

# Lightweight Jitter Suppression Algorithm for Medical Endoscopes

Jiliang Lin<sup>1</sup>, Minglang Chen<sup>2</sup> and Caixu Xu<sup>2,\*</sup>

<sup>1</sup>School of International Education, Xiamen University of Technology, Xiamen 361000, China

<sup>2</sup>Guangxi Key Laboratory of Machine Vision and Intelligent Control, Wuzhou University, Wuzhou 543000, China

\*Corresponding Author

## Abstract

Digital video stabilization technology is an important branch of shake-suppression technology, which is widely used in medical and military fields with its advantages of high accuracy and portability. In order to reduce the low-frequency jitter caused by doctors when shooting and recording with handheld medical microscopes, this project investigates a low-cost jitter suppression algorithm for medical microscopes. We also design digital video stabilization technology algorithms based on OpenCV and C++ programs to achieve effective suppression and elimination of slight jitter in medical microscope videos. Experiments show that the algorithm in this paper provides a significant solution to the problem of slight jitter in medical microscope video, improves the efficiency of doctors in testing, and provides a technical guarantee for the practical application of medical microscope.

## Keywords

Digital Video Steady Image Technology; Medical Instruments; Image Processing.

## 1. Introduction

Whether in daily life or in the professional medical field, the inevitable and incomplete elimination of different frequencies of jitter in video shooting has become a criticism. In hospitals, medical staffs need to examine patients deep inside their bodies when holding medical microscopes, and in this process, some slight shaking is inevitable due to the movement of the microscope, which causes a certain degree of blurring of the transmitted images and affects the doctor's diagnosis. In order to reduce the interference of jitter on medical microscope images, video stabilization technology has received continuous attention at home and abroad.

The current techniques for video stabilization are divided into three main directions: mechanical stabilization [1], optical stabilization [2], and digital video stabilization [3]. Among them, mechanical and optical stabilization started earlier and are the two more traditional research directions for image stabilization, while digital video stabilization is a new type of stabilization technology that has gradually emerged in recent years. Mechanical stabilization and optical stabilization are the traditional video stabilization technology, mechanical stabilization through the motor for driving, to the rotary transformer and induction synchronizer as the angle sensor for real-time angle feedback, currently used in large high-precision equipment for stable shooting. The optical image stabilization mainly relies on gyroscope sensor to measure the horizontal and vertical direction angular rate of the shooting, and through analog-to-digital conversion output digital signal, analysis of digital information, with the optical lens to compensate for light deviation to achieve the effect of image stabilization. However, mechanical image stabilization equipment such as cloud stage is large and inconvenient to operate for the fine operation of medical microscopy is really inconvenient,

while the optical stabilization lens production and development costs are high, expensive, and due to the anti-shake shooting quality will be degraded, the quality of medical images with high image clarity requirements is intolerable when the reduction.

Digital image stabilization is a late start compared to traditional stabilization techniques, but its advantages such as low cost and portability are unmatched by traditional stabilization techniques. Rohit [4] et al. proposed a Boosted HAAR cascade and representative point matching digital motion stabilization algorithm using successive stages to identify and stabilize images. This work achieved significantly smoother sequences after motion compensation. It also improves the robustness, accuracy and quality of the video compared to conventional digital stabilization algorithms. Lee [5] et al. used CNN networks and LSTM structures in deep learning algorithms to extract and compare features for each frame using TensorFlow to implement image stabilization in OpenCV open source. Wahyu [6] et al. proposed a new digital image stabilization framework based on dense optical flow to select features representing the displacement of two consecutive frames, and finally used the Kalman filter to compensate the trajectory, thus achieving digital image stabilization of UAVs.

In this paper, we adopt digital video stabilization as a technique applied to medical microscope jitter suppression research, and embed the algorithm of digital video stabilization in the form of software into the equipment of medical microscope, without the consideration of the external volume of the equipment, through an in-depth study of the theoretical basis of digital video stabilization, and adopt C++ language for algorithm design with the help of Visual Studio platform. By learning the functions of each function of the OpenCV library, we design the jitter suppression effect that can realize the video captured by medical microscope, and carry out experimental tests on the jitter suppression algorithm for medical microscope, and objectively analyze the practicality of the research target through experimental data.

## 2. Related Work

### 2.1. Image Pramid-Based Lucas Kanade Improved Optical Flow Method for Corner Point Detection and Optical Flow Tracking

The image pyramid is introduced in the feature point tracking algorithm, the purpose is to solve the situation that appears between consecutive frames of video beyond the limitation condition of LK optical flow method, mainly the phenomenon of not satisfying small motion, using the image pyramid, the optical flow of the image as well as the affine transform is calculated in the first layer, that is, the highest layer, and the calculation result is passed to the next layer, but the passed result is only used as the initial value of the next layer image, the next layer image The optical flow and affine transform of the next layer are calculated by the data coming from the image of the upper layer, and so on, layer by layer, until the initial image of the bottom layer is calculated, and the optical flow and affine transform of the last layer are obtained [7]. The schematic diagram of the pyramid feature tracking principle is shown in Figure 1.

