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Block Based Video Stabilization

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ABSTRACT: Movement of hands or camera while capturing video leads to unstable video. To stabilize those unstable videos many approaches are proposed. Out of those, Digital Video Stabilization consists of Motion Estimation, Padding & Histogram Equalisation and Motion Compensation. In the block based method the frame is divided into 16*16 square block called Macroblock. Motion Estimation is the process of finding particular macroblock of previous frame into current frame. For this block matching criterion are used. This paper uses Sum of Absolute Difference (SAD). Block Matching Algorithms suggests where to apply this SAD in the macroblock. This paper uses Full Search or Exhaustive Block matching Algorithm (EBMA). Using this block matching algorithm, motion vectors are calculated. Padding is the process of keeping these motion vectors within certain range. Histogram equalisation of motion vectors try to uniform these motion vectors.In motion compensation macroblocks are adjusted according to motion vectors to obtain stabilized frame.

KEYWORDS: Motion Estimation,Sum of Absolute Difference (SAD), Full Search Algorithm, Motion Vectors, Motion Compensation, Interframe Transformation Fidelity (ITF).

I.INTRODUCTION

The multimedia techniques now has become so advanced and are so readily available that videos can be taken from even mobiles.But, when capturing videos from these devices or even from high quality cameras video becomes shaky because of movement of hands of person capturing video. The another reason for video becoming shaky is that cameras itself are in motion. e.g. video taken from unstable platform.

So, to stabilize these kind of shaky videos firstly mechanical stabilization was used. In this cameras are put on mechanical devices such as tripod and gyros. The latest gyros use MEMS which involves use of vibratory gyroscope. [1] Then optical video stabilization technique was evolved which uses some mechanical device to incident light rays properly on the sensor, which would have fell rather than sensor if that mechanical device would not have been used. [2] In both mechanical and optical techniques it can be seen that some mechanical device is used which needs space for embedding which is difficult to manage in case of small multimedia devices like mobile. Also, optical technique is quite expensive when compared to latterly evolved and latest technique called digital video stabilization. [3] It doesn't use any mechanical device. It lets shake of a camera to take place (obviously if taking place) to let user freely capture videos (which wasn't possible in mechanical and optical techniques which restricted shake of camera to take place putting restrictions on user to freely capture videos). And then corrects shakiness in the captured video (if any) after full video is taken.

The digital video stabilization technique shown in fig. 1 considers motion estimation, histogram equalization of motion vectors and Motion Compensation. In motion estimation current frame is compared with previous frame to find best matching block by using block matching criteria to calculate motion vectors for that block. Padding & Histogram equalization of motion vectors keeps motion vectors within particular range and uniformally distribute them. In motion compensation frame is adjusted according to motion vectors and also compensation of prediction error is done.

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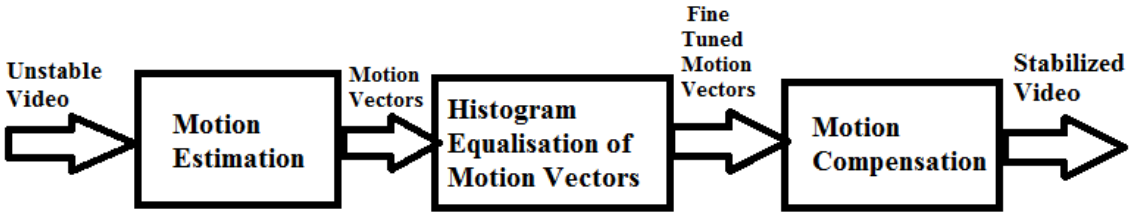

Fig. 1 Digital Video Stabilization Aproach

II.MOTION ESTIMATION

In case of shake of camera taking place, location of particular object in the previous frame of video shifts to somewhere else in the current frame. The amount by which shifting of location of that particular object has taken place between previous and current frame is called motion vector. The goal of any motion estimation technique is to calculate these motion vectors.

