Research on Electronic Image Stabilization Technology of Vehicle-Mounted Remote-Controlled Weapon Station

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Abstract. The image information of the vehicle-mounted remote-controlled weapon station is jittered and blurred when the stance changes or vibrates, which increases the aiming difficulty and observation fatigue of the shooter, in order to realize the stable marching fire of the vehicle-mounted remote-controlled weapon station, the two-stage stable scheme with the shared gyro sensor is adopted in the system design, namely, the aiming device is rigidly fixed on the initially stable weapon platform, and then the electronic image stabilization is carried out. This paper proposes an approach combining two image stabilization schemes: gyro sensor data and image projection registration, optimizes the selection of image compensation data by registering and comparing the results of the two stable data, and uses the special features of the two schemes to improve the robust stability of electronic image stabilization, which ensure the observation effect of video image stabilization of the vehicle-mounted remote-controlled weapon station.

Keywords: remote-controlled weapon station, electronic image stabilization; projection; time registration; angular velocity.

1. Innovation Point
This paper adopts the gyroscope target angular velocity as the sighting telescope of image data processing algorithm to normally scan motion estimation, and proposes an approach combining the two image stabilization schemes: gyro sensor data and image projection registration, registers and contrasts the results of two stable data, optimizes the selection of image compensation data, improves the robust stability of electronic image stabilization, and ensures the stable observation effect of the video image of the vehicle-mounted remote-controlled weapon station.

2. Introduction
The requirements of fast, efficient, and maneuverable make more weapons be loaded on vehicles or ships, however, the bumpy road results in severe vibration of the vehicle body, which causes the image to be observed by the human eye to be jittered and blurred, and it is impossible to aim at the target during shoot, moreover, long observation of vibration images makes the observer prone to fatigue. Generally, the fire control system of armored vehicles is designed with the special field stable platform, which is quite expensive. The remote-controlled weapon station project is not equipped with the special field
stable system out of consideration for system volume, weight and cost. When the attitude of the carrier changes or vibrates, the obtained image information becomes blurred, which reduces the measuring and aiming accuracy. In order to achieve the stable marching fire of the vehicle-mounted remote weapon station, it is necessary to solve the problems of weapon disturbance, field of view jitter, and image blur when marching, and conduct stable treatment for the real-time video image.

3. Electronic Image Stabilization

The image motion compensation technology is the most basic technology in electronic image stabilization, its basic principle is: first, the angular displacement of the video capture device of the sighting telescope is found and converts it into the image jitter displacement on the display, when the image is displayed, move equivalently in the opposite direction in accordance with the detected motion drift, and realize fast and accurate detection of shifting jitter and directly remove it. Electronic image stabilization technology is to reduce random interference in the image and keep the image stable. This paper obtains the motion vector of the image by the method of obtaining the angular deviation of the gyroscope sensor and the image projection registration method, and then the optimal result is used for image motion compensation to realize the stable processing of the real-time video image.

The image used for observation is composed of continuous multi-frame images, there are always differences in the contents among frames, there are many reasons for the changes of image contents, such as noise interference, the movement of local objects in the scene, and the motion of sighting telescope itself. From the perspective of the motion of the sighting telescope, the sources that cause the motion of the sighting telescope of the remote-controlled weapon station include four aspects:

I. Vibration changes in the angular displacement of the sighting telescope caused by vibration;
II. The up and down or left and right translation of the sighting telescope caused by the motion of the vehicle-mounted platform;
III. Since the rotation shaft of the vehicle-mounted platform and the sighting telescope are not concentric, the sighting telescope will move up and down or left and right due to the angular displacement vibration of the vehicle-mounted platform;
IV. The rotation of sighting telescope caused by man-made active manipulation when the observer tracks the target shooting;

The purpose of electronic image stabilization is to eliminate the translation or angular displacement bumps caused by the platform or the vehicle vibration while retaining the man-made manipulation motion; it mainly consists of motion vector estimation and motion compensation two parts. The motion vector estimation among image sequences includes accurate estimation of the vibration vector and the global motion vector of the active motion of the platform.