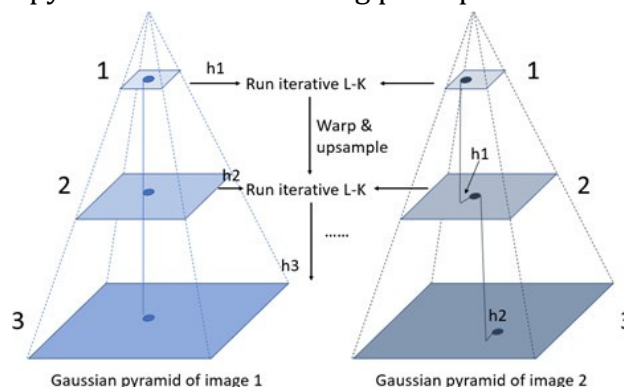


Figure 1. Pyramid feature tracking schematic

Suppose that the two consecutive frames of the image in the video are denoted as I and J, respectively, with I (x, y) and J (x, y) accurately describing the grayscale values of the two images at a feature point in two-dimensional coordinates, and the value of d is obtained by finding the sum of squares of the minimum grayscale difference, at which point the top-level loss function is set as shown in (1):

$$D(I, J) = \sum_{x=-}^+ \sum_{y=-}^+ ((I(x, y) - J(x, y)))^2 \tag{1}$$

The images are sorted by resolution into the image pyramid, the original image is ranked at the bottom of the image pyramid, the lowest resolution image is placed at the top, and the scaling ratio between consecutive layers is 50%, and the top original image is calculated by using a recursive method for the top low-resolution image. Assuming the Lth layer, the loss function is shown in (2), where  $g^L$  is the initial value of optical flow at the Lth layer and  $dL$  is the sum of squares of the minimum gray differences.

$$D^L(I, J) = \sum_{x=-}^+ \sum_{y=-}^+ ((I^L(x, y) - J^L(x, y)))^2 \tag{2}$$

### 2.2. Image Scaling Method based on Region Sub-Block Extraction

The image scaling based on region sub-block extraction is performed by first dividing the data matrix of the original image into region sub-blocks, then extracting the pixel values in the extracted region sub-blocks, and finally constituting a new image from the extracted pixels. The extraction method based on the pixel values of region sub-blocks is to calculate the mean or median value and extract the pixel values in the region sub-blocks, which are divided and selected by setting an equal scaling factor. For example, the data of the original image matrix is  $f(x, y)$  with a resolution of  $8 \times 8$ , while the resolution of image  $g(x', y')$  is  $2 \times 2$ , and its region sub-block extraction method is shown in Figure 2.

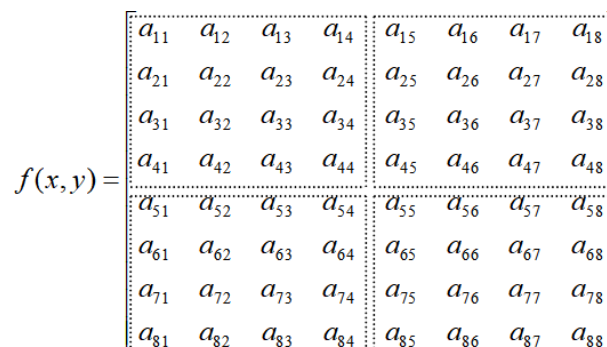


Figure 2. Regional sub-block extraction map

When the sub-block regions are extracted from the original image, the expression of  $g(x', y')$  is shown in (3).

$$g(x, y) = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \tag{3}$$

The equation contains four values,  $A_{11}$ ,  $A_{12}$ ,  $A_{21}$ , and  $A_{22}$ , which are generated by calculating the mean or median of the pixel values of the extracted sub-blocks in  $f(x, y)$ .