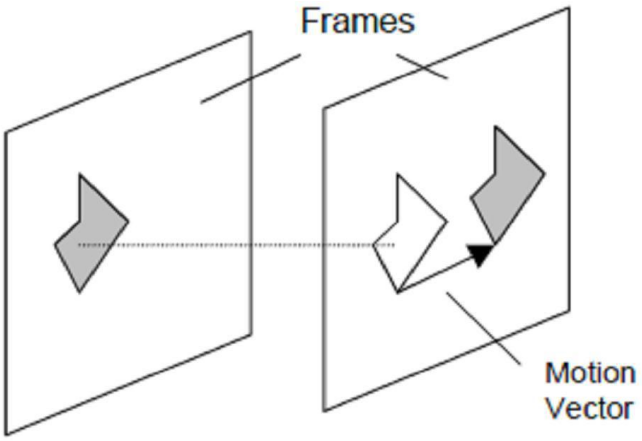

Fig 2. Motion Estimation and Motion vectors

Block based approach divides each frame of video sequence into 16*16 blocks called macroblock. [4] But, to find motion vectors, we have to firstly search where that particular macroblock in previous frame has now been shifted in the current frame. [5] This process is called Block Matching and depends on the values of block matching criteria. To get the best match of macroblocks, the block matching criteria's value should be minimum. There are many block matching criterion but due to its simplicity, generally Sum of Absolute Difference (SAD) is used. [6] Depending upon which points in the macroblock, the block matching criterion is to be applied, various Block Matching Algorithms (BMA) are proposed over the time. There are many block matching algorithms but this paper considers Full Search Algorithm because it gives best PSNR (Peak Signal to Noise Ratio) and ITF (Interframe Transformation Fidelity) but no. of search points are very high compared to other methods. In Full Search, SAD is applied over the whole frame from left to right and top to bottom.

The absolute of difference of the pixels between current and previous frame at first point in macroblock is calculated. Then sum of these absolute differences at each point in the whole macroblock is calculated. As stated earlier, this SAD value should be minimum to find best macroblock. And this procedure is repeated for each macroblock until the corresponding macroblock is found in the current frame.
Formula of Sum of Absolute Difference is given by:

$$SAD = \sum_{i=0}^{N-1} \sum_{j=0}^{M-1} |fcurrent(j,i) - fref(j + \mathrm{Vx}, i + \mathrm{Vy})|$$

Where, N= height of block

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M= width of block
i= index of horizontal direct
j= index of vertical direction
V_x, Vy= motion vectors of reference block
$f_{current}(x,y)$= pixel intensity at current block
$f_{ref}(x,y)$= pixel intensity of reference block

III.PADDING AND HISTOGRAM EQUALIZATION OF MOTION VECTORS

Due to motion estimation, motion vectors were obtained. In other words, motion vector is the vertical displacement of pixel emerged due to the shaking of camera. It is desired that these motion vectors should be within particular range called motion vector range. But, if the handshaking is vigorous the motion vectors obtained will have higher displacement exceeding this motion vector range. So, it is desired that these motion vectors should be brought within the motion vector range. Also, they should be as uniform as possible so that the motion compensation procedure doesn't become tedious. The motion vectors are kept within motion vector range using padding procedure and the uniform motion vectors are obtained by using histogram equalization Padding procedure simply copies the peripheral part of block to form a new column and row to its adjacent area. Now, in the histogram equalization procedure is applied to motion vectors to obtain uniform motion vectors for the ease of procedure of motion compensation. The idea comes from a well known procedure of histogram equalization to improve contrast of an image. In this procedure, brightness or darkness which has been accumulated at particular region is fairly made uniform to improve the contrast of an image. In the similar manner, motion vectors will be made as much uniform as possible.

IV.MOTION COMPENSATION

Motion compensation does two things. Firstly it reconstructs the frame according to motion vectors obtained through previous processes. And also compensate for prediction error. In reconstruction of frame, first of all, macroblock in previous frame is simply copied to same position in current frame. And then according to the motion vectors obtained from previous procedures it is shifted to a new position in current frame. This procedure is done over all the macroblocks to reconstruct current frame.

