimness	Image sharpening by HPF	To highlight fine details
	Climate Change		Snow	Low Contrast	Bilinear Interpolation HE	Enhance low contrast section to high contrast
			Rain	Noise	Morphological Component Analysis	Removal of patches of white noise by structuring elements
	Night		Level of darkness not known	Dark	Adaptive Contrast enhancement	Contrast enhancement in dim areas
Indoor	Ambient light		Darkens the outer section	Irregular illumination	Global illumination	Improving brightness through additional light sources
Capturing Device	Camera Shake		Motion Blur	Streak result	Deconvolution method	Depend upon blur kernel estimated

or under exposure HDR is helpful. It comes in handy in frame averaging, improving SNR, to deblur, denoise noisy videos. It also provides a range of controls to upgrade colour, compression artifacts, and host of deficiencies which plague images.

Capturing Device:

There is a part for capturing device in the preservation of video frame quality. There is no denial that components in capturing devices such as Flash Diffuser, Focus assist, etc. Main device namely lenses used its type and quality is very important in ensuring image quality. So, good quality lens are fundamental in capturing device. Even after ensuring the quality of lenses the quality of image is affected if the mode of setting is not proper. If the lens is not accommodated correctly that also affects quality. Focus adjustment of the camera dependent on the mode set in the camera. Mode setting is done based on the lighting available. In certain cases positioning of the camera can affect quality of the image exposed. When images are taken from a discomfited position the captured images may contain shadows and undesirable noise as well.

VIII. DOMAINS OF ENHANCEMENT

Video processing is done either under spatial-based domain or frequency-based domain [4][15] as shown in Fig 2. Spatial-based domain refers to the image plane itself. Approach under spatial domain is through direct manipulation of pixels of an image.

The theory of spatial-based domain approach is easy to understand. An advantage of this technique is that the time transform (DWT), and discrete cosine transform (DCT) are used for modifying spatial frequency spectrum. Advantages of transform-based video enhancement are many. They are (i) Less complexity of computations, (ii) it is easy to view and the image composition can be carried out by the frequency, and (iii) it is easy to apply special transform domain properties. Fig 4 shows the operation of frequency domain enhancement. To filter an image in the frequency domain compute F(u,v) the DFT of the image then multiply F(u,v) by a filter function H(u,v) finally compute the inverse DFT of the result. The current methods of video enhancement are broadly divided into two categories as shown in Fig 5: Self-enhancement and frame-based fusion enhancement. Conventional methods of video enhancement are enhancement of low quality video itself. It lacks ability to enhance background information. complexity is low and so real time implementation is easy. A major drawback in this method is that it lacks robustness and perceptibility, Fig 3 shows the operation of spatial domain enhancement. Frequency-based domain technique uses modified spatial frequency spectrum of the image. Various Fourier transform techniques like, discrete wavelet

Such as contrast enhancement method, HDR-based video enhancement, compressed-based video enhancement, and wavelet-based transform video enhancement. These methods are termed self- enhancement of low quality video. It does not have enough luminous in the poor quality video. The main cause for this situation is that in the dark video, some regions of the image are very dark so that the information in the video is irretrievably lost. In such a condition however best you may try to illuminate the region enhancement of the image is not possible. On the other hand frame-based fusion enhancement means such low quality video, which may fuse illumination information belonging to different time. This method extracts high quality background information. A survey of enhancement technique is shown in Table III.

