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Research of Digital Image Stabilization on Airborne Video

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Abstract. Video image plays an important role in people's life as an important information media. It is inevitable to be bumpy in the process of vehicle movement, at this time; the video acquired from vehicle traveling data recorder video will have the phenomenon of random jitter. In order to improving the effect of digital image stabilization, the purpose of this paper is to research the method of digital image stability of airborne video. This paper introduces the method and the composition of DIS, the basic principle and method of motion compensation. This paper has a further study of gray projection algorithm, and has made improvement at one point about traditional gray projection algorithm: enhancing grayscale contrast through image preprocessing, this solved the problem of gray-level changed not obvious. This paper had also proved these improvements are effective by experimental simulation.

1. Introduction

Digital image stabilization technology eliminates the chattering phenomenon caused by video surveillance through the image dithering algorithm. Because it is implemented by software, it does not occupy space, and has the advantages of easy integration, which meets the demand and reducing the cost of video surveillance. Generally, digital image stabilization system consists of two parts: motion estimation and motion compensation. It first estimates the global motion vectors between two adjacent frames in the input video sequence. After calculating the global motion vector of the two images, the corresponding motion compensation and correction are carried out, and finally the stable video is output. In comparison, digital image stabilization technology has more advantages. It is implemented by software, which meets the demand and helps to reduce the cost of video surveillance. The structure of the digital image stabilizing system is shown in Figure 1.

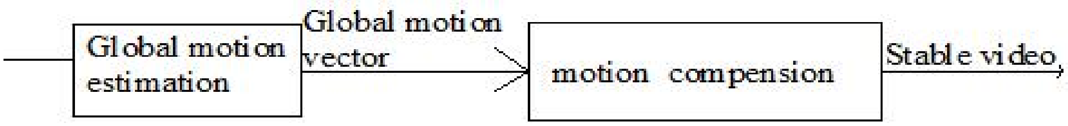


Figure 1. Digtal image stabilization system

2. Theory of digital image stabilization technology

There are many kinds of motion in airborne video imaging, such as the car in the straight, turning, reversing the normal movement, in addition to the random jitter also produced by camera. Digital image stabilization is a new video stabilization technology. Compared with traditional video stabilization techniques, digital image stabilization technology has the advantages of small volume, easy integration and operation, good flexibility, high accuracy advantages, and it has good development prospects in many fields. Digital image stabilization technology eliminates the random jitter phenomenon in video sequences by software. The implementation usually estimates the motion vectors generated by successive two frames in the video sequence. Then, the motion compensation of the current frame is carried out to achieve the purpose of video stabilization. Generally, digital image stabilization system can be divided into two parts: motion estimation and motion compensation.

2.1 The analysis of random jitter

A typical example of intra frame motion is high-speed object making the image blurred, such as when shooting a speeding car, intra frame blur is prone to occur. In this paper, the intra-frame movement is not studied, and the movement mentioned in the text refers to inter-frame movement. The other is inter-frame motion. It is caused by the low frequency vibration of the camera. This time each frame image is relatively clear. But the random jitter between the frames makes high frequency noise appear between the video sequences. In this case, it is necessary to estimate the motion vector between the image frame and the frame. The video sequence will be compensated according to the motion estimation parameters. After correction, the image sequence is output. Finally, the image stabilization is achieved.

Suppose that any point in the two-dimensional image is $[x, y]^T$, after movement, changing to position $[\hat{x}, \hat{y}]^T$, defining transformation matrix

$$M = \begin{bmatrix} m_0 & m_1 & m_2 \\ m_3 & m_4 & m_5 \\ m_6 & m_7 & 1 \end{bmatrix}$$

Then the motion transformation equation is

$$\begin{bmatrix} \hat{x} \\ \hat{y} \\ 1 \end{bmatrix} = M \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

In the formula, m_2 and m_5 represent the translation of the image in two directions, horizontal and vertical. m_0, m_1, m_3, m_4 representing the degree and size of rotation. m_6, m_7 representing the expansion of the plane dimension.

2.2 The analysis of motion compensation

2.2.1 The theory of motion estimation. In the image motion of airborne camera, there are two parts: the traveling motion of the carrier and the dither of the high frequency. Normally, the normal motion of a camera carrier is required to be preserved.If this part of the motion is mistakenly compensated, it will cause the video image to appear pseudo static, which is not what we want and the random jitter of the camera is what we really need to compensate for the elimination. The normal sweep belongs to a relatively smooth motion, belonging to a smooth signal, and its frequency is relatively low, and random jitter is relatively high frequency signal. In motion compensation, the high frequency random signal and low frequency smoothing signal should be filtered in the motion of the airborne camera, and then the corresponding random jitter can be compensated.