## 3. The Design of Jitter Suppression Algorithm based on OpenCV

### 3.1. Design Framework

The algorithm of this paper is based on the summary of the research on the existing digital Steadicam algorithm, using the OpenCV library to build a digital Steadicam system, this book

will build the digital Steadicam system module according to the key points of the digital Steadicam system, then each module will correspond to the standard functions in the OpenCV function library, and finally use the standard OpenCV function to realize the main functions of the system, the operation of the OpenCV library in C++ form in Visual Studio 2019 environment. According to the traditional method of digital video processing, the algorithm design mainly consists of three parts: video pre-processing module, motion estimation module, and motion compensation module. A series of pre-processing operations such as data reading, frame extraction, and format setting are performed by the pre-processing module; then the motion estimation module is used to process the key targets in the medical video for accurate corner point detection to capture the feature points, and this paper adopts the more advanced Shi-Tomasi corner point detection to achieve the acquisition of high-quality corner points, and then the image pyramid-based Lucas Kanade improved optical flow algorithm to achieve the detection target in the video for the optical flow tracking of the feature points, through the motion information storage to achieve the tracking of the feature points for the information storage function; then through the motion compensation module to process the motion information, with the help of the accumulator to calculate the detection target each feature point of the motion trajectory, in general the motion trajectory presents the effect of large changes. The moving average filter is used to smooth the trajectory, the motion transformation matrix is extracted and applied to the looped video frames, and finally the frames with black border artifacts are repaired by designing a video repair device for the excessive smoothing. Through the above three parts of processing, the input video will reduce or even eliminate most of the jitter, aiming to solve the problem of unavoidable small-amplitude jitter generated by medical personnel holding a medical microscope, this algorithm is shown in the anti-shake effect of the output video, and the block diagram of the algorithm design is shown in Figure 3.

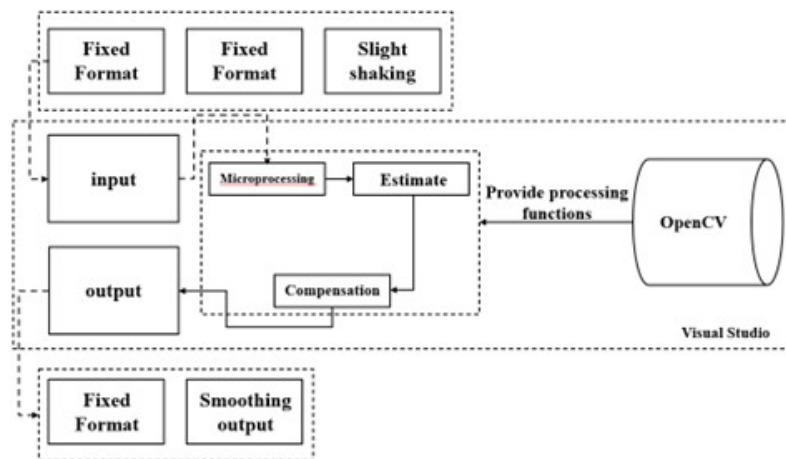


Figure 3. Algorithm design framework

### 3.2. Pre-processing Module

Set up the input and output video, extract the basic elements of each frame in the video, including the brightness, contrast, color and other aspects of the image, and convert the first frame of the input video into a grayscale map for subsequent feature point acquisition. Video pre-processing is a crucial step in medical microscope video processing, which can improve the stability of the whole system to external environmental changes, reduce the noise in the formation, transmission and reception process of the video, and improve the accuracy of the system to process the video. For example, some videos are shot when the external environmental conditions are not good enough, or during the transmission process, there are some errors or some error points on human, through video pre-processing can reduce the subsequent errors and improve the processing effect. The *VideoCapture* (video manipulation

class) in OpenCV library is chosen to read, write, draw frames and display the medical microscope video to be processed.

### 3.3. Motion Estimation Module

The processing of this module includes: acquiring feature points, tracking feature points, and finally estimating the motion between frames, obtaining vector information and storing it. The feature point acquisition utilizes the Shi-Tomasi corner point detection technique, which is an improved algorithm based on the Harris principle, using a different corner point response function from Harris, and the Shi-Tomasi corner point detection divides the correlation function for similarity calculation and finally achieves corner point detection. Feature point tracking utilizes the Lucas-Kanade optical flow tracking algorithm based on the optical flow method, and after obtaining the corner points, it is able to apply the LK optical flow method to match the optical flow values to achieve the tracking of feature points [8]. After obtaining the positions of the feature points from the first two steps, the motion vector information is obtained using the Euclidean transform, which is stored in a well-defined array for subsequent smooth changes.

#### 3.3.1. Feature Point Acquisition

The feature point acquisition is based on the video characteristics to choose the appropriate corner point detection technology, because Harris and Shi-Tomasi for edge corner point detection and noise response is better than Moravec corner point detection, and Shi-Tomasi corner point detection algorithm is faster than Harris corner point detection algorithm, so the algorithm in this paper feature point acquisition selected Shi- The response function of Shi-Tomasi corner point detection function is implemented by calling the *goodFeatureTrack()* function in the OpenCV library, as shown in (4), and the response function is used for the acquisition of high-quality feature corner points.

