

TECHNIQUES OF VIDEO STABILIZATION

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ABSTRACT

This paper describes the Video Stabilization also a new approach to low level image processing, in particular edge and corner detection. In the last decade utilization of handheld video cameras have become quite popular however the videos captured by unprofessional users or by fixed and vehicle mounted cameras have resulted in shaky and unclear videos. In this work we aim to use a video stabilization algorithm using point feature matching technique to reduce the vibrations in acquired video sequences. The paper presents motion estimation techniques, motion models, feature detection techniques, robust sampling consensus and mainly the RANSAC paradigm. Implementation of the feature points matching based stabilization algorithm was done using the MATLAB platform and applied to three different videos with jitter.

Keywords: RANSAC, Feature detection, robust sampling consensus, Motion estimation.

I. INTRODUCTION

Video stabilization is a technique which is used by many different fields in today's world to achieve a stable video sequence from a shaky video. Medicine, military and robotics are three main fields in which video stabilization is heavily used. For example, in endoscopy and colonoscopy videos need to be stabilized to determine the exact location and width of the problem. Videos captured by aerial vehicles on a reconnaissance flight need to be stabilized for localization, navigation, target tracking, etc. Furthermore utilization of digital cameras has always been popular and hence video stabilization has entered our daily life with the aim of removing shaky motions from videos captured by non-professional users. Different approaches to stabilize shaky videos as follows.

Different Approaches to Video Stabilization

There are mainly three approaches to video stabilize a shaky video. These include mechanical, optical, digital stabilization methods.

1.1 Mechanical Video Stabilization Technique

Mechanical image stabilization systems using the vibration feedback of the camera which is detected via special sensors like gyros accelerometers etc. are the earliest developed stabilization techniques. In mechanical methods, accelerometer and gyros sensors are used for motion detection and then the camera is moved against the movement direction. Figure 1 demonstrates a camera with mechanical stabilizer where a gyroscope is attached to the camera.



Fig 1: Camera with Mechanical Stabilizer

1.2 Optical Video Stabilization Technique

Optical stabilization techniques were developed a few years after mechanical techniques. Instead of moving the whole camera, just the pieces of the lens glass move. This stabilization technique is referred to as optical stabilization, which is the most effective one and employs a moveable lens assembly that variably adjusts the path length of the light as it travels through the camera's lens system. In this technique, the angle and speed of the camera shake are detected by two gyro sensors. According to the movement direction of the entire lens, the selected lens elements should be moved so the image passing through the lens can be steady and sharp when it hits the imaging sensor.

1.3 Digital Video Stabilization Technique

In general, stabilizing a video by digital algorithms contains three main steps including motion estimation, motion smoothing, and image composition.

II. MOTION ESTIMATION

Motion estimation is an important step for video stabilization algorithms. It is the attempt for estimating the displacement of points between two successive video frames. In a video frame, motion is manifested as an alteration in pixel intensity values, which can be used to determine the motion of objects.

Equation (1) presents a simple representation of the problem where t and $(t+\Delta t)$ are two consecutive video frames. As depicted in Fig. 2, Δx and Δy are the motion vector components.

$$I(x, y, t) = I(x + \Delta x, y + \Delta y, t + \Delta t)$$

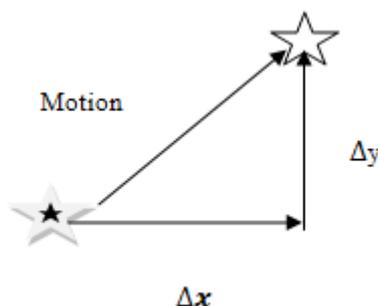


Fig 2: Motion Vector Component

In order to find Δx and Δy , the following equation should be solved.

$$I(x, y, t) - I(x + \Delta x, y + \Delta y, t + \Delta t) = 0$$

However the existence of noise, camera displacements and light alterations can prevent the zero difference. Direct and Indirect motion estimation techniques are two different approaches to the problem. After introducing different motion models for two dimensional images, direct and indirect motion estimation techniques are discussed.

2.1 Principle Types of Motion Models

Mathematical equations describing the mapping procedure of pixel coordinates between two images are referred to as motion models. Any pixel coordinate in an image can be described as; $x=(x,y) \in R^2$. For most transformations non-homogenous coordinates are sufficient however for perspective or projective transformations homogeneous transformations are needed. In what follows we give examples for various transformation types.

