International Journal of Image Processing and Vision Science

Volume 1 | Issue 1 Article 12

July 2012

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S. Anusha
Chaitanya Engineering College, Vishakapatnam,(A.P)., anushasmahanthi@gmail.com

Hemanth Kumar
Chaitanya Engineering College, Vishakapatnam,(A.P), h.k@gmail.com

S. K.P. Chaitanya
Chaitanya Engineering College, Vishakapatnam,(A.P), skpchaitanya@gmail.com

A Hybrid Filter with Impulse Detection for Removal of Random Valued Impulse Noise from Colour Videos

S.Anusha , Mr.Hemanth Kumar , S.K.P.Chaitanya

M.Tech in Digital Electronics & Communication
Chaitanya Engineering College,
Vishakapatnam,(A.P).
anushasmahanthi@gmail.com

Abstract : This paper presents a three dimensional hybrid filter to remove random valued impulse noise from colour video sequences. The switching median technique is utilized to protect noise free isolated pixels from filtering so as to avoid blurring of frames. The restoration of noisy pixels is done by brightness information obtained from median filtering and chromaticity information is obtained from vector directional filtering. This hybrid filter is applied in three dimensional sliding window where spatial as well as temporal information about neighbourhood is available for restoration of frame under consideration. Only noise free pixels of three dimensional sliding window are used for restoration of frame under consideration. Simulation results show that the proposed three dimensional hybrid filter yields superior performance in comparison to other filtering methods

Keywords— Colour video filtering, Impulse detector, Random valued impulse noise, Median filtering, Vector directional filtering.

I. INTRODUCTION

Impulse noise is often introduced into frames of videos during acquisition and transmission. Based on noise Values, it can be classified as easier –to-remove salt and pepper noise and more difficult random valued impulse noise [2]. We focus on removing the latter. Several filtering methods have been proposed for the removal of impulse noise from colour images using different approaches. Most of these techniques use vector processing approach as it is widely accepted that it is more appropriate than component-wise filtering approach, which can generate colour artefacts in filtered images. The vector median filter (VMF) [3], vector directional filter (VDF) [4], and the distance directional filter [5] are most commonly used vector filters for noise removal from colour images. The main drawback of applying component wise filtering is that inherent correlation among different channels may be lost, resulting into colour artefacts.

Often, the filtering operation is preceded by an impulse detection stage separately, which ensures that only the noisy pixels are filtered. This prevents blurring which is caused by filtering of noise-free pixels. Filtering of only noisy pixels results into better preservation of detail features. Most of the impulse detection methods available in literature require a threshold value to make a decision whether the pixel under consideration is noise free isolated pixel or an impulse. The decision of filtering is based on neighbouring pixels

Further, to overcome the problem of colour artefacts in component-wise filtering scheme, colour of filtered pixel may be restored separately using some suitable colour correction method. For colour correction a VMF is followed by VDF to obtain the angle information in [7] for restoration of corrupt pixel the scheme uses a vector approach for both detection as well as for filtering. However, in [9] it has been shown that component-wise filtering approach provides a better estimate for magnitude of filtered vector and prevents blurring caused by changes in noise free components. In the proposed work the impulse detection is done using switching median technique [8] and we generalize the filtering scheme proposed in [9] resulting in a three dimensional hybrid filter which can be used for impulse noise removal from colour videos. Generalization of some basic filters to three dimensions is given in [6] but our generalised hybrid filter yields much better peak signal to noise ratio (PSNR), mean absolute error (MAE) and normalized colour difference (NCD).

II. IMPULSE DETECTION

The impulse detection is based on the assumption that a noisy pixel takes a value which is substantially different than the neighbouring pixels in the filtering window, whereas noise-free regions in a frame have locally smoothly varying values separated by edges.

