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Review of Impulse Noise Removal from Digital Video

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Abstract: With the advancement in communication and information technology, legacy system are replaced by high speed computer as a result of this the world is shifting from analog to digital systems. Now, it is possible to transmit the digital videos over a communication channel and vice versa. Color video processing systems are used for a variety of purposes ranging from capturing scenes, processing of frames for feature extraction etc. Digital videos are generally contaminated by noise. Impulse noise is one such noise which may corrupt the frames of a digital video during acquisition, transmission over a noisy channel or in storage etc. This paper discussed in details about the color video processing and various schemes for removal of impulse noise for digital video.

Keywords: Digital video, Frames, Impulse noise

I. INTRODUCTION

Environment is one of the rich resources of information available for humans and the major portion of the information is available in visual form and analysing visual information by human is referred as understanding. The same is applicable to computers as well; the process of receiving and analysing visual information by a computer (digital) is called as digital image processing. In comparison with legacy system, recent computers are more powerful and the hardware and software requirements for digital image processing can be fulfilled. Video processing is a particular case of signal processing, where the input and output signals are video files or video streams. Video processing is the extension of image processing. A digital video is comprised of a number of images called frames. The frames are extracted from the videos and processed independently or in combination with the neighbouring frames.

II. DIGITAL IMAGE AND DIGITAL IMAGE PROCESSING

An image I may be defined as a 2D function $f(i, j)$ where i and j are spatial (plane) coordinates and the amplitude of f at any pair of coordinates (i, j) is called the intensity or gray level of the image at that point. $I = f(i, j)$. Where $i = 0$ to M and $j = 0$ to N for an image of size MN. When i, j (spatial coordinate) and the amplitude values of f, all are finite and discrete quantities then we call the image a digital image [1]. Digital images are 2D representation of the real world 3D scene.

When f is vector valued function i.e. the values of three color components are pasted together the image is called multichannel or color image [2].

$$\boldsymbol{f}(i,j) = \begin{bmatrix} R(i,j) \\ G(i,j) \\ B(i,j) \end{bmatrix}$$

Digital image processing refers to processing of a digital image by computer means. It encompasses the processes whose inputs and outputs are images and, in addition, encompasses the processes that extract attributes from images. For image processing, the analog image is digitized through sampling and quantization process that is called digitization. Each sample of the image is called a pixel. Sampling method can affect the size and details of the image. The quantization process converts the continuous or analog data into discrete data, which refer to brightness value of each pixel [3].

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III. Applications of Digital Image Processing

Digital image processing and analysis techniques are used today in a variety of problems. Many of the application oriented image analyzers are available and working satisfactory in real environment. The followings are a few major application areas [2].

1. Bio-medical: ECG,EEG,EMG analysis, cytological, histological and stereological application, automated radiology and pathology, X-ray image analysis, mass screening of medical image such as chromosome slides for detection of various diseases, mammograms, cancer smears, CAT, MRI, PET, etc.
2. Scientific Application: High energy physics, bubble chamber and other forms of track analysis, etc.
3. Criminology: Finger print identification, human face registration and matching, forensic investigation, etc.
4. Military Application: Missile guidance and detection, target identification, navigation of pilotless vehicle, reconnaissance, and range finding, etc.

IV. Noise in Digital Images and Videos

Noise is one of the common problems in digital image and videos, generally digital images and videos are contaminated by noise because noise can appear during the process of capturing, transmitting, storing or manipulating of an image [4]. Following are the most common sources of noise:

1. Video cameras & Video recorders, which are used for producing or recording.
2. Conversion of image from optic to electronic presentation.
3. During transmission

The noise types that appears in images and videos, most commonly and visible by human vision are:
Impulse Noise: This type of noise is presented as wrong data in values of some pixels in an image or frame of a video. It is usually caused by transmission and manipulating errors, as well as due to faulty sensors. So it may be correlated as well as uncorrelated.
Gaussian Noise: This is also known as electronic or white noise. It is frequent to find it with other types of noise. This noise affects the whole image, because each pixel is corrupt in image. It is a correlated noise by nature because being electronic, affects three channels. It is common that an image is corrupted by this noise in case of video cameras, video coders and television.
Double Exponential Noise: This is the result of acquisition of image by laser. In optics community, it is also known as lunar of laser because image presents small disturbances as small spots. This type of noise appears only during acquisition, and for this reason it is correlated.
Film grain Noise: This is a function of detection/recording mechanism of an image and it describes the intrinsic noise produced by the photographic emulsion during this process. For the most practical purposes, it is effectively modelled as a Gaussian process (white noise). The randomness is introduced by the variable number of photons required to expose a particular grain and by variable size of the grain.