2.2.2 The method of motion filrering. Motion filtering is a commonly used compensation method for video with scanning motion. The basic idea is that assuming that the changes in the relative positions of the acquired video sequences have continuous and smooth features, and the video containing high-frequency dither signals, the direction and amplitude of the image position change are discontinuous and irregular. Motion filtering method is from the beginning of the first frame of the video global motion vector accumulated video sequence. By this method, the position signal of each frame in the video sequence is calculated. The formula is shown in (2-1).

$$FPS(n)=\sum_{i=1}^{n} GMV(i) \tag{2-1}$$

The FPS(n) represents the position of the video n frame image, and GMV(i) represents the change in the position of the current image and the previous frame. From the above we can see that the high frequency jitter vector of video can be considered as noise signal. Therefore, low-pass filtering of FPS(n) signals is necessary, Then the stable image position signal is separated from SFPS(n), Finally, the motion compensated vector CMV(n) is obtained. The calculation formula is as shown in (2-2).

$$\mathrm{CMV}(n) = FPS(n) - SFPS(n) \tag{2-2}$$

3. Gray projection digital image stabilization algorithm

Gray projection algorithm is a fast matching algorithm, even in the case of large translational jitter, the operation speed is also very fast. The gray projection method is matching image according to the image of the whole row and column gray projection curve correlation. It maps the signals in two-dimensional space into two independent one-dimensional signals. The two one-dimensional signals represent the gray projection curves of rows and columns, respectively. Then related operations are performed. Find the single peak value in the correlation value curve that is the displacement size of the current image relative to the reference image. The projection method is able to detect the translational motion between video sequences. It has the advantages of high speed and high precision. So, it can handle large moving fast, and is more commonly used motion estimation algorithm.

3.1 Improved gray projection algorithm

Through the above analysis, we can conclude that there is a problem in the traditional gray projection algorithm: If the gray contrast of the captured video images is not obvious, this will cause great interference to the algorithm. After the above understanding of the gray projection problems and we will improve the traditional gray projection algorithm based on these problems. In order to solve this problem, this paper carried out the histogram equalization and image filtering. The following will be a specific analysis of the study.

3.1.1 Image filtering. When the two consecutive frames in the video sequence produce larger motion vectors, the edge information of the two frames must be different. In this case, if the edge information is involved in the subsequent correlation calculation, it will cause a great deal of interference. Generally, it can be solved by projection filtering, such as filtering through median filter. Median filter is a nonlinear spatial filter, it sets an odd number of points in the template region. The gray values of the pixels in the region are sorted according to the size, and the median values are taken. For a template region containing even numbers of points, the gray values of the two pixels in the middle of the sort need to be averaged. The median filter requires move template a bit by bit in the image to be processed. Until the median filter is completed for each pixel in the image. The main function of the median filter is to remove the isolated pixels, that is, isolated noise, so that the neighborhood gray values of each pixel point closer to each other, while the filter can protect the edge of the image.

3.1.2 Histogram equalization. Because of the different scenes of video capture, such as the influence of illumination, background and noise, there is a big gap between the video sequence and expectation. For a single video sequence with a relatively gray scale, the estimation of motion vectors is prone to errors. Therefore, before the image map, it is necessary to preprocess the image sequence of the video. Histogram equalization of image sequences is processed here. Before histogram equalization, we first need to understand the histogram of the relevant concepts, the image histogram is a one-dimensional discrete function. Formula is as follows:

$$p(s_k) = \frac{n_k}{n} \tag{3-1}$$

In the equation, $k = 0, 1, \cdots, L-1$, s_k represent the k level image gray value, n_k represents the number of pixels whose gray value is s_k , A is the total number of pixels, $p(s_k)$ is the probability that n_k appears in all pixels.

Histogram equalization is a common method in image processing. It uses image histogram to adjust the contrast. The method is used to increase the local contrast of the image, especially when the contrast of the useful data of the image is close. In this way, the brightness of the image can be better distributed on the histogram, which can be used for local contrast enhancement, and does not have too much impact on the whole. Histogram equalization is achieved by extending brightness. The basic principle of histogram equalization is to transform the histogram of original image into uniform distribution. The value of K is more abundant in the upcoming approach. In this way, the effect of extending the gray range of the image is achieved. On the basis of formula (3-1), the enhancement function EH is used to process pixels. The original gray value s_k maps into t_k through function. Such as type (3-2).

$$t_k = EH(S_k) \tag{3-2}$$

In the formula, the enhancement function needs two conditions. Firstly, $EH(s_k)$ should remain monotonic in the $0 \le s_k \le 1$ range. Secondly, within the $0 \le s_k \le 1$ interval, the mapped range should satisfy $0 \le EH(s_k) \le 1$. The original image in a condition to ensure the transformation of gray level ranking unchanged, whereas condition two is to ensure that after mapping the pixel value in the allowable range. An inverse transformation formula, such as formula (3-3).

$$s_k = EH^{-1}(t_k) \tag{3-3}$$

The formula satisfies the above two conditions, and $0 \le t_k \le 1$.

