A Study on Object Tracking Signal Generation of Pan, Tilt, and Zoom Data

Jin-Tae Kim

Department of Aerospace Software Engineering, Hanseo University, Korea
jtkim@hanseo.ac.kr

Abstract

CCD cameras monitoring a moving object generally operate with a fixed view point or a defined pattern. As a result, a free-moving object can move out of the CCD camera's field of vision quickly, and automatic control is required to observe the object continuously. This paper proposes a signal generation algorithm for the automatic control of a CCD camera. Using the control signal, the monitoring camera can track a moving object and keep it near the image center for a longer time. The proposed method is validated in experiments that automatically move a mark located at a specified position to the image center. The proposed algorithm computes horizontal and vertical displacements between the detected object position and the image center and converts them into angles. Finally, pan/tilt data are generated from the angles. To evaluate the proposed algorithm, we compare the generated data in the automatic control with measured data in manual control and carry out the object tracking using a simple object. The experimental results show that the difference between the generated and measured data is a negligible quantity, and the object, which is moving within ranges of $\pm 52^\circ/\pm 40^\circ$ of pan/tilt, is kept within about $\pm 13^\circ/\pm 10^\circ$ from the image center.

Keywords: Automatic Control, Image Center, Object Tracking, Pan/Tilt/Zoom

1. Introduction

Since the objects that are monitored are moving and the CCD cameras' fields of view (FOV) are limited, the objects can move out of the FOV of the CCD cameras in a short time [1]. Therefore, most CCD cameras move along defined patterns, but that is not enough [2]. Methods that attempt to solve this problem include installing more CCD cameras, or controlling CCD cameras in order to continuously keep objects of interest in the center area of the image [3,4].

Monitoring systems using image processing techniques obtain images through CCD cameras, detect the positions of moving objects of interest, and create camera control signals based on the positions of the object in order to track the object [5-8]. This paper suggests a method to appropriately create CCD camera controlling signals including pan and tilt information based on the positions of objects using image processing techniques in order to continuously monitor moving objects. This paper describes methods to calculate necessary information to control given controllable CCD cameras through image processing techniques, and compares the results of the calculation with results of actual measurements. Then, information useful for CCD camera control is demonstrated. In addition, a tracking experiment is conducted with a simple object using control signals created by the method suggested in this paper to show that the created control signals are valid.
2. Comparison Experiments of Signals

We have conducted an experiment to estimate the pan, tilt, and zoom data generated by the equations mentioned earlier. For the experiment, we installed a dome monitoring camera in the laboratory and acquired 640x480 images and attached markers at fixed positions. Figure 1 shows the experiment environment. Horizontal and vertical lines are drawn to confirm the markers alignment. After acquiring images, we calculated the camera signals required for the experiment. Then, we transmitted the calculated control signals to the camera using an RS-232C connection.

![Figure 1. Experimental Environment](image)

2.1. Pan Data

To validate the calculated pan data, we attached makers at designated horizontal locations as shown in Figure 1. The horizontal angle was calculated to move each mark to the image center. Then, by using the horizontal angle, the pan data was calculated. After generating the pan data, we have compared the calculated data with actual measurements using manual camera movement.

The absolute difference between the calculated pan data and the actual measurements is up to 8. A difference of 8 means approximately 0.2 in the horizontal angle, or a distance less than 3 pixels. The difference was caused by inaccurate marker location and inaccurate decisions for the marker position.

2.2. Tilt Data

The experiment to validate the calculated tilt data is similar to the experiment for the pan data. First, we set up markers at designated vertical locations. However, the lower half of the image was used for difficult-to-acquire data. The vertical angle of each mark was calculated, and tilt data was calculated by substituting the vertical angle.

Like the pan data, the tilt data generated a slight difference between the calculated values and the measured values. Here, the maximum difference of 9 was shown, which is equivalent to approximately 0.13° in the vertical angle or a distance of less than 2 pixels. This difference occurs for reasons similar to that expressed for the pan data.

2.3. Zoom Data

We measured the magnifications of 32 selected zoom data to derive a relational equation between the zoom data and the ratio obtained from 3th degree polynomial fitting using the magnification and the zoom data.
To evaluate the validity of the calculated zoom data, we set up a target magnification and by substituting it, calculated the zoom data. Then, using the calculated zoom data, we magnified an image and compared its sizes before and after magnifying a target. It can be seen that the target magnification is not generated in both the calculated magnifications and the measured magnifications. However, the magnification errors are less than 4%, which is acceptable for tracking the target.