V. Noise Models

In many practical situations, images (or frames) are corrupted by impulse noise caused by faulty sensors and transmission errors. The impulse noise is often generated by bit errors, especially during the acquisition or transmission over a noisy channel. The color image (or frame) corrupted by impulse noise is shown as

$$x_{i,j}^{(k)} = \begin{cases} o_{i,j}^{(k)}\ with\ probaility\ (1-p) \\ n_{i,j}^{(k)} with\ probabilty\ p \end{cases}$$

Where (i,j) denotes the spatial coordinates of digital image $\boldsymbol{x}$ and k denotes the color channel which varies from 1 to 3 for color images. The contamination component $n_{i,j}^{(k)}$ is a random variable and $o_{i,j}^{(k)}$ shows the original pixel component. p is noise density per channel. In this article we are discussing three different models for impulse noise, which is called as:

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1. Impulse Noise Model-1 (Salt and Pepper Noise with equal probabilities):

In this model $n_{i,j}^{(k)} = \begin{cases} 0 & with\ prbability\ \frac{p}{2} \\ 255 & with\ probabilty \frac{p}{2} \end{cases}$

This is a special case of uniform or random valued impulse noise, as this noise can take on only two values 0 or 255 with same probability, assuming 8-bit per channel color image representation. Complete expression for an image corrupted by this noise model is given by:

$$x_{i,j}^{(k)} = \begin{cases} o_{i,j}^{(k)} & with\ probability\ (1-p) \\ 0 & with\ probabilty\ \frac{p}{2} \\ 255 & with\ probaility \frac{p}{2} \end{cases}$$

2. Impulse Noise Model-2 (Salt and Pepper Noise with different probabilities):

In this model $n_{i,j}^{(k)} = \begin{cases} 0 & with\ prbability\ p1 \\ 255 & with\ probabilty\ p - p1 \end{cases}$

This is a also a special case of uniform or random valued impulse noise, as this noise can take on only two values 0 or 255 but probabilities of both may be different. An image corrupted by this noise model is shown by:

$$x_{i,j}^{(k)} = \begin{cases} o_{i,j}^{(k)} & with\ probability\ (1-p) \\ 0 & with\ probabilty\ p - p1 \\ 255 & with\ probaility\ p1 \end{cases}$$

Where $p>p1$ and $p1$ shows the probability of salt.

3. Impulse Noise Model-3 (Random Valued Impulse Noise):

In this model $n_{i,j}^{(k)}$ ϵ [0,255] Noise can take any value from 0 to 255 for 8-bit images. Noise values are uniformly distributed random numbers in the dynamic range of the image.

VI. PARAMETERS TO DETERMINE IMAGE AND VIDEO QUALITY

The quality of a restored image depends on the degree of similarity between restored image and actual image. The measure of this similarity is based on the difference in statistical distribution of pixel values. Certain parameters used to determine subjective quality of an image are as under:

1. MSE (Mean Square error) Criterion*:* It measures the average value of the square of error between approximated values and desired values as follows

$$MSE = \left(\frac{1}{\mu MN}\right) \sum_{i=1}^{M} \sum_{j=1}^{N} ||\boldsymbol{z}_{i,j} - \boldsymbol{o}_{i,j}||_2^2$$

Where $\boldsymbol{z}_{i,j}$ and $\boldsymbol{o}_{i,j}$ are the pixel values of pixel at location (*i*,*j*), in the restored image and original image of size $M \times N$. $||.||_2$ denotes the Euclidean distance between pixels and µ denotes the number of color channels which is 3 for color images. For a filtered color video, MSE for each frame is calculated and then an average over all filtered frames is taken to calculate MSE of overall video.

2. PSNR (Peak Signal to Noise Ratio) Criterion**:** PSNR is defined as the ratio of maximum possible power of a pixel to the power of corrupting pixel that affects the fidelity of its representation. It is expressed in the logarithmic decibel scale.

$$PSNR = 10\ log_{10}(\frac{255^2}{MSE})$$

Where MSE is the mean square error of restored image or video.

3. MAE (Mean Absolute Error) Criterion: It measures the average value of absolute differences by which a pixel in restored image differs from the desired one.

   Where $\boldsymbol{z}_{i,j}$ and $\boldsymbol{o}_{i,j}$ are the pixel values of pixel at location (*i*,*j*), in the restored image and original image of size $M \times N$. Here |.| denotes city block distance between pixels. For a filtered color video, MAE for each frame is calculated and then an average over all filtered frames is taken to calculate MAE of overall video.

4. NCD (Normalised Color Difference) Criterion*:* Since RGB is not a perceptually uniform Color Space in the sense that differences between colors in the space do not correspond to color differences as perceived by humans, the restoration errors are often analysed using perceptually uniform color spaces. So CIELAB color space is used. NCD criterion using this color space is used to evaluate the color distortion in the perceptual way to humans [5].

$$NCD = \frac{\sum_{i=1}^{M}\sum_{i=1}^{N}\left([L_z^*(i,j)-L_o^*(i,j)]^2+[a_z^*(i,j)-a_o^*(i,j)]^2+[b_z^*(i,j)-b_o^*(i,j)]^2\right)^{\frac{1}{2}}}{\sum_{i=1}^{M}\sum_{j=1}^{N}([L_o^*(i,j)]^2+[a_o^*(i,j)]^2+[b_o^*(i,j)]^2)^{\left(\frac{1}{2}\right)}}$$

Where L_o* denotes the luminance and a_o*,and b_o* denotes the chrominance value of original image pixel while L_z*, a_z*,and b_z*denotes the luminance and chrominance values in filtered image at pixel. For a restored color video, average NCD over all filtered frames is computed.

VII. CONCLUSION

There are various methods available, which are used for removing the noise from a digital video. As we discussed various noised models and different type of noise but based on literature survey. We need a three dimensional hybrid filters which utilizes the advantages of component-wise approach along with the vector processing techniques to restore brightness and color independently, in addition with the use of detector and temporal information available from neighbouring frames.

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