4. Image Stabilization of Gyroscope Data

4.1. System platform architecture of remote-controlled weapon station

The system structure of image stabilization of gyroscope data and is shown in Fig.1, a fiber optic gyroscope and a video capture device that can be sensitive to pitch and roll toward two directions are installed in the sighting telescope, the sighting telescope is rigidly connected to the remote-controlled weapon, the system also includes a console, image processor, monitor display, drive control actuator.

During the drive of the vehicle, the gyroscopes measure the velocity and angular deviation of the weapon platform in the roll and pitch direction of the inertial space, and control the stability of the weapon platform via the platform stabilization drive device, the stabilization precision of the platform can be controlled within 1.5mil. The video capture device captures the target image and sends it to the image processor. The principle of image stabilization of gyroscope data is based on the stable axis of the gyroscope, on the basis of the automatic stabilization of the weapon platform, the residual error (angle deviation) of the weapon platform relative to the stable axis of the gyroscope is obtained, the image processor converts the number of displayed pixels to the stabilized angular deviation, then it
conducts image motion compensation on the video image sequence in accordance with the conversion result to achieve image stabilization.

4.2. Data processing of gyroscope image stabilization

Finally, the motion compensation of electronic image stabilization is calculated based on the number of translation pixels, this algorithm should consider the following three factors:

(1) This system adopts 6x continuous field zoom sight ing telescope, the field angles of Different focal lengths are different;

(2) The angular deviation given by the system includes the set firing angle and lead, this firing angle and lead should not cause image compensation, when calculating the angular deviation, the influence of the firing angle and lead should be removed.

(3) Since the exposure time is different under different brightness backgrounds when the image is acquired, the image display has a time delay with not less than 30ms from acquisition to display, therefore, time registration technology should be used to ensure that the gyroscope's angular deviation is synchronous with the capture time image.

Therefore, the pixel compensation data of the gyroscope image stabilization is related to the field angle of the sighting telescope, the display pixel resolution of the monitor, the set shooting angle and the lead when shooting, and the angular deviation during image capture, the formula is as follows:

The number of horizontal compensation pixels = \( \frac{\text{horizontal angle deviation} + \text{shooting lead}}{\text{horizontal field angle}} \times \text{the number of display horizontal pixels} \) (1)

The number of vertical compensation pixels = \( \frac{\text{vertical angle deviation} + \text{firing angle}}{\text{vertical field angle}} \times \text{the number of display vertical pixels} \) (2)

The advantage of this algorithm is that since this algorithm is based on the stable axis of the gyroscope, there is no spatial position estimation of the reference comparison template, so there is no need to estimate the global motion vector of the active motion of the platform.

The disadvantage of this algorithm is because the gyroscope is sensitive to angular velocity and angle signal, it cannot eliminate the up and down or left and right translation caused by the motion of the vehicle-mounted platform, or the up and down or left and right translation of the video capture device caused by the angular displacement vibration of the vehicle-mounted platform due to the deviation of the vibration axis distance. Moreover, this algorithm depends heavily on the repetitive measurement
accuracy of the gyroscope angular deviation, and the stabilization effect is poor when the repetitive measurement accuracy is low.

5. Image Processing Algorithm and Image Stabilization

Because the image processing algorithm directly processes the video image sequence without intermediate links, it has high accuracy and good image stabilization effect under the condition of rich image background, which can directly eliminate the impact of translational jitter.

The most critical step of image stabilization of image processing algorithm is to estimate the motion vector among image sequences. Motion vector estimation is to estimate the motion vector of consecutive frames by conducting image algorithm processing on the image sequence. The calculation in this step is complicated, the amount of calculation is large, and the time consuming is long. Typical stable algorithms are [1]:

1. Representative point matching (RPM): this algorithm is not sensitive to image changes because the representative point is determined, and the representative point is not the point with obvious characteristics on the image, and it cannot compensate for rotation and slow shaking.

