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Review of Video Stabilization Techniques Using Block Based Motion Vectors

Dhanashree Bhujbal, Prof. B.V. Pawar

P.G. Student, Department of Electronics & Telecommunications,PVPIT, Pune, Maharashtra, India
Associate Professor, Department of Electronics & Telecommunications,PVPIT, Pune, Maharashtra, India

ABSTRACT: Taking selfies and videos from advanced multimedia devices (Personal digital assistants, mobile phone cameras, smart phones, camcorders, etc) is a very recent trend. The main aim of digital video stabilization is to get rid of unwanted movements, undesirable jiggle, blur and poor quality video. Many video stabilization techniques hence are developed with different algorithms & methods. The paper presents the review of different methods acquired for the motion estimation and video stabilization. This paper focuses on block based approach. Block Based approach divides each frame into macroblocks and matches current frame with the previous frame from the video sequence. Applying criteria such as Sum of Absolute Difference (SAD) we acquire difference between two frames. Using this block matching algorithm, local & global motion vectors are calculated. The stabilized video is achieved by applying steps such as motion vector validation, motion smoothing and finally motion compensation is done. Using video stabilization quality standards such as PSNR & ITF, we can plot graph and assess the proposed algorithm.

KEYWORDS: Block Matching, Macroblock, Motion Estimation, Motion vector, Video stabilization.

I. INTRODUCTION

With increasing popularity of many applications such as hand held devices like camcorders, smart phone cameras, digital cameras, surveillance systems, unmanned aerial vehicle (UAV) systems the video processing have become increasingly important. Thus, it is inevitable presence of some unwanted motion effects, blur, and jitter in videos taken by hand or from mobile platforms. Therefore it is desirable to apply digital video stabilization algorithm to acquire good quality video to get rid of undesirable motion.

Video stabilization deals with object Motion and camera motion which are two main sources of dynamic information in videos. Camera motion comprises of pan, zoom, tilt and/or combination of these basic components which is also referred as global motion. Whereas object motion is considered as movement of objects in a scene also referred as local motion.

II. RELATED WORK

Video stabilization is video enhancement technique aiming at removing misalignment of video frames and unwanted motions or vibrations in the captured video sequence. Researchers have developed many video stabilization algorithms. Stabilization of video is done for 2D, 2.5D,3D motion models and for compressed video streams such as MPEG, MPEG-2, H.264 or MPEG-4. Matsushita et al.[11],proposed direct pixel based full frame video stabilization method with motion inpainting. They used affine motion model for estimation and the Gaussian kernel filtering was used to smoothen camera motion.Motion estimation is the base of any video stabilization algorithm. A fast video stabilization technique was explored by Ko et al. [12]in which gray coded bit-plane matching algorithm was used which estimates local and global motion vectors.

Battiato et al. [13] proposed a robust block-based image/ video registration approach for mobile imaging devices. Using some simple rejection rules estimated Interframe camera transformation parameters from local motion vectors. In this registration approach they used motion estimator, filters and error matrix to stabilize video frames. They tested their work on ARM device and achieved stabilized video sequence for the real time performance.Cai et al.[2] explored camera motion estimation algorithm using histograms of local motions for mobile platforms. They considered highest peak in each histogram of local motions.The sortedarrays are also implemented to avoid selecting the number of bins for histogram.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 3 , March 2016

Okade et al. [14] proposed a novel compressed domain framework for video stabilization which was fast and robust. In comparison to the existing pixel based stabilization techniques. Further they utilized wavelet analysis to estimate the camera motion parameters from block motion vectors. This method was efficient and better in case to avoid computational complexity.Rawat and Singhai [10] developed adaptive motion smoothening method for removing high frequency jitters.This method stabilizes worst and large motion videoswhere multiple moving objectsare present in the scene. Manish Okade et.al [16] proposed robust learning based camera motion characterization scheme for video stabilization. They carried out experimental validation using exhaustive search motion estimation obtained block motion vectors as well as H.264/AVC and reduced processing time for stabilizing video sequence.