The above analysis shows that the original histogram can be accumulated, Because the cumulative operation can satisfy the above two conditions, At the same time, the distribution of s_k can be transformed into t_k uniform distribution, Such as type (3-4).

$$t_k = EH(s_k) = \sum_{i=0}^{k} \frac{n_i}{n} = \sum_{i=0}^{k} p_s(s_i) \tag{3-4}$$

In this type, $0 \le s_k \le 1$, $k = 0,1,\cdots,L-1$, According to the above formula, we can calculate the histogram equalization of the original image. In fact, the value of t_k need to be deal with.

Figure 2 is the histogram equalization before and after the two comparison chart.

(a) the original image (b) Histogram equalization of images

Figure 2. Compared before and after the image histogram equalization

3.1.3 Image map. Image mapping is the basic idea of gray projection algorithm. The gray information of the rows and columns is superimposed on the image information, and finally two gray projection curves are obtained. It can be represented by expressions (3-5) and (3-6).

$$Col_k(j) = \sum_{i=1}^{N} Cur_k(i,j) \tag{3-5}$$

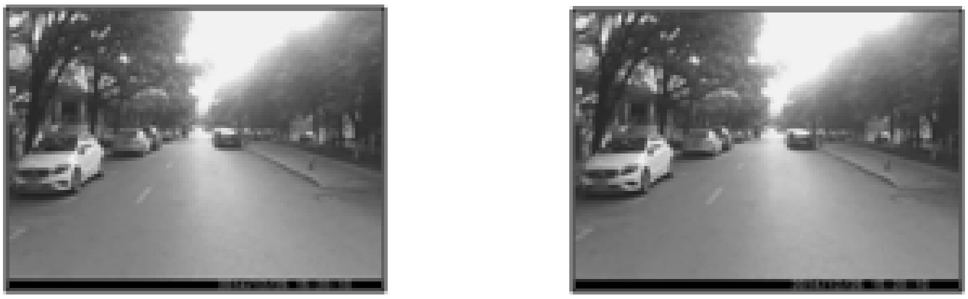
$$Row_k(i) = \sum_{j=1}^{M} Cur_k(i, j) \quad (3\text{-}6)$$

In the formula, $Cur_k(i, j)$ is the gray value of the k image at the (i, j) position. $Col_k(j)$ is the projection gray value of column k in column j . $Row_k(i)$ is the gray projection value of line k in line i , and the image size is $M \times N$.

3.1.4 The digital image stabilization of gray projection algorithm. The experiment is conducted by MATLAB programming, the video resolution is 640 *480, the frame rate is 25FPS.

Image preprocessing here is divided into image filtering, histogram equalization, two sub experiments respectively. Filtering is to remove the isolated noise point, the experiment selected the median filter method, and the method can filter out the noise at the same time to protect the image edge information. Histogram equalization is to enrich the gray scale of the image and enhance the contrast of the image.

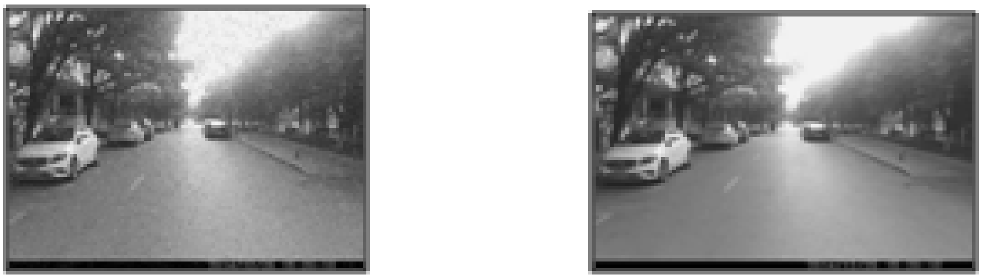
In this paper, the image filter experiment selects the median filter, and the template selects the size of 3 * 3. Take an image from the actual video sequence and compare the images before and after median filtering, as shown in Figure 3.