2. Feature tracking algorithm (FTA): FTA algorithm often selects characteristics with obvious features in the image, for example: corner points, straight edges, curved edges, other local features, global features such as core, surface area, and the long and short axis of the inertia moment. In the real scene, the characteristics tracking algorithm will face serious problems where each feature is greatly affected by various interferences: such as the cover of the target, the shadow of the scene, the change of the background, etc., these changes make the tracking of the characteristics very difficult.

3. Projection algorithm (PA): image matching is carried out based on the correlation of the gray projection curve of the image overall rank; it can detect the translation motion among frames of the image sequence, the detection accuracy of the algorithm is detected by subsequent tasks, the accuracy can be improved by doing partial cross-correlation calculation at the peaks of the rows and ranks. The advantage of this algorithm is fast calculation speed and it is not sensitive to the overall change of the image gray scale. It is the most commonly used motion estimation algorithm, the algorithm used in this study is the projection algorithm.

Another key issue of image stabilization for image processing algorithms is how to use image information to distinguish the jitter amount and the normal scanning motion of the sighting telescope, the optimization algorithm adopts the number of times the angular deviation reaches the maximum per unit time to automatically adjust the adaptive mean filter algorithm of the filter window width, and predict the normal scanning motion of the camera [2]. Predictions are sometimes inaccurate, this research combines the gyroscope data, directly adopt the measured precession angular velocity of the gyroscope to describe the normal scanning motion of the sighting telescope.

The basic algorithm commonly used in electronic image stabilization is the projection algorithm, this algorithm is relatively complete, it can quickly and accurately process image sequences with translational motion, simple rotational motion (single-axis small-angle rotation), and small target moving objects on the image, but at present, it mainly deals with image sequences with clear matching features. These sequence images are rich in background, the motion among frames is small, and there is no or very little local motion. The actual situation is complex and changeable, which makes the algorithm have great limitations [3]. There are the following problems:

The algorithm cannot effectively solve the possible accurate inter-frame image matching of large-angle rotation and zoom motion, condition.

2. The update problem of the comparison template needs to be treated carefully: even without the normal scanning motion of the sighting telescope, the scene during the vehicle drive is constantly changing, so the template should be updated, but the continuous template update in real time will cause the accumulation of continuous errors in the inter-frame difference data, so the template must be stable and not updated within a certain interval, and the template update problem under the condition of zooming must be dealt with, and the accumulated error must be eliminated regularly;
(3) The electronic image stabilization of the image algorithm is only accurate and effective when there is a clear matching feature among the image frames it processes, however, some image scenes such as blue sky or white wall or dark field of view have no matching features or the matching features are not obvious in the horizontal or vertical direction, resulting in matching errors.

(4) Intra-frame motion affects the calculation results: in addition to the various motions of the sighting telescope itself, there may be local motions such as the foreground motion target and the motion of small objects in the background in the shooting scene. During processing, these local motions will cause adverse effect on the extraction of inter-frame motion parameters [4], so the projection algorithm of the entire image is used to minimize the influence of intra-frame motion.

6. Joint Algorithms and Image Stabilization
The core idea of the image stabilization of joint algorithm is based on the gyroscope data, although its accuracy is low and cannot be sensitive to translational motion, but the data is accurate and reliable, the error and the translational disturbance of the carrier should not be large, its accuracy should be within the stable accuracy range of the stable platform (1.5mil peak-to-peak value), the image processing algorithm is to improve the data accuracy based on various measures, it should be based on gyroscope data, The image algorithm data beyond the error range of the gyroscope data should be rejected and abandoned.

The image processor algorithm structure of this research is shown in Fig.2:

![Fig. 2 the image processor algorithm structure of this research](image)

1. In order to improve the accuracy of the image processing algorithm under weak lighting conditions, the histogram image enhancement technology is used to convert the image brightness, if the gray scale of the image in the 0-255 range is enhanced and converted completely according to the algorithm of the textbook, it will amplify the gray scale noise and affect the image observation and calculation. So this research adopts the adaptive algorithm to enhance the gray scale in the 0-50 to 0-(75-90) range, the experiment proves that the observation effect is good.