1. Translation transformation

Equation describes a two dimensional translations. This transformation preserves the orientation.

$$x'=x+t$$

Or

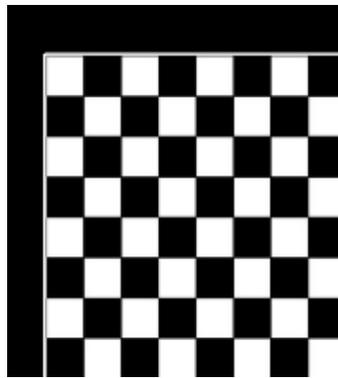


Fig 3: Example of Translation transformation

2. Euclidean transformation

Euclidean transformation which is the union of Translation and Rotation transformations can be expressed as the following equation.

$$x'=[R \ t]x$$

$$R=$$

$$RRT=I$$

$$|R|=1$$

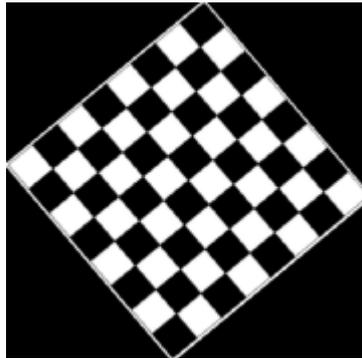


Fig 4: Exapmle of Euclidean transformation

2.2 Indirect Motion Estimation Technique

In indirect motion estimation methods, image features are used with the purpose of estimating motion between frames. In these methods the first step is to find strong features of each frame. There are several methods to find feature points in an image. Harris and SUSAN corner detection are some examples. Generally corner points have higher chance to be in the next frame as well.

As each feature will have a distinct vector, a filter is required in indirect algorithms to filter out the outliers. RANSAC is a popular example

The following steps constitute the indirect algorithm to compute a two dimensional homographic transformation between two frames.

1. Corner point features are computed in sub-pixel precision.
2. Considering the similarity and proximity of the neighborhood point intensity, a set of corner points matches is computed.
3. Determination of more corner point correspondences based on the H calculated in the previous step with the purpose of defining a search region around the transferred point position



Fig 5: Corner Points for Two Consecutive Frames

4. SALIENT POINTS OF IMAGES

In general, points containing the dominant information of an image are referred to as salient points. As mentioned in previous chapter the first step of any robust estimation technique is detecting the salient points.

Corner points and edges of an image are the best candidates for salient points. In this chapter applied algorithms to detect salient points are discussed.

3.1 Corner points

Corner Detection is a popular research area in image processing and therefore many corner detectors have been presented. Some of them are widely used in industries. such as Harris detector and SUSAN detector. The intersection of two edges is referred to as a corner point. Corner detector algorithms are widely used in applications like image registration, object recognition, motion estimation etc. A large number of corner detector algorithms have been introduced in the literature. Some representative ones are as follow.

1. Moravec corner detector algorithm

Moravec corner detector algorithm developed in 1977 is one of the first techniques to find corner points. In this algorithm corner points are defined as points with enormous intensity alternation in all directions. Considering each pixel location as (x, y) and its intensity as $I(x, y)$, Moravec algorithm runs as follow.

1. The intensity variation for each pixel from the neighborhood pixel is calculated by equation where a and b are the window size.

$$Vu, v(x, y) = \sum (I(x+u+a, y+v+b) - I(x+a, y+b))^2$$

2. Cornerness measure is calculated for each pixel by the following equation

$$C(x, y) = \min(Vu, v(x, y))$$

3. All $C(x, y)$ less than a certain threshold values are set to zero.
4. In order to find local maxima non-maximal suppression is performed.

Finally all the remaining non-zero points are considered as corners.

2. Harris corner detection algorithm

In Harris and Stephens's corner detection algorithm which is an improved version of Moravec algorithm, rather than using shifted patches the differential of corner score with respect to the direction is considered. The corner score also referred to as autocorrelation is presented by equation 4.3 for the given shift (u, v) . In this equation (xi, yi) is the corresponding point in the window centered at (x, y) and I is the image function.

$$E(u, v) = \sum_{x, y} w(x, y) [I(x+u, y+v) - I(x, y)]^2$$

For small shifts $[u, v]$ we have a *bilinear* approximation

$$E(u, v) \cong [u, v] M \begin{bmatrix} u \\ v \end{bmatrix}$$

where M is a 2×2 matrix computed from image derivatives:

$$M = \sum_{x, y} w(x, y) \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I_y^2 \end{bmatrix}$$

where $w(x, y)$ window function, $I(x+u, y+v)$ shifted intensity.

The Harris corner detector implementation is divided into five steps.

1. Color to grayscale

The first step of this implementation is identical to the one for the Canny implementation.

2. Spatial derivative computation

This step computes the first derivatives $I_x(u, v)$ and $I_y(u, v)$ of the input image $f(u, v)$ by applying the approximations.