#### 3.3.2. Feature Point Tracking

$$(\cdot) = (1, 2) \quad (4)$$

Compared with the Lucas Kanade optical flow algorithm, the Lucas Kanade improved optical flow algorithm based on the image pyramid can effectively solve the problem of large changes between the front and back frames with the help of the image pyramid, which scales the image pyramid layer by layer to The jitter suppression algorithm in this paper solves the problem of large changes in pixel motion by calling the *calcOpticalFlowPyrLK()* function in the OpenCV library, which calculates the optical flow value of the feature points, that is, the tracking of the feature points, and solves the problem of large changes in pixel motion between the front and back of the video by establishing an image pyramid. The problem of excessive pixel motion between two frames.

#### 3.3.3. Motion Information Storage

In the above step, the optical flow calculation of the captured feature points is performed by the improved Lucas Kanade algorithm based on image pyramid, at which time the detailed motion information of the feature target pixel points in the video is obtained, including horizontal position information, vertical position information and motion direction angle information, by designing a container to store the motion vector for motion estimation, using the C++ programming language standard template This paper adopts the dynamic array Vector in STL to design the container for storing the motion vector, which effectively solves this problem. Unlike other containers, vector dynamic array has the function of dynamic expansion, which can automatically expand the memory space according to the number of data deposited, effectively avoiding the extra work of manually expanding the memory space capacity when the number of motion information is counted, and significantly reducing the time consumed by the program running. This paper designs a motion vector store based on vector dynamic array to

solve the problem of storing the motion information after the tracking of feature points in the process of motion estimation and to lay the foundation for the calculation of motion trajectory in the subsequent motion compensation module, which stores the motion vector information in order after the optical flow tracking, and the specific information stored is the two coordinate points of each motion vector in the two-dimensional image coordinate system. The specific information stored is the second coordinate point of each motion vector in the two-dimensional image coordinate system, and the direction of the motion that can describe the passing of the feature point to the next frame, the storage container model is shown in Figure 4.

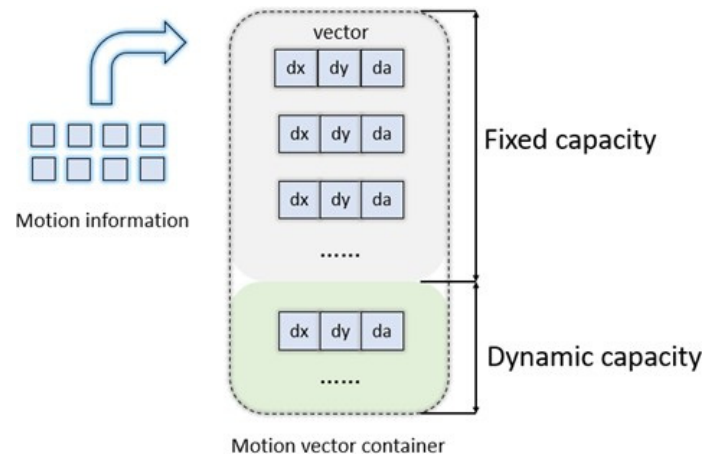


Figure 4. Motion vector storage container

### 3.4. Motion Compensation Module

Motion compensation of digital video is done by correcting the motion offset between video frames and reference frames and repairing the video after overcorrection according to the actual situation, and the two common types of motion compensation are: motion compensation based on fixed reference frames and motion compensation based on adjacent reference frames. The difference between the two types of motion compensation lies in the selection of reference frames [9]. In this paper, the motion compensation method based on adjacent reference frames is mainly selected.

#### 3.4.1. Motion Compensation based on Adjacent Reference Frames

The motion compensation method based on adjacent reference frames is to digitally process the video to be processed, read the two frames before and after the video and perform a single motion compensation, if the video has  $n$  frames, then a total of  $n-1$  times of reference and corresponding vector compensation is performed, the advantage of which is that there is no large change between adjacent frames, and the method can achieve that even if the information of adjacent frames is processed, there will not be a large loss of feature points between the front and back frames. The method has the advantage that there is no large variation between adjacent frames, and the method is able to process the information of adjacent frames without a large loss of feature points between the front and back frames. The flow chart is shown in Figure 5.

In this paper, we mainly use image smoothing technology to accumulate the global motion vector obtained in the motion estimation module, so as to obtain the video image position curve, which can reflect the change of image position in each frame, and we use filtering technology to smooth the curve to make it output a smooth curve, i.e., low-pass filtering of the curve, so as to realize the function of compensation of motion between frames. In addition, this module also provides the function of repairing boundary artifacts, which can effectively solve the black shadow effect at the edge of the image caused by excessive motion compensation, and finally output a stable video. For the motion compensation module, an accumulator is first designed to

accumulate the motion vector information provided by the estimation module to calculate the motion trajectory of the feature points, and then a filter function is designed to smooth (filter) the obtained motion trajectory according to the principle of moving average filtering technique.