III. VIDEO STABILIZATION

The Video stabilization can either be achieved by hardware or post image processing approaches which are described as below:

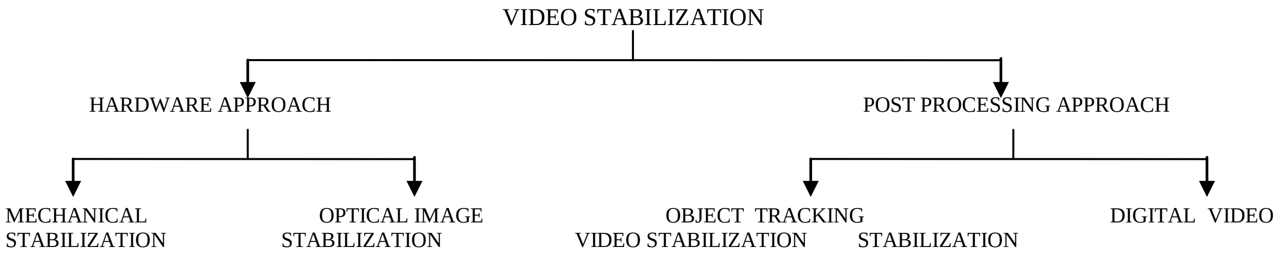


Fig 1: Video Stabilization Approaches

A. Hardware Approach

I. MECHANICAL STABILIZATION

In the first category we use hardware motion sensors or mechanical devices such as gyros, accelerometers and mechanical dampers. Thus instead of holding camera in hand, mechanical stabilizers such as tripod, Steadicam are used which reduce platform vibration and in turn provide stabilization. [1]

II. OPTICAL IMAGE STABILIZATION

In optical image stabilization(OIS) CCD/CMOS sensors, microcontrollers, Hall sensors are used. Optical stabilization is much expensive than digital technique but its computational complexity is low as it is concerned with light rays falling on the camera's lens.[1] In these approaches detection and correction steps are applied before acquisition so as to avoid post processing computation.

B. Post Image Processing Approach

I. OBJECT TRACKING VIDEO STABILIZATION

The second category is of object tracking [2, 3]where objects such as person, vehicle, and road signs are the targets to track. This is also known as video tracking. The objective of video tracking is to associate target objects in consecutive video frames.

II. DIGITAL VIDEO STABILIZATION

This is the estimation based approach. In this category, a video stabilization pipeline usually comprises three stages: motion estimation, motion smoothing, and motion compensation [5].In this paper, we will review these stages of video stabilization and different approaches related to it.

IV. MOTION ESTIMATION

Motion estimation is fundamental unit of video stabilization. Better the motion estimation performed better will be the results. Classification of motion estimation techniques is given below:

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 3 , March 2016

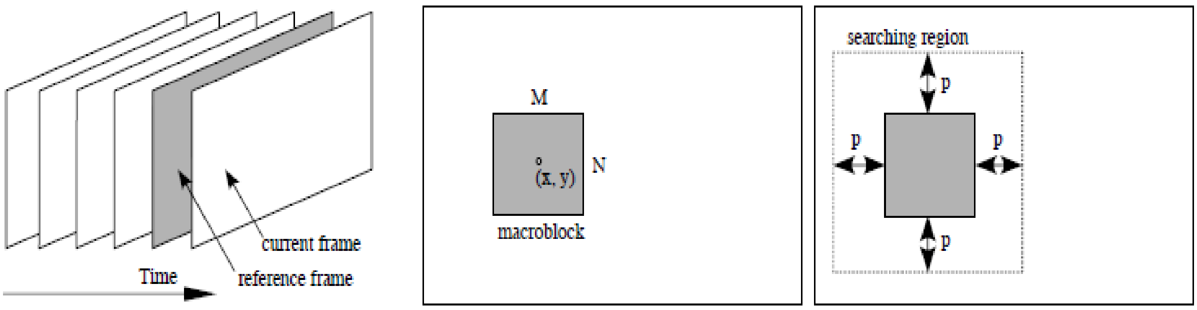
A. Feature Based Method

Feature based methods include corner matching, edge pattern matching, SIFT point matching [8, 9]. Currently, more work is done in compressed domain. H.264 /AVC is the most widely used recent video coding standard. Even if feature based approaches are faster than the direct pixel based approaches, their efficiency depends on feature point selection thus are less accurate.

