A Study on Video Stabilization Algorithms

Swetha.J[1]

Lecturer, E&C Department

S.J(Government) Evening Polytechnic, Bangalore

Leela.R[2]

Lecturer, E&C department

Government Polytechnic, Nagamangala

Abstract— **Persons using low-cost hand held cameras are untrained, thus captured videos suffers from severs handshakes and jitters. Hence digital video stabilization algorithm is required to acquire video sequences by removing these unwanted handshakes and jitters. There are various approaches used for stabilizing the captured videos.**

This paper focus on different existing methods for video stabilization. It focuses on the motion estimation and smoothing modules & various schemes under it.

This survey provides information about the existing methods and their improvements, hence providing a platform for new researchers for innovating new techniques for further research.

Keywords — **Motion Compensation, Motion Estimation, Motion Smoothing, Video Stabilization.**

I. Introduction

Video stabilization refers to algorithm used to improve the video quality by removing unwanted camera shakes and jitters. The removal of unwanted vibrations in a video sequence induced by camera motion is an essential part of video acquisition in industry, military and consumer applications.

The video stabilization can either be achieved by hardware or post image processing approach. Hardware approach can be further classified as mechanical or optical stabilization. Mechanical stabilizer uses gyroscopic sensor to stabilize entire camera. Optical stabilization activates an optical system to adjust camera motion sensors [1].

There are various algorithms Proposed for stabilizing videos taken under different environment from different camera systems by modifying these three stages. Image post processing techniques are favourable over mechanical or optical approaches since modern VLSI techniques will allow a more compact camera design.

II. BASIC CONCEPT OF VIDEO STABILIZATION

The goal of any video stabilization algorithm is to create a new video sequences where the motion between the frames has effectively removed. In general any digital video stabilization algorithm consist of three modules: motion estimation module (ME), motion smoother module (MS) and motion compensation module (MC) as in Fig. 1. ME estimate the motion between the frames, and send the motion parameters to MS, which removes the unwanted camera motions. MC then computes the global transformation necessary to stabilize the current frame.

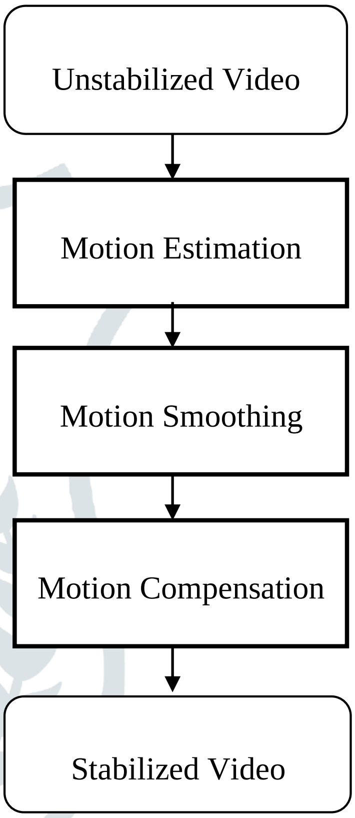

Fig. 1 Steps followed for video stabilization

III.VARIOUS DIGITAL VIDEO STABILIZATION TECHNIQUES

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In the past decades, the more research done on motion estimation and motion smoothing techniques because of these are crucial part any video stabilization algorithm.

A. *Motion Estimation*

Motion estimation is the process of determining motion vectors from adjacent frames in a video sequence. The motion vectors may relate to the whole frame or specific part, such as rectangular blocks, arbitrary shaped patches or even per pixel.

In any video stabilization algorithm, the crucial component lies on motion estimation. Since in real word camera motion often involves some type of global transformation it is particularly important to get an accurate estimate of the global motion when performing motion estimation

For successful video stabilization, the accuracy of the motion estimation must be as high as possible. In the last two decades, the researchers have developed many video stabilization algorithms. For any video stabilization technique the inter frame motion may be modeled using 2D or 3D motion model. The 2D motion models [2, 3 and 6], are computationally less complex and efficient enough to estimate inter frame motion. Due to its higher efficiency and low computation, cost the 6-parameter 2D affine motion model commonly used to estimate motion vectors.

The motion estimation methods can be broadly classified as feature based approaches or direct pixel based approaches.

Various feature based approaches are proposed for video stabilization. Chang *et al.*, [2] presented a feature tracking approach based on optical flow, considering the fixed grid of points in the video. But this approach was developed for a specific motion model. Rong Hu, *et al.*, [3] in 2007 proposed an algorithm to estimate the global camera motion with SIFT features. These SIFT features have been proved to be affine invariant and used to remove the intentional camera motions. Junlan Yang *et al.*, [4] in 2009 used SIFT feature points and particle filtering framework to estimate the global motion between two frames. To estimate intentional motion from accumulative motion Kalman filter is used. Derek Pang *et al.*, [5] in 2010 proposed the video stabilization using Dual-Tree complex wavelet transform (DT-CWT). This method uses the relationship between the phase changes of DT-CWT and the shift invariant feature displacement in spatial domain to perform the motion estimation. Optimal Gaussian kernel filtering is used to smoothen out the motion jitters. This phase based method is immune to illumination changes between images, but this algorithm is computationally complex.