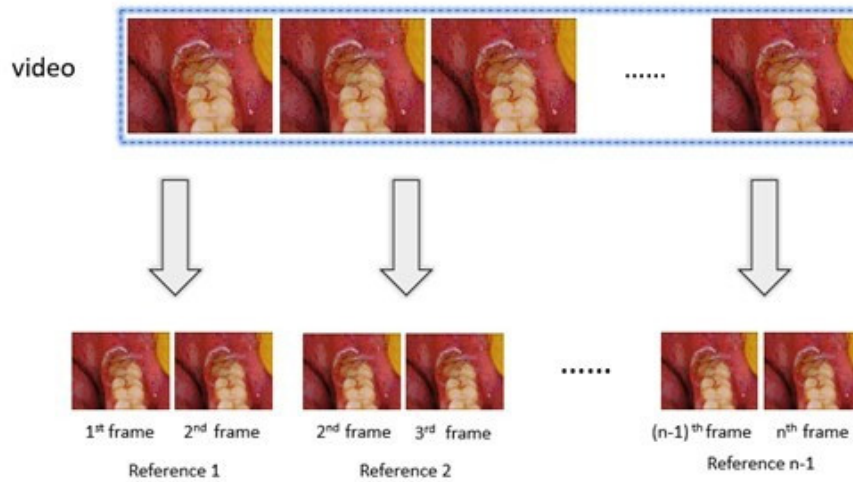


Figure 5. Motion compensation based on adjacent reference frames

### 3.4.2. Motion Trajectory Calculation and Quantization

The motion trajectory calculation is the premise of the subsequent motion vector compensation, the motion estimation module stores the motion vectors, n motion vector information is put into the motion vector container, the motion trajectory calculation needs to pass the motion vectors from the storage container in turn, and extract the three elements of the motion vector: horizontal coordinate x, vertical coordinate y, and motion angle a, respectively, this paper designs an accumulator to accumulate the information of the three elements of the motion vector, by accumulating and returning to the motion trajectory, calculate the motion trajectory calculation model as shown in Figure 6.

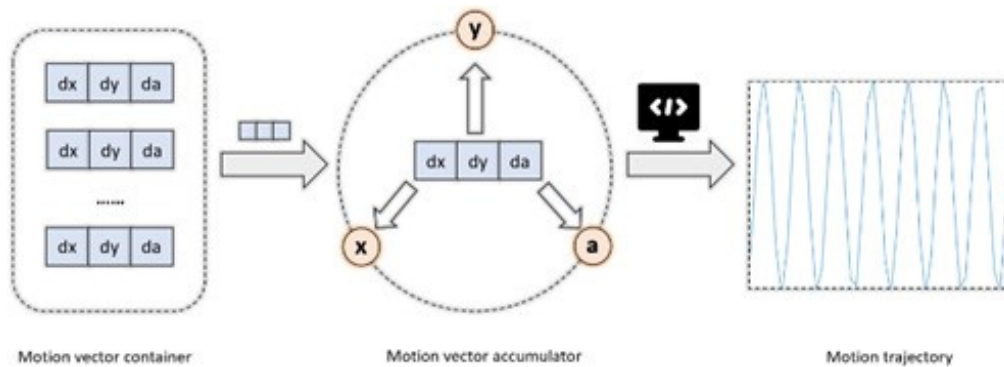
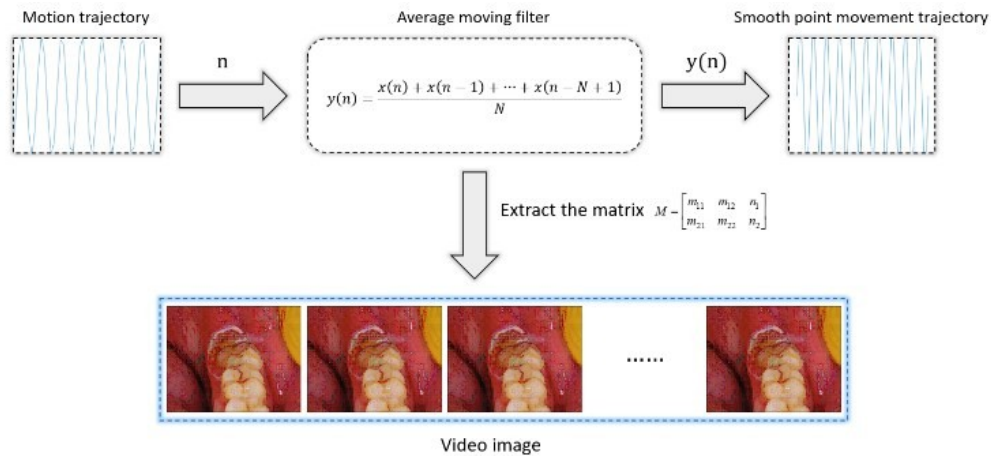