B. Direct Method

Direct method of motion estimation includes gray coded bit-plane matching [1, 4, 5, 12],block matching[6], optical flow[7], phase correlation method. Direct pixel based approach measures the contribution of every pixel in the video frame. In this paper we will review block matching method for motion estimation.

Block Based Method:
Block based Method is the efficient method for stabilization. In this approach each video frame gets divided into macroblock (size: 16*16). Macroblocks of current frame and previous frames are matched on the basis of certain block matching algorithm. Fig 2 shows steps of block based motion estimation such as choose motion vector (x, y) , select macroblock of size M X N, choose search range p, search best matching block. [15]



(a)frames sequence (b)A macroblock selected from the current frame(c)A search region in the reference frame

Fig 2: Block Based Motion Estimation [15]

V. BLOCK MATCHING COST FUNCTIONS

There are some cost functions which are considered as criteria for matching blocks, these are given below:

a) The Mean Absolute Difference (MAD) is a criterion used to determine which block should be used. Typically, the lower the MAD the better the match and block with the minimum MAD is chosen. MSE is the old quality standard which calculates Mean squared Error as follows:

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

$$\text{MAD} = \frac{1}{N^2}\sum_{i=0}^{N-1}|C_{ij} - R_{ij}|$$

Where N= width or height of macroblock
Cij = Pixels compared in current macroblock
Rij = Pixels compared in previous macroblock

b) Sum of Absolute Difference (SAD) is given by:

$$\text{SAD} = \sum_{i=0}^{N-1}\sum_{j=0}^{M-1}|fcurrent(j,i) - fref(j + V_{x,i} + V_y)|$$

Where, N= height of block.
M= width of block.
i= index of horizontal direct.
j= index of vertical direction.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 3 , March 2016

Vx, Vy= motion vectors of reference block.
fcurrent (x,y)= pixel intensity at current block.
fref(x,y)= pixel intensity of reference block.

c) Peak Signal to Noise Ratio (PSNR) can be calculated by:

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

Where I_{max} = Max value of intensity of pixel.

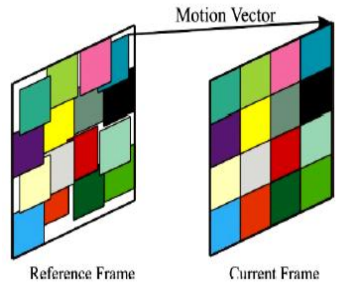
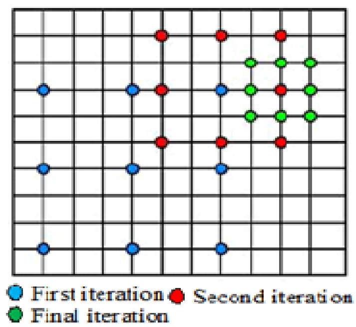
d) Interframe Transformation Fidelity is the recent quality index based on the PSNR. ITF is given as:

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

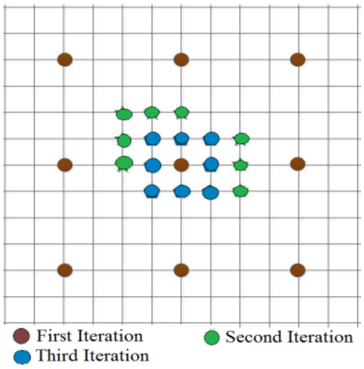
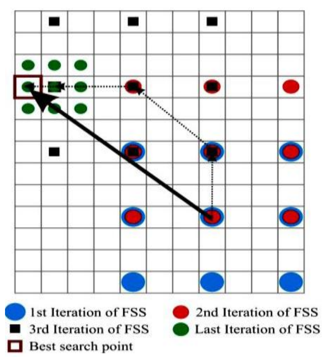
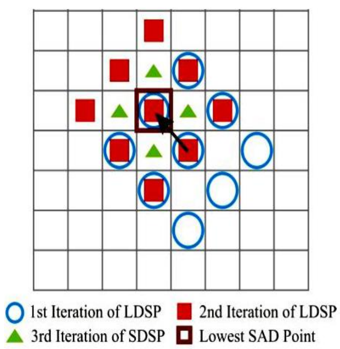
Where, PSNR = PSNR between current and previous frame.
N_{Frame} = no. of frames in video.