3. Building the matrix M

In this step, three sub-pipelines are applied in parallel to perform these computations. Each sub-pipeline is formed by a multiplier, a 5×5 NE block, and a Gaussian filter.

4. Harris response

The Harris response operator computes the values of R. To keep the pixel stream within an 8-bit resolution without losing weak corner values, R is truncated at 255. This approach can create large regions around the corner spot with saturated values, making difficult the following NMS process. To solve this, a threshold block eliminates low R values that do not represent corners followed by an extra Gaussian filter to blur these saturated regions, producing a maximum spot at the center of these regions.

5. Non-maximum suppression

The final step is to select the best values representing corners. To do this, a 9×9 NMS block analyses a region (window) and marks the maximum value as a detected corner.

3. Noble corner detection algorithm

In Noble corner detector algorithm the corner score C is defined as a function of matrix M. This algorithm neglects the parameter k previously introduced in Harris algorithm and suggests the following equation as corner score.

$$C = \det(M) / [\det(M) + \epsilon]$$

The constant ϵ has entered the equation to prevent singularity if $\text{tr}(M)$ is equal to zero.

5. SUSAN corner detection algorithm

SUSAN corner detector algorithm firstly introduced by Smith and Brady uses a circular mask to detect corner points. In this algorithm the intensity of the nucleus of mask is compared with all other pixels in the mask and the area of mask with similar intensity as nucleus called USAN (Uni-value Segment Assimilating Nucleus) is chosen. The white area of each mask presents USAN. Assuming m^* is a point in the mask, m_0 is the nucleus and t is the radius, the comparison function and the area of USAN.

4. EDGE POINTS

In a digital image edges are points where the intensity sharply changes. Finding edge points is an essential step for many image processing applications like pattern recognition and feature extraction.

Many methods have been proposed in the literature for edge detection. Most of them can be classified in two major categories namely, search-based and zero-crossing based. In search-based methods first of all a measure for edge strength is defined and then estimating the local orientation of the edge it will be checked if the pixel is local maximum along gradient direction. In zero-crossing based methods zero crossing in Laplacian of image is searched to find edges.

Applying small modifications in many corner detection algorithms can change them to an edge detector. For example in previously explained Harris corner detector algorithm if $\lambda_1 \approx 0$ and λ_1 has a positive value the detected point is an edge or in SUSAN corner detector if the geometrical threshold g is chosen large enough the algorithm will work as an edge detector.

5 BLOB POINTS

In a digital image points with different properties such as different colors and brightness are referred to as blobs. Blob detection algorithms can be classified in two categories. Differential and local extrema based methods. Differential methods work using the function derivatives considering the position and local extrema based methods try to find the local minima and maxima of the function.

6. READING VIDEO FRAMES

The first position and local extrema based methods try to find the local minima and maxima of the function. step of video stabilization algorithm is to read the first two consecutive frames (Frame A and Frame B) of the video as grayscale images.

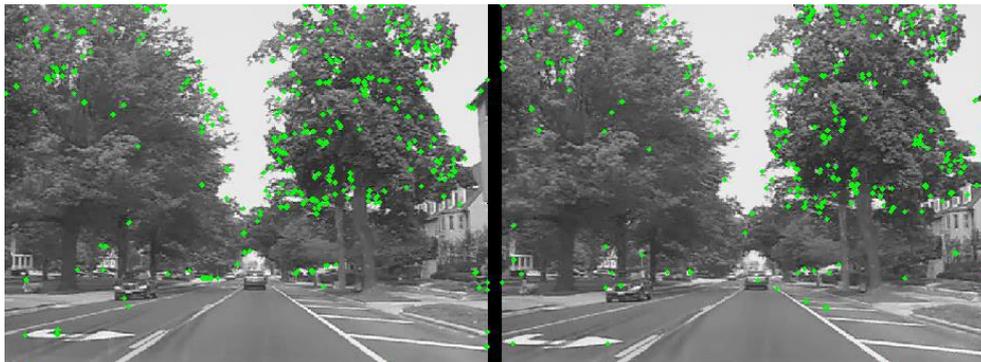


Frame A

Frame B

7. SALIENT POINTS COLLECTIONS

The next step is to find salient points of each frame where Harris corner detection algorithm is used.



8. CONCLUSION

In this work a point feature matching technique to stabilize shaky videos. Finding the feature points using Harris corner detection algorithm in each frame we estimated the motion between the subsequent frames and then video frames have been warped to remove the jitters. Results indicate a remarkable elimination of high jittery from shaky videos.

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