Figure 6. Motion trajectory calculation model

### 3.4.3. Trajectory Smoothing and Affine Transformation Extraction

In the previous step, the motion accumulator outputs a curve that can clearly describe the change of the video frame by frame - the motion trajectory, which intuitively reflects the jitter of the moving target in the video, if the curve of this motion trajectory can be smoothed, by extracting the motion transformation matrix of this smoothed trajectory and applying. If the curve of this motion trajectory can be smoothed, and the motion transformation matrix is extracted and applied, then a motion-stabilized video output can be obtained in theory. In this chapter, by designing a moving average filter which is based on the statistical law, each image sequence of consecutive video frames is viewed as a queue of fixed length N. After a new measurement, the first sequence of the above queue is removed and the remaining N-1 sequences are sequentially shifted forward and the new sampled image is inserted as the tail of the new queue; then arithmetic operations are performed on this queue, i.e., the accumulated

the obtained motion trajectory is smoothed, and a smoother motion trajectory is obtained by moving average filter. In the process of extraction, suppose the input image sequence is  $x$  and the output motion trajectory is  $y$ . Finally, the transform matrix of the processed smooth motion trajectory is extracted, and the video is motion corrected by this transform matrix. The process is shown in Figure 7.

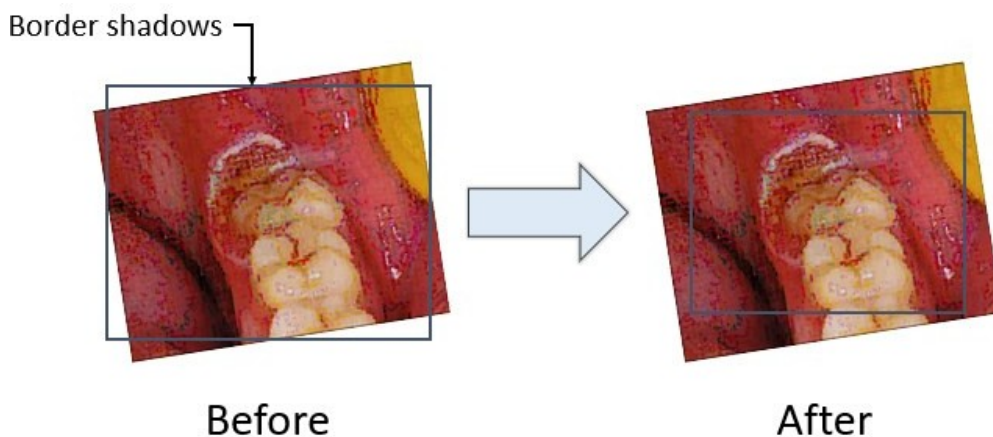


**Figure 7.** Trajectory smoothing and application process

In this paper, we use the `getRotationMatrix2D` function in OpenCV to perform the affine transformation to realize the motion vector correction function. According to the principle of affine transformation in the previous section, we set the radiation matrix as shown in (5).

$$M = \begin{bmatrix} m_{11} & m_{12} & n_1 \\ \dots & \dots & \dots \\ m_{21} & m_{22} & n_2 \end{bmatrix} \tag{5}$$

After some of the above processing, a stabilized video output will be obtained, but the processed video exposes a problem that some video frames appear as boundary artifacts after motion compensation due to excessive jitter during shooting [10], and a restorer must be designed to reduce the reduction of the filter on the video quality. The video restorer slows down the boundary artifacts of video frames by moderate size scaling of the smoothed video frames, and achieves the purpose of video restoration by scaling the size of a single frame in small increments to cover the artifacts with image magnification, and the video restoration demonstration diagram is shown in Figure 8.



**Figure 8.** Video Restoration

### 3.5. Algorithm Operation Flow

The low-cost jitter suppression algorithm for medical microscopy designed in this paper is firstly implemented by taking the video file as the input target of the algorithm, by performing the function of pre-processing module on this video, then the function of motion estimation module is implemented, the Shi-Tomasi corner point detection is performed on the video frame by frame to determine whether it is a high quality corner point, the high quality feature point is tracked using the image pyramid based Lucas Kanade improved optical flow algorithm for tracking, obtain the motion information vector by optical flow tracking, store the motion information of the video into the designed vector array container, then carry out the functional implementation of the motion compensation module, calculate the motion trajectory by the accumulator, get the motion trajectory and then use the moving average filter to smooth the curve, and then perform the smoothing curve The extracted matrix is applied to the video to complete the suppression of video jitter, and finally the video restorer is used to scale and repair the video frames with boundary artifacts and output the video, the flowchart of the algorithm is shown in Figure 9.