These feature-based approaches are although faster than direct pixel based approaches, but they are more prone to local effects and there efficiency depends upon the feature point's selection. Hence they have limited performance for the unintentional motion.

Direct pixel based methods uses each pixel in the frame to estimate the global motion. Hany Farid and J.B. Woodward in 1997 [6], modeled motion between video frames as a global affine transform and parameters are estimated by hierarchical differential motion algorithms. Temporal mean and median filters were applied to this stabilized video sequence for enhancing the video quality. But they have not implemented the motion smoothening or compensation algorithms. Olivier Adda, *et al.*, [7] in 2003 presented various motion estimation and compensation algorithms for video sequences.

Matsushita *et al.*, [8], in 2006 proposed the direct pixel based full frame video stabilization method with motion in painting. They achieved video stabilization by assuming an affine motion model between each pair of frame to represent the inter frame error between adjacent frames. Then an 'L' level Laplacian image pyramid is constructed and inter-frame error is estimated using hierarchical differential motion estimation which leads to enhanced accuracy, robustness and improved efficiency. Estimation process involves SSD minimization with Gauss Newton minimization, which uses a first order expansion of the individual error quantities before squaring. The limitation of this method is that it strongly relies on the result of global motion estimation which may become unstable when a moving object covers large amount of image area. For fast moving objects neighboring frames will not be warped correctly, and there will be visible artefacts at the boundaries. The convergence ability of the Gauss Newton minimization is also limited.

Feng Liu *et al.*, [9] in 2009 proposed an algorithm of content preserving warps for 3D video stabilization for hand held cameras. The key insight of the work is that for the purposes of video stabilization, small shift in viewpoint can be faked by a carefully constructed content preserving warp, but result is not physically accurate. The major limitation of this approach compared to 2D video stabilization is that it first requires running structure from motion, and method is also more brittle and heavy weight.

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B. Motion smoothing

The result of the motion estimation process described in the last section is capable of computing the motion vectors between two frames. The objective of motion smoothening is to removes the jitters and undesired motions present in the captured video. These undesired motions usually consider as high frequency motion such as vibration, and can effectively remove by low pass filters. Thus, motion smoothing also called as motion filtering.

After estimation to smooth the undesired camera motion in the global transformation chain, various approaches have been proposed [10, 11, and 12]. Buehler *et al.* [10] in 2001 proposed Image based rendering algorithm to stabilize video sequence. The camera motion estimated by non-metric algorithm, and then image-based rendering technique applied to smooth the camera motion. This method produced very accurate results in most of the cases, but it required tuning of motion model parameters to match with the type of camera motion in the video. Matsushita *et al.* [8] developed an improved method called Motion in painting for reconstructing undefined regions and Gaussian kernel filtering used to smooth the camera motion. Sunglok *et.al* [11] in 2009, proposed Adaptive RANSAC method to solve this problem, based on Maximum Likelihood Sample Consensus (MLESAC). For motion, smoothening Kalman filter used to relieves high frequency motion. However, the Kalman filter required to self adjusts for advanced adaptation.

Fatma *et.al* [12] in 2004 proposed an image sequence stabilization system with absolute frame displacement filtering using adaptive polynomial filtering with LMS and RLS algorithms. Polynomial filter based on RLS algorithm perform better but they has a larger computational complexity.

Yang *et.al* [13], 2006 has proposed an adaptive image stabilization technique. Method uses sub-sampled multi-resolution block motion estimation to calculate the global motion vectors. An adaptive IIR filter proposed to smooth the unwanted motions. Method also incorporates a two-dimensional compensation method that eliminates the motion fluctuation perpendicular to the panning direction. Tanakian *et.al* [16] in 2011 have proposed a digital video stabilization system by adaptive motion vector validation and filtering. Method uses block motion estimation and adaptive IIR filter filters the unwanted motions. Cai *et.al* [14] in 2009, proposed a robust video stabilization algorithm using feature point selection and delta optical flow. After estimating the motion vectors, a first order IIR filter used for motion smoothening in real time. For post processing applications, they suggested to use non-causal filters. Tang *et.al* [15] in 2009, have proposed a fast video stabilization algorithm based on block matching and edge completion. After estimating the global motion vectors a statistical methods is used to get the global vibrant motion vector.

Because of the environment is often non stationary, the use of adaptive filters produces better smoothing vectors than other filters.

C. Motion Compensation

Motion compensation is the process of removing temporal redundancy between frames in order to produce stabilized video. It is different from motion smoothing which is used for removing spatial redundancy between frames.

Using the smoothed motion vectors from motion smoother, motion compensation is performed frame by frame. For example, stabilized frame2 is obtained by performing motion compensation original frame1 using the corresponding smoothed motion vector. To get stabilized frame3, stabilized frame2 and its corresponding smoothed vectors are used and so on. In such a fashion, the entire stabilized video sequence can be generated.

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IV. CONCLUSIONS

Review of the various video stabilization techniques based on motion estimation and smoothing are presented in the paper. From previous section, it is clear that direct based methods are efficient than feature based methods but computational load is heavy due to consideration of each pixel in frame. For motion smoothing, adaptive filters will gives better results as it will change filter coefficients according to the nature of environment.

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