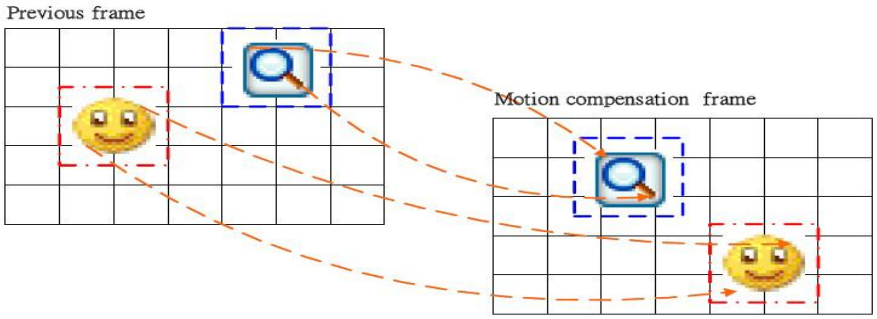

Fig 3. Motion Compensated Frame

Suppose, if any new object comes into the scene in the current frame which was not present in the previous frame, then SAD values over the macroblocks in the region of new object suddenly comes very high which should be actually minimum as possible. Hence, the current frame is unable to find its matching macroblock in the previous frame. This is called as prediction error and motion estimation and motion compensation jointly compensates this prediction error. The motion estimation described early also does one thing apart from its job of calculating motion vectors. It calculates the difference between the previous frame's pixel value and that of current frame consisting of new object. (i.e. the frame which would have been considered as the current frame if new object would not have come into the scene) And in motion compensation process, it adds the obtained difference in motion estimation process to the pixel value of current frame with that new object to form new current frame compensating the prediction error.

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This current frame obtained at the end of all the procedures acts as the previous frame for next or future frame. And whole procedure of motion estimation, padding, histogram equalization and motion compensation is repeated over all the frames to get the stabilized video.

V.VIDEO STABILIZATION QUALITY STANDARDS

The very basic video stabilization quality standards are Mean of Squared Error (MSE) and Mean of Absolute difference (MAD). MAD is rarely used as the quality standard and MSE is an old quality standard. These both are block matching criterion also which can be used like SAD in block matching process. MSE is given by: [7]

$$\mathrm{MSE} = \frac{1}{\mathrm{N}^2}\sum_{\mathrm{i}=0}^{\mathrm{N}-1}\left(\mathrm{C_{ij}} - \mathrm{R_{ij}}\right)^2$$

Where N= width or height of macroblock

C_{ij} = Pixels compared in current macroblock

R_{ij} = Pixels compared in previous macroblock

Peak Signal to Noise Ratio (PSNR) is most popular and widely used video stabilization quality standard. To calculate PSNR, MSE has to be calculated. PSNR is given by:

$$\mathrm{PSNR} = 10\log_{10}\left[\frac{(\mathrm{I_{max}})^2}{\mathrm{MSE}}\right]$$

Where, $\mathrm{I_{max}}$ = max value of intensity of pixel

This paper has used Interframe Transformation Fidelity (ITF) which is recent video stabilization quality standard and is based on PSNR. ITF is given by: [8]

$$\mathrm{ITF} = \frac{1}{\mathrm{N_{frame}} - 1}\sum_{\mathrm{k}-1}^{N_{frame}\ -1}\mathrm{PSNR(k)}$$

Where,

PSNR (k) =PSNR between current and previous frame

$\mathrm{N_{frame}}$ = no. of frames in video

VI.EXPERIMENTAL RESULTS

Various videos were tested on MATLAB while performing experiments. Every video was tested with different frame numbers. The first graph is of vertical displacement of the pixel v/s frame number. It shows how the vertical displacement of the pixels (motion vectors) occurred through each frame. The second and more important graph is of ITF values v/s frame number. ITF of output video is compared with that of that of unstable i.e. shaky input video at a particular frame and this for all frames is shown in graph.