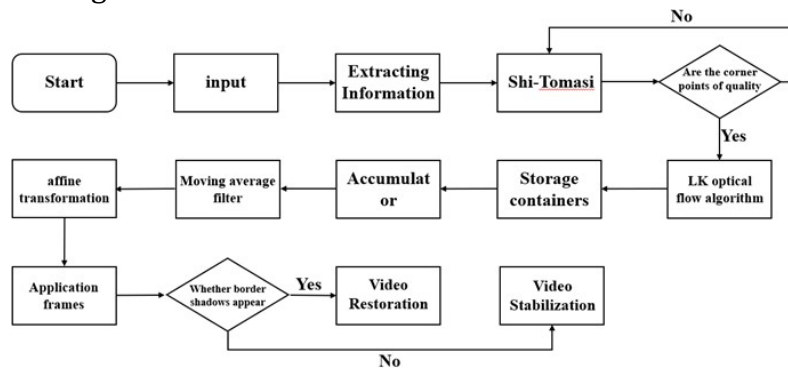


Figure 9. Algorithm operation

## 4. Experiment

### 4.1. Introduction

This paper conducts experiments on a computer equipped with an Intel(R) Core (TM) i5-7300HQ processor and 8GB RAM, the computer operating system is Windows 10, and the experimental software and function libraries used are Visual Studio Community 2019 and OpenCV4.1.0, respectively. The former is a video of tooth detection under the lens of medical microscope, and the latter is a video of hair observation under the lens of medical microscope. The purpose is to verify the feasibility and efficiency of the algorithm applied to the medical microscope, and also to demonstrate the actual effect of jitter suppression.

### 4.2. Results

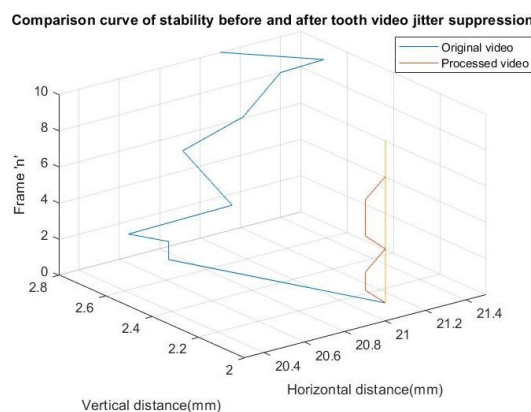


Figure 10. Tooth video graph jitter suppression situation curve comparison graph

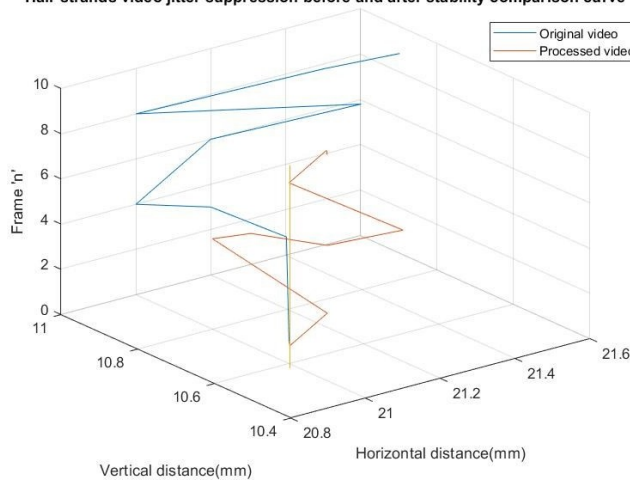
**Table 1.** Measurement Data for Dental Video Chart

Original Video			Jitter offset distance a		Processing Video		Jitter offset distance b		Correction distance	
Frame n	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)
1	21.0	2.0	0	0	21.0	2.0	0	0	0	0
2	20.5	2.5	0.5	0.5	20.9	2.0	0.1	0	0.4	0.5
3	20.5	2.5	0.5	0.5	20.9	2.0	0.1	0	0.4	0.5
4	20.3	2.5	0.7	0.5	21.0	2.0	0	0	0.7	0.5
5	20.7	2.4	0.3	0.4	20.9	2.0	0.1	0	0.2	0.4
6	20.8	2.7	0.2	0.7	20.9	2.0	0.1	0	0.1	0.7
7	21.1	2.7	0.1	0.7	20.9	2.0	0.1	0	0.2	0.7
8	21.4	2.8	0.4	0.8	21.0	2.0	0	0	0.4	0.8
9	21.5	2.7	0.5	0.7	21.0	2.0	0	0	0.5	0.7
10	21.1	2.8	0.1	0.8	21.0	2.0	0	0	0.1	0.8