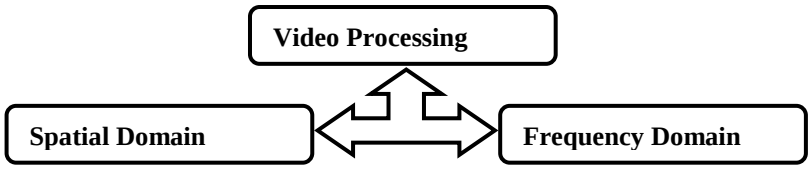

Fig. 2. Video Enhancement Techniques

Fig. 3. Spatial Domain Enhancement Operation

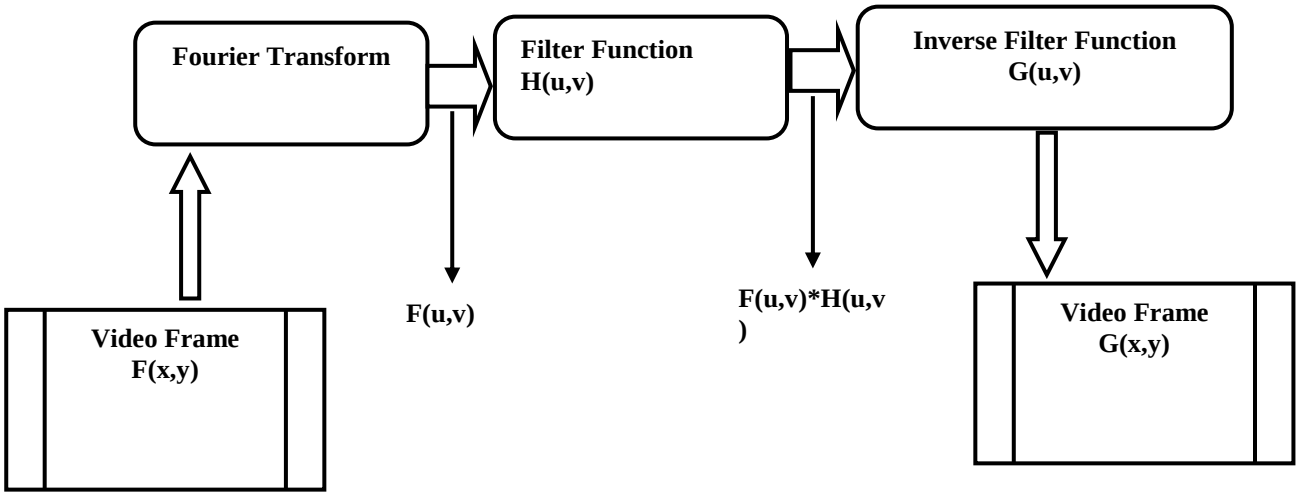

Fig. 4. Frequency Domain Enhancement Operation

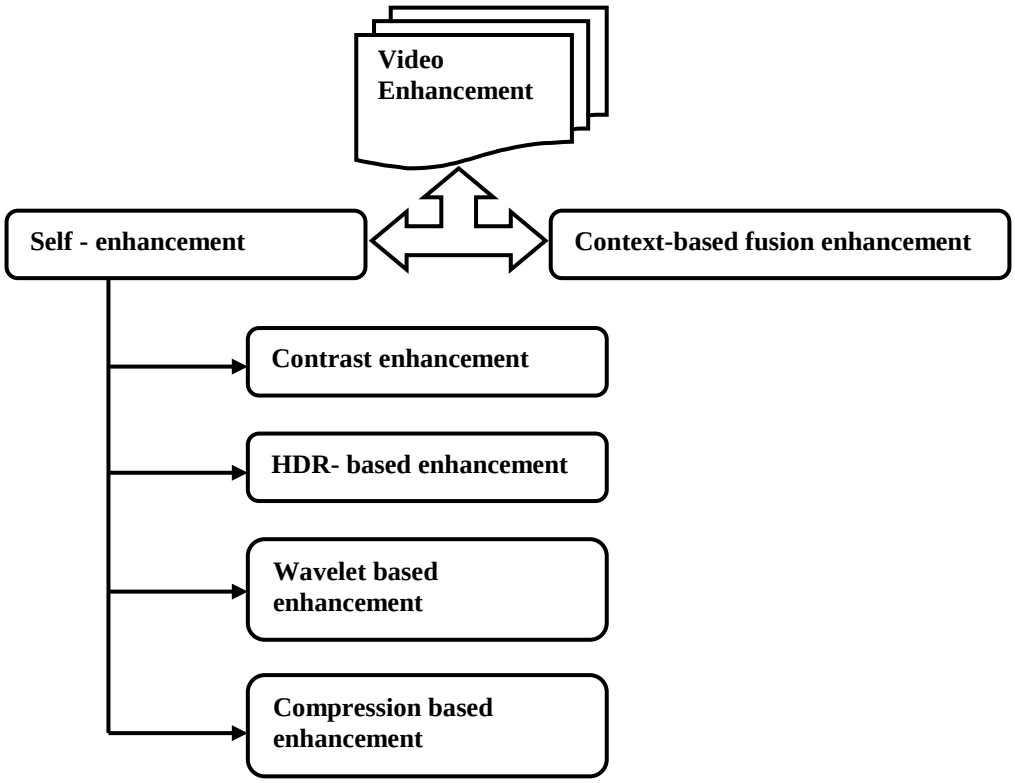

Fig. 5. video Enhancement cstegories

Table- III: A survey of video enhancement Techniques

Paper ID	Year	Processing Technique	Application
[5]	2017	Bilateral filter	Better smoothness for videos
[6]	2017	Histogram equalization and wavelet transform	Underwater image quality enhancement
[7]	2019	Improved retinex and mask-weighted least squares method	Enhancing night time image
[8]	2018	Camera response model and illumination estimation techniques	Naturalness-preserved low-light image enhancement
[9]	2018	Dual channel prior-based method	Improving video taken under poor intensity lighting
[10]	2019	Gradient thresholding airlight and weight-guided image filtering (WGIF)	Haze removal
[11]	2018	FastDeRain -directional gradient priors in combination with sparsity	Video rain streak removal
[12]	2010	Contrast LimitedAdaptiveHistogram Equalization(CLAHE)	Improving the visibility of surveillance videos degraded by fog and/or rain
[13]	2016	FACE (Fully Automated Context Enhancement)	Night surveillance videos
[14]	2015	Kalman Filter and NLM filter	Enhance extremely low light video

IX. CONCLUSION

Videos expose much attractive but valuable knowledge that can be much use to researchers in various ways. Videos are captured either under controlled environment or uncontrolled environment. So clarity of the video frames may prove to be unnatural due to visibility, atmospheric condition or capturing device used for surveillance imaging, so far the correct viewing and for using the information for further processing it is necessary to apply various techniques like deployment of general purpose and domain-specific algorithms to develop the video frames to a higher level of quality. This paper deals with possible noise that can occur in video frames and techniques to improve video frames. In addition various illumination methods are suggested for capturing videos either under heterogeneous situations or exposed conditions and different methods for improving the videos taken under various conditions of lighting.

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