Let **x**i,j,t ={ xi,j,t (1), x i,j,t (2) , xi,j,t (3)} be a multichannel pixel in RGB colour space at location (i,j) in tth frame of video **I**, which is corrupted by random valued impulse noise. If noise density is p, then observed pixel is given by,

$$\mathbf{x}_{i,j,t} = \begin{cases} \mathbf{o}_{i,j,t} & with\,probability\ (1-p) \\ \mathbf{n}_{i,j,t} & with\,probabilty\ p \end{cases} \quad (1)$$

Where **o**i,j,t and **n**i,j,t represents the original and noisy pixels respectively at location (i,j) in tth frame. Consider a three dimensional sliding window consisting of pixels {**x**i‘,j‘,t‘} , where |i-i‘|≤1, |j-j‘|≤1, |t-t‘|≤1. Output of detector is represented in terms of a flag image {***f***i,j,t} where,

$$f_{i,j,t}^{(k)} = \begin{cases} 1: \ if \ x_{i,j,t}^{(k)} - median\left(W_{3\text{x}3\text{x}3}^{(k)}\right) \geq Tol^{(k)} \ for\ k = 1\ to\ 3 \\ 0: \ otherwise \end{cases} \quad (2)$$

Here $f_{i,j,t}^{(k)} = 1$ implies that kth component of **x**i,j,t is noisy and *Tol(k)* is some suitable threshold based upon the difference of maximum and minimum intensity levels in kth colour component of a frame. Threshold may be different for different components decided separately for each component. Further, the median function used takes the component-wise median of pixel values of all 27 pixels present in the filtering window. Value of k varies from 1 to 3 for colour videos, each for a colour channel. This is switching median type detector generalized in three dimensions for impulse noise detection in frames of a colour video. Neighbours in previous and next frames provide temporal information for the current pixel and hence must be taken into consideration.

III. FRAME RESTORATION

During frame restoration the pixels observed noisy are filtered. The pixels in neighbourhood of current pixel, identified as noisy must not be used in filtering as they provide no relevant information about current pixel. Further, it is well known that VDF can provide best possible colour information about the filtered pixel. However the magnitude of filtered vector obtained through VDF is not very reliable. Therefore, we must use the colour information provided by VDF in form of directions of filtered pixel vector, while magnitude information is obtained by median filter i.e. by component-wise approach, which provides a very good estimate of pixel magnitude because noise in one component does not affect the magnitude of other components but the chromaticity of the pixel is affected which can be approximated by VDF. Therefore a good estimate of brightness as well as chromaticity can be found using this hybrid filter. Let **v**i,j,t=(vi,j,t(1),vi,j,t(2),vi,j,t(3)) be the output of three dimensional generalized vector directional filter for a noisy pixel , i.e.

vi,j,t= VDF{Wm} (3)

Where Wm contains only noise free pixels of for which flag {***f***i,j,t} =0. Let **u**i,j,t=(ui,j,t(1),ui,j,t(2),ui,j,t(3)) be the output of video median filter applied on noise free pixels of three dimensional filtering window i.e.

ui,j,t(k)= *median*({Wm(k)}) for k=1 to 3 (4)

Then final output of the three dimensional hybrid filter will be

$$z^{(k)}_{i,j,t} = \begin{cases} v^{(k)}_{i,j,t} \times \frac{\|u_{i,j,t}\|}{\|v_{i,j,t}\|} \quad if\ f^{(k)}_{i,j,t} = 1; \\ x^{(k)}_{i,j,t}, otherwise \end{cases} \quad for\ k = 1 to\ 3 \qquad (5)$$

The function ||.|| calculates the magnitude of vector and for a pixel in vector notation represents the intensity value of pixel. The final output of filter has the colour as obtained by generalized vector directional filter (GVDF) and brightness obtained by video median filter (VGMF) after impulse detection through three dimensional switching median detector. This frame restoration technique utilized spatio-temporal information about neighbourhood of current pixel in combination with the available filtering methods. The function ||.|| calculates the magnitude of vector and for a pixel in vector notation represents the intensity value of pixel. The final output of filter has the colour as obtained by generalized vector directional filter (GVDF) and brightness obtained by video median filter (VGMF) after impulse detection through three dimensional switching median detector. This frame restoration technique utilized spatio-temporal information about neighbourhood of current pixel in combination with the available filtering methods.