**Table 2.** Measurement Data for The Video Chart of Hair Strands

Original Video			Jitter offset distance a		Processing Video		Jitter offset distance b		Correction distance	
Frame n	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)	Horizontal direction (mm)	Vertical direction (mm)
1	21.0	10.6	0	0	21.0	10.6	0	0	0	0
2	21.3	10.9	0.3	0.3	20.9	10.5	0.1	0.1	0.4	0.4
3	21.2	11.0	0.2	0.4	21.0	10.5	0	0.1	0.2	0.5
4	21.0	11.0	0	0.4	21.0	10.8	0	0.0	0.0	0.2
5	21.1	11.0	0.1	0.4	21.0	10.7	0	0.1	0.1	0.3
6	21.2	11.0	0.2	0.4	21.0	10.5	0	0.1	0.2	0.5
7	21.5	10.9	0.5	0.3	21.1	10.4	0.1	0.2	0.4	0.5
8	21.0	11.0	0	0.4	21.0	10.6	0	0	0.0	0.4
9	21.4	10.9	0.4	0.3	21.1	10.6	0.1	0	0.3	0.3
10	21.5	10.8	0.5	0.2	21.0	10.5	0	0.1	0.5	0.3

Hair strands video jitter suppression before and after stability comparison curve



**Figure 11.** Hairline video chart jitter suppression situation curve comparison chart

The comparison of the two sets of measurement data and curves shows that in a total of 20 comparison frames used for testing, the vertical direction achieves jitter elimination through jitter suppression, and the horizontal direction efficiently slows down the magnitude of jitter, providing effective jitter suppression for videos with low frequency jitter.

## 5. Conclusion

This paper proposes a low-cost jitter suppression algorithm for medical microscopes, which is aimed at the problem that medical microscopes in the handheld state of the doctor cannot avoid a slight jitter, which not only affects the doctor's detection process, but also may lead to the doctor's final judgment of the patient's condition deviation, thus causing medical accidents. The algorithm is based on OpenCV and C++ program design, and the design framework consists of three parts: pre-processing module, motion estimation module and motion compensation module. The pre-processing module successfully implements the functions of reading and lifting frames of medical videos, ensuring the implementation of obtaining the length, width, frame rate and format of the original video. The motion estimation module is able to estimate the motion vector information of the feature points in each frame of the video by using Shi-Tomasi angular point detection to capture the feature points in each frame, using the Lucas Kanade improved optical flow algorithm based on image pyramid to track the motion feature points in real time, and finally the module is able to achieve the estimation function of the motion vector information of the feature points in each frame of the video, the motion compensation module achieves the smoothing of the motion trajectory of the feature points in the video by moving average filtering method, and uses transformation techniques such as scaling, rotation and mapping to The motion vector compensation function for video jitter is finally realized by using the transformation techniques of scaling, rotation and mapping to slightly repair the over-processing after video smoothing. The experimental results show that the algorithm studied in this paper has a good jitter suppression effect on the medical microscope video with slight jitter.

## Acknowledgments

Industry-University-Research Project of Wuzhou High-tech Zone (2020G001). National Natural Science Foundation of China (61961036). National Natural Science Foundation of China (62162054).

## References

- [1] Information on: [https://doi.org/10.1007/978-3-319-00369-6\\_11](https://doi.org/10.1007/978-3-319-00369-6_11).
- [2] Blahnik, Vladan and Schindelbeck, Oliver. "Smartphone imaging technology and its applications" *Advanced Optical Technologies*, Vol. 10 (2021), No. 3, p.145-232.
- [3] M. Souza and H. Pedrini: Digital Video Stabilization: Algorithms and Evaluation, *Anais Estendidos do XXXII Conference on Graphics, Patterns and Images (Rio de Janeiro, 2019)*. p.35-41.
- [4] Information on: <https://doi.org/10.1016/j.imavis.2020.103957>.
- [5] K. M. Lee and C. H. Lin: Video Stabilization Algorithm of Shaking image using Deep Learning, *The Journal of The Institute of Internet, Broadcasting and Communication*, Vol. 19 (2019), No. 1, p.145-152.
- [6] Rahmaniar, Wahyu, & Amalia Eka Rakhmania: Online Digital Image Stabilization for an Unmanned Aerial Vehicle (UAV), *Journal of Robotics and Control (Online, 2021)*. Vol. 2, p.234-239.
- [7] Hambali, Roby, Djoko Legono, and Rachmad Jayadi: The application of pyramid Lucas-Kanade Optical Flow Method for tracking rain motion using high-resolution radar images, *Jurnal Teknologi*, Vol. 83 (2020) No.1, p.105-115.

- [8] S.Ji,Z.Feng and Z.Deng: Video stabilization algorithm based on background feature point matching, 2020 Chinese Automation Congress(Shanghai, China, November 6-8, 2020),p.2009-2013.
- [9] C.S. Wang: Research on Video Stabilization Algorithm Based on Feature Tracking (MS., Hubei University of Technogy, China 2020).
- [10]M. Zhao: Researches of Digital Image and Video Inpainting Algorithms (Ph.D., Hunan University, China 2011).