(a) original image (b)Median filtered image

Figure 3. Compared before and after image median filtering

The median filtering effect can be visually in the picture above magnification is observed obviously, but the effect is not intuitive under normal size. In order to make the experiment more obvious, we can add noise to the original image first, and then add median filtering to the image after adding noise. The following experiment will add salt-and-pepper noise to the original image. Figure 4 shows the effect of adding the salt and pepper noise before and after median filtering.

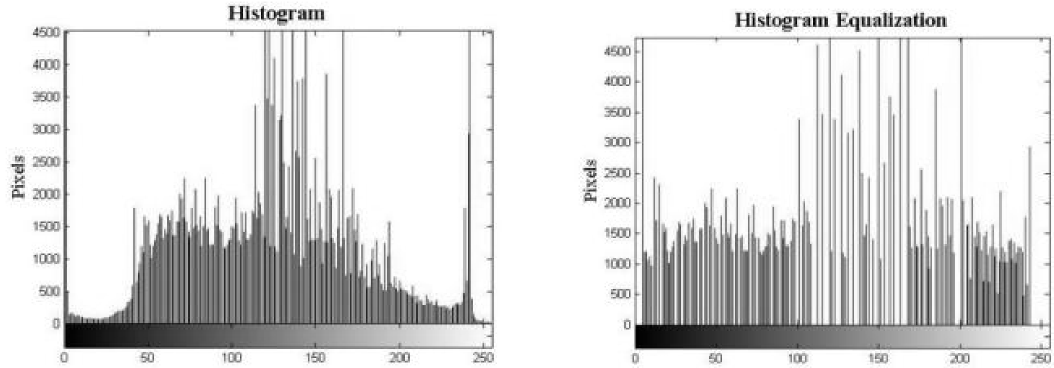


(a) Add the image of the salt and pepper noise (b) Median filtered image

Figure 4. Compared before and after median filtering with salt and pepper noise

(a) After equalization of reference frame histogram (b) The current frame after histogram equalization

Figure 5. Compared before and after image histogram equalization



(a) Reference frame raw histogram (b) The reference frame after histogram equalization histogram

Figure 6. Compared before and after histogram equalization of reference frames

As can be seen from the figure above, the median filter can make the nearby pixels closer to the real value, and then remove the isolated noise points. The following experiments take the two frames in the actual video sequence as an example to process the equalization. As shown in Figure 5.

Figure 6 is a reference frame before and after histogram equalization histogram, we can see that the gray level equalization is more uniform. In this chapter, the gray scale projection algorithm is deeply researched and improved, and the basic principle of gray projection algorithm is analyzed in detail.

4. Conclusion

This paper focuses on airborne video digital image stabilization method. The basic principles of motion compensation are briefly introduced. In this paper, a gray projection algorithm with relatively fast computation speed is chosen for the case of large motion offset. In view of the problems existing in the traditional gray projection algorithm, this paper makes a little improvement: before motion vector estimation, image preprocessing is used to enhance the image gray contrast and enrich the image details. Which solves the problem that the gray scale projection is limited by the gray scale change is not obvious. Finally through the experimental simulation shows that through this improvement, it improves the effect of gray projection algorithm.

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6. References

[1] Kim Choong, Myeong-Gyu Song, No-Cheol Park, et al. Design of a hybrid optical image stabilization actuator to compensate for hand trembling [J]. Microsystem Technologies, 2011, 17(5): 971-981.
[2] Cardani Brent. Optical image stabilization for digital cameras [J]. IEEE Control Systems Magazine, 2006, 26 (2): 21-22.

[3] Yin De-Sen, Yue-Jin Zhao, Bin Wang. Motion filter for digital image stabilization [J]. Beijing Ligong Daxue Xuebao/Transaction of Beijing Institute of Technology, 2008, 28 (SUPPL.1): 144-147.
[4] Maheux J, Cruickshank J M, Sevigny L. Video-rate image stabilization system [J]. Opto-Contact: Workshop on Technology Transfers, Start-Up Opportunities, and Strategic Alliances, 1998.
[5] Jiatao Qiu. Research on Electronic Image Stabilization Algorithm and Visual Tracking Algorithm [D]. Xian: University of Electronic Science and Technology of China, 2013
[6] Jin Luo, Jie Xu. Vehicle image stabilization algorithm based on Lane crossing point [J]. Computer technology and development, 2013, 23 (3): 1-4.
[7] Lu Yu. Research of electronic image stabilization technology based on image matching [D]. Changchun, Changchun University of Science and Technology, 2009.
[8] Bo Wang. Research of Digital image Stabilization Method on Airborne Video [C]. Xuzhou, China university of mining and technology, 2-15.
[9] Zhanlong Yang. Research on feature point based image registration and stitching technology [D]. Xian, University of Electronic Science and Technology of China, 2008.