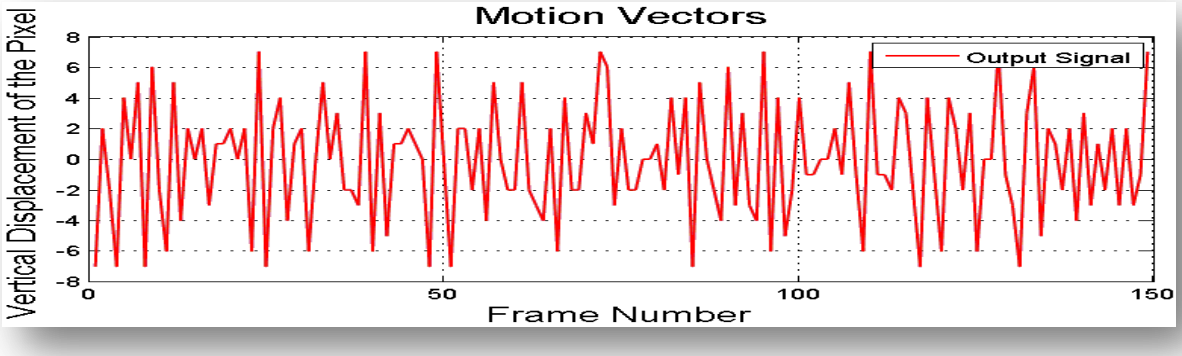

Fig.4 Motion Vectors

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In the fig. 4, it can be seen that there is shift in the position of blocks i.e. motion vectors in almost every frame and due to padding procedure the motion vectors are within the particular range i.e. 7.

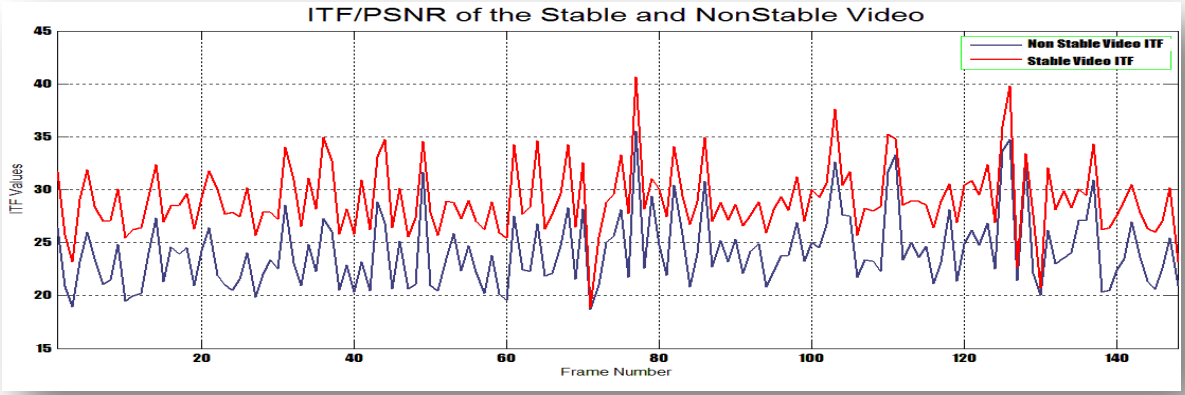

Fig.5 Comparison of ITF of Stabilized and Non Stabilized Video Over Each Frame

In fig. 5 it can be seen that ITF of output video (shown in red line) is much more than that of input unstable video (shown in blue line) at almost every frame.

Fig.6 Unstable Frame (Left) and Stable Frame (Right)

In the fig. 6, 5th frame of unstable frame of input video fly on leaf is shown at left side. On the right side, exactly that frame of output video is shown. The black part in that image at the corner is proof of shakiness being compensated.

Also, ITF % gain is given by:

$$\%\text{gain} = \frac{\text{ITF of output video} - \text{ITF of Input video}}{\text{ITF of Input video}} * 100$$

Average of all these ITF's of output video of all frames is calculated and presented in following table.

TABLE I
ITF OF INPUT AND OUTPUT VIDEO

Video Sequence	No. of Frames Used	ITF of Input (Shaky)Video	ITF of Output Video	% Gain
Fly on Leaf	150	21.79	26.64	22.25

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Household Objects	600	24.56	28.18	14.73
House	200	22.12	26.79	21.11

VII.CONCLUSION

In this paper, block matching algorithm of Full Search Algorithm was used which gives best PSNR or ITF of any block matching algorithm. Also, Sum of Absolute difference which is easy to use has been discussed. This paper proposed use of histogram equalization and padding in video stabilization area. This paper has used recent video stabilization quality standard of Interframe Transformation Fidelity (ITF) and Processing Gain. Various videos from different situations were used. Results were satisfactory and produced better ITF and processing gain while compared with unstable videos.

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