VI. BLOCK MATCHING ALGORITHMS FOR MOTION ESTIMATION

There are various methods related to block matching algorithms:

Serial No.	Techniques	Methodology	Reference Figure
1.	FULL SEARCH METHOD OR EXHAUSTIVE BLOCK MATCHING SEARCH (FSA / EBMA)	Full search algorithm (FSA) or Exhaustive Block Matching Search is a very common block matching algorithm. In this, macroblocks are matched from top to bottom, left to right. This method gives best PSNR to evaluate Interframe fidelity (ITF). ITF is the PSNR between two consecutive stabilized video frames. By plotting PSNR & ITF we can prove the efficiency of block based method for video stabilization. FSA is simple in implementation, robust and accurate but the computations are more since it evaluates every possible pixel. Refer Fig. 3.1 **Application:** To obtain best picture quality and highest PSNR	 **Fig 3.1: Full Search Method[18]**
2.	THREE STEP SEARCH	Three step search is said to be one of the fast search algorithm. In TSS, the first iteration evaluates nine points considering one at centre and other in all direction equidistant at step size 4 from central point. SAD is calculated for these points and the smallest SAD point is chosen as a new centre. The process continues by reducing step size into half. TSS is simpler but less efficient than FSA. Fig 3.2 shows the TSS method and iterations. **Application:** Recommended in MPEG2	 **Fig 3.2: Three Step search[17]**

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 3 , March 2016

3.	NEW THREE STEP SEARCH (NTSS)	New three step search uses center biased checking point scheme in which a center point is selected in particular search region. In NTSS, the first iteration it evaluates 8 points considering step size 4 and other 8 points are equidistant at the step size 1 from search origin. In second iteration, if the minimum cost function value is found at the center of the search window, the search is stop, otherwise change the search origin with min. cost function and repeat first iteration procedure. This algorithm has the best case of 17 checking points and worst case of 33 checking points. Refer Fig. 3.3. **Application:** More efficient than TSS for small motion.	 **Fig 3.3: NTSS Search method**
4.	FOUR STEP SEARCH (FSS)	In first iteration,4SS algorithm uses a search pattern with nine checking points in window size of 5x5 pixel. If min. cost function is available in this window size then the search procedure moves to 4th step and stop the search after finding min. cost function by using small nine point search pattern, which is known as halfway stop. In second iteration min. cost function is set as center of 5x5 search window. If the point is at center of 5x5 window in second step then stop search by performing fourth step otherwise third step is performed exactly the same as 2nd step. In the fourth step the pattern size decreases from 2 to 1 which reduces the window size up to 3x3. At the end of fourth step search the min. cost function is best matching point. Significance of 4SS algorithm is its robustness & reduction in computation. **Application:** Initial small step size so more efficient for small MV.	 **Fig 3.4: Four Step Search[18]**
5.	DIAMOND SEARCH (DS)	DS algorithm considers two patterns for searching. One is Small Diamond Search Pattern (SDSP) and other is Large Diamond Search Pattern (LDSP). SDSP consists of five checking points while LDSP consists of nine checking points with one point at centre and others being around that centre point. At nine points of LDSP, min.cost function is calculated. If that point is other than centre point then new LDSP is formed. i.e. other new eight points with previous min. cost function point as centre is considered. This procedure repeats until the min. cost function point is at achieved at centre point. Once that point is found at centre, LDSP is switched to SDSP at which min. cost function is found. The block with min. cost function is achieved is the best matching block. Refer Fig 3.5. **Application:** Adopted and incorporated in MPEG-4 verification model.	 **Fig 3.5: DS method[18]**