2. In order to reduce the noise interference, median filter is used on the image, the role of median filter is to make points with different gray scales look closer to their neighboring values, the algorithm adopts FPGA to find the median gray scale value of NxN pixels to fill the gray scale of the current pixel, the median filter can remove those isolated pixels that are brighter or darker relative to the neighboring area, thereby improving the stabilization accuracy;

3. When calculating the row and rank projection, the scene around the field during the actual operation of the vehicle image may have new background entry and old background exit due to the motion of the camera, therefore, in order to have a clear match, when setting the template, the four edges of the image are reduced by 64 pixels;
4. The template projection compares all the row and rank projection of the whole image one by one within the 0-128 pixels field at present, calculates the absolute sum of the projection differences of each row and rank, and finds the minimum and maximum of the absolute sum of the differences, and record the sum of the absolute value of the projection difference;

5. When setting the template, it is necessary to query the angular velocity of the gyroscope target motion, according to the value of the angular velocity, two modes, static state and motion state, are set;

6. In the static state, the update of the comparison template need interval, in this research, the car speed is set to update every 5s, its purpose is to compare with the static template to eliminate the cumulative effect of the difference among image frames. When the 2.5-degree field is at 60km/h, the scene entering and exiting the field directly ahead does not exceed 5 pixels, and does not exceed the search range of 128 pixels. However, the scene where the entering and exiting field angle perpendicular to the motion direction of the car body exceeds 100 pixels, at this time, the field scene changes too fast, the range of inter-frame difference can be set, if it exceeds 50 pixels, use the gyroscope data directly, and update the deviation data of the template and the center position of the template;

7. When the template is updated in the static state, the center point position deviation dx0 and dy0 of the new template at the update time should be recorded at the same time;

8. The image inter-frame difference sel in the static state is equal to the absolute value of the projection difference and the minimum point minus 64, So if the value is 64, it means that there is no image motion among frames;

9. The image stabilization compensation data formula of the current image in the static state is:

\[ dx = dx0 + selx; \quad dy = dy0 + sely \] (3)

10. Since this system takes the gyroscope axis as the basic control firing angle and lead, the gyroscope should be used as the basis to eliminate the accumulated error of the image template regularly. This algorithm is to update dx and dx0 to the gyroscope data synchronously when the gyroscope data and the image algorithm data are less than 5 pixels after the time exceeds 20 seconds, and updates image comparison template synchronously.

11. Due to the dramatic changes in the image scene during the motion state, the template is updated for each frame, when the template is updated, the center point position deviation dx0 and dy0 of the new template should be recorded at the update time;

12. The number of active motion pixels of the sighting telescope is calculated as follows:

\[ mv = \frac{vx}{frame\ rate} \times horizontal\ field\ angle \times display\ horizontal\ pixel\ number \] (4)

13. The image stabilization compensation data formula of the current image in the motion state is:

\[ dx = dx0 + selx - mvx; \quad dy = dy0 + sely - mvy \] (5)

14. Because the image processing algorithm cannot effectively solve the accurate inter-frame image matching of possible large-angle rotation and zoom motion, etc., there will be the matching error when there is no matching feature in the scene such as blue sky or white wall, or the matching feature is not obvious in the horizontal or vertical direction, therefore, the situation of the image scene should be monitored in real time, when there is no matching feature (the difference between the maximum and minimum of the absolute value of the projection difference and the ratio should not be less than the threshold TH), the gyroscope data is directly used. When the difference between the image processing algorithm and the gyroscope data is greater than 10 pixels, there may be situations such as large-angle rotation motion and zoom motion, so the gyroscope data is directly used. When using gyroscope data, it is necessary to update the image template synchronously and record the center point position deviation dx0 and dy0 of the new template;

7. Conclusion

After adopting the joint algorithm in this research, the environmental adaptability to weak illumination conditions and weak image feature scenes is significantly enhanced, and its stability accuracy is improved in better image feature scenes, and the test results are good in the various assessment tests in the demonstration and verification stage of the prototype.
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