IV. SIMULATION RESULTS

To access the performance of the proposed method, we compare it with several methods, video vector median filter (VVMF), generalised vector directional filter (GVDF), video generalised directional distance filter (VGDDF), video median filter (video-MF), video switching vector median filter (VSVMF), generalised switching vector directional filter (GSVDF), video switching median filter (VSMF). The video sequence used in simulation is ‗Salesman' in which size of each frame is 176144. The first 16 frames were extracted for filtering, each corrupted by uncorrelated random valued impulse noise of 20% noise density. The hybrid filter is applied from frame no. 2 to frame no.15. The criteria used to compare the performance of various filters are peak signal to noise ratio (PSNR), mean absolute error (MAE) and normalised colour difference (NCD). The average value of mean square error (MSE), average MAE and average NCD over this length of 14 filtered frames of video sequence is computed. Peak signal to noise ratio is computed from average MSE. For a single frame these parameters are defined as:

$$PSNR = 10log_{10}\left(\frac{255^2}{\left(\frac{1}{3MN}\right)\sum_{i=1}^{M}\sum_{j=1}^{N}\|\boldsymbol{z}_{i,j}-\boldsymbol{o}_{i,j}\|_2^2}\right) \qquad (6)$$

$$\text{MAE}=\sum_{i=1}^{M}\sum_{j=1}^{N}|\boldsymbol{z}_{i,j,}-\boldsymbol{o}_{i,j}| \qquad (7)$$

TABLE I COMPARISON OF PERFORMANCE IN TERMS OF PSNR, MAE AND NCD FOR VIDEO SEQUENCE ‗SALESMAN'

Restoration Method	PSNR	MAE	NCD
VVMF	27.749	5.8086	0.051371
GVDF	25.063	7.3505	0.058371
VGDDF	27.665	5.8277	0.050121
Video-MF	27.768	5.8452	0.063546
VSVMF	29.081	2.6982	0.021567
GSVDF	27.553	3.0697	0.022994
VSMF	29.174	2.7112	0.023913
Proposed Hybrid Filter	**29.769**	**2.1174**	**0.017603**


(a)


(b)


(c)


(d)

(e)

(f)

(g)

(h)

(i)

(j)

Fig.1. Restoration performance of different filters applied on the 5th frame of _Salesman‘ Test video sequence (a) original frame, (b) noisy frame corrupted by 20% random valued impulse noise, (c) VVMF, (d) GVDF, (e) VGDDF, (f) Video-MF, (g) VSVMF, (h) GSVDF, (i) VSMF (j)Proposed hybrid filter

Where $Z_{i,j}$ and $O_{i,j}$ are the pixel values of pixel at location (i,j), in the filtered and original frame of test video sequence. The frame size is *MN* and maximum intensity level in each colour channel is 255. ||.|| denotes the Euclidean distance between pixels and |.| denotes city block distance between pixels.

$$NCD = \frac{\sum_{i=1}^{M}\sum_{i=1}^{N}([L_z^*(i,j) - L_o^*(i,j)]^2 + [a_z^*(i,j) - a_o^*(i,j)]^2 + [b_z^*(i,j) - b_o^*(i,j)]^2)^{\frac{1}{2}}}{\sum_{i=1}^{M}\sum_{j=1}^{N}([L_o^*(i,j)]^2 + [a_o^*(i,j)]^2 + [b_o^*(i,j)]^2)^{\left(\frac{1}{2}\right)}} \quad (8)$$

V. CONCLUSIONS

This paper has proposed the generalization of hybrid colour image filtering method for restoration of colour video sequences. The filter uses the component-wise filtering to preserve the brightness information which may result in colour artifacts that are removed by using color information provided by VDF. The use of impulse detector improves the results as it avoids blurring of frames as well as it limits the use of noisy pixels in filtering which may affect the results to a great extent. The hybrid filter presented here is different from that presented for colour images as it also utilises the temporal information about the current frame which is unavailable in case of 2D colour image. This spatio-temporal hybrid filtering results in better subjective quality of video in terms of PSNR, MAE and NCD.

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