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 3 , March 2016

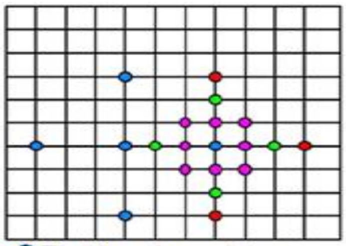
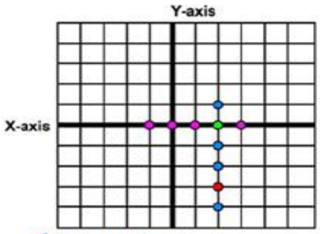
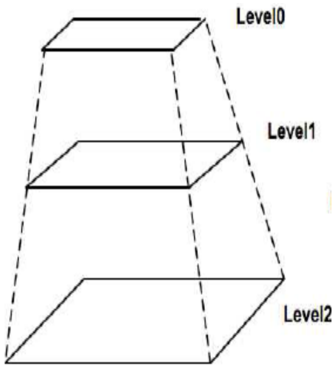
6.	LOGARITHMIC SEARCH METHOD	In this search, a point is centred at the search region while other four points are placed diagonally to the centre as diamond shape. The step size for first iteration is half of the search range and the cost function in the centre of search region and four neighbouring points are taken. During second iteration, the centre of the diamond is shifted to the least valued cost function, if it is not a center, the cost functions in two corresponding diagonal points are drawn. The step size reduces till it becomes one pixel. This search is more accurate for estimating motion vectors for a large search window size. **Application:** Suitable for Fast Motion sequences	 **Fig3.6:2D Logarithmic search[17]**
7.	ONE AT A TIME SEARCH	One at a time search is another type of fast search algorithm, in which motion vectors are calculated along X-axis and Y-axis independently. Firstly the point search is done along the X-axis, then the next three points along same axis are matched. The process ends when the best matching point has selected a centre.The location of this point on the x-axis is used as the x-component of the motion vector. Same process is carried out along the Y-axis for the estimation. It requires less number of points than other fast algorithms. However, the motion vector accuracy is poor. Refer Fig. 3.7. **Application:** Used in real time videos for optimal estimation solutions.	 **Fig3.7:one at a time search[17]**
8.	HIERARCHICAL BLOCK MATCHING ALGORITHM (HBMA)	HBMA is simple which successively refines motion vectors at different resolutions. Initially a pyramid of reduced resolution video motion vector is formed from video sequence. The highest resolution image is extracted from the original video frame and the other images in the pyramid are formed by down sampling the original image. Down sampling is of bi-linear type. At the highest resolution the block size of N x N is reduced to (N/2) x (N/2) in the next resolution level. The search range is also reduced. At the lowest resolution the process of motion estimation starts. The full search motion estimation is performed for each block at the lowest resolution. HBMA does not need large computations. The motion vectors from lowest resolution are scaled and passed on to each block to next level. As the level increases, the motion vectors are refined with a smaller search area. Refer Fig 3.8 **Application:** Suitable for videos with different resolutions	 **Fig 3.8: Multi Resolution Pyramid for Hierarchical Block Matching [17]**

Table 1:Summary of Techniques, methodology, reference figures for different Block Matching Algorithms.

VII. MOTION SMOOTHING

Motion Smoothing is further step in video stabilization. In this step, unwanted global motion vectors are filtered. There are several types of filters used to smoothen the motion. Some of the past techniques were low pass filter, IIR, FIR filters. While recently Gaussian filters, Adaptive IIR filter, Kalman filters are used. Motion smoothing is required to smooth undesired camera motion after motion estimation and to remove accumulation error prior to motion compensation.

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 3, Issue 3 , March 2016

VIII. MOTION COMPENSATION

Motion compensation compensates prediction error as well as reconstructs frame according to the motion vectors obtained previously. In motion compensation,difference between current frame and previous frame is taken and the corresponding result is added in the pixel value of current or future frame to get new current frame compensating the prediction error.

IX. CONCLUSION

In this paper, the review of the different approaches and techniques of video stabilization are discussed. The paper revealed the basic stages such as motion estimation, motion smoothing, and motion compensation in the video stabilization pipeline. Different categories of motion estimation such as pixel based and feature based motion estimation method are discussed. Different block matching cost functions are discussed which are considered as quality standards for getting accurate results in the process of motion estimation. Here we have discussed various block matching algorithms such as Full search method, TSS, NTSS, 4SS, FSS, DS, logarithmic search, one at a time, HBMA. These algorithms contain different flow of execution and can be applied for different types of video sequences. The speed of these block based motion estimation algorithms can be improved by reducing number of search points and using early stop or halfway process.
To summarize it, as the block matching algorithm is the latest and faster method for stabilization of video further work can be done in the same area. In future scope, speed of acquiring motion vectors and reduction in calculations are the parameters to be emphasized.

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