Figure 2 shows the pan data error and tilt data error for various magnifications by zoom data. The errors occur in areas that are far from the image center, or for larger magnification. However, the errors are within 6 pixels for the pan data and 3 pixels for the tilt data, which are also acceptable for tracking the target.

3. Object Tracking Test of the CCD Camera

In this Section, object tracking tests are performed in order to evaluate the performance of the proposed control signal generation algorithm for the CCD camera. Prior to the tracking test, appropriate frame frequency and pan/tilt data were selected to track objects in the test environment, using a DMP23 dome camera, RS-232C communication, and a P4 2.4GHz PC for image processing.

3.1. Initialization and Acceleration of Camera

For the CCD camera to track an object, control signals generated based on the location of the object are provided to the camera at regular intervals. For smooth object tracking, the motions of the camera responding to the control signals must be analyzed. Figure 3 shows the location of an object in an image after movements of the camera, after control signals had been sent to the camera commanding the camera to move the object to the center of the image. From Figure 3, it can be seen that initial movement distances are very short, movement distances are different among different frames, and time is required for the movement speed to increase and reach a certain level. Therefore, when controlling the camera for each frame, control signals with appropriate frequencies and sizes must be generated for normal operation of the camera.
3.2. Effect of Frame Frequency

A certain time is required for a CCD camera to receive control signals and to move to the designated location. The control signals are produced for each frame, so frame frequencies must be considered. Under high frame frequencies, smooth object movements may be shown, but the camera may not perceive control signals due to the short time intervals. Under low frame frequencies, the camera will normally receive control signals, but unnatural object movements may be shown. Figure 4 shows the effect of frame frequencies on camera control when signals are generated to move an object located in an outer area of an image to the center of the image. For a frame rate of 15Hz, the movements of the object progressing smoothly and continuously, and an image quality that is not uncomfortable for the eyes is maintained. On the other hand, in the case of 20Hz frame rate, one of every two control signals is not received, thus there is no movement in one of every two frames, and the data are accumulated. The accumulated data make the next movement larger. Consequently, these are the same movements as those made when moving the camera using data that is two times larger using a frame frequency of 10Hz, thus, the result is that the low frequency produces movements that are repellent to the eyes. In this test, 15Hz is used as a basic frequency to control the CCD camera.

Figure 3. Changes in the Location of an Object Made through Single Control Signals

Figure 4. Object Movements Depending on Frame Frequencies
3.3. Effect of the Size of Pan/tilt Signals

As mentioned above, the distance to be moved at any given time is limited since the camera is moved in units of frames, thus this should be analyzed. If signal data are small, the movements of the camera are not affected, but the speed to track objects is reduced, thus objects may disappear from the field of vision of the camera if the objects move fast. On the other hand, if control signals are large, objects may be tracked quickly, but data that are not moved within a cycle are generated and accumulated. When the accumulated data grows larger than a certain size, then the camera will produce abnormal movements.

In object tracking, the camera moves only one time per cycle unless the frame frequency is very low. The movement distances in units of pixels of the initial movements made when tracking an object at a location with single control signals, as shown in Figure 5. The pan/tilt data obtained by converting the distances. This is important information generating effective pan/tilt data for continuous object tracking. Although there are some differences depending on the location, the average numbers of pixels of the movements are maintained at similar values around 12.2/7.6, and if these are converted into pan/tilt data, the values are 39.9/42.2. Based on this, the pan/tilt data were assumed to be 40/40 in order to track objects. Figure 4 shows the movement distances in the units of frame when a moving an object to the center of the image with pan data. The movements are stable to some extent with the pan data of 30 and 40, but with pan data at 50, it is shown that the data that could not be moved in a frame are accumulated and produce movements at a moment. The pan data of 30 is limited in tracking fast objects, and the pan data of 40 is more effective. Similar results were identified in tilt data as well.

![Figure 5. Movement Distances during a Frame by Pan Data](image_url)

Pan/tilt data of 40/40 are also limited in tracking fast objects. In this paper, to track fast objects, the frame frequency is maintained, and control signals are generated once per 3 frames. If one control signal is generated per two frames, two opportunities for movements will be available, but these are limited in enhancing the speed at the beginning and end of the movement. However, if one control signal is generated per three frames, three opportunities are given, and the speed may be enhanced for the second movement. Consequently, the speed can be doubled in the test, and this enables fast object tracking.
3.4. Fast-moving Object Tracking

The maximum pan/tilt data, 40/40, is limited in tracking fast-moving objects, and abnormal operations of the CCD camera restrict increases in the size of the control data. So, this paper proposes a method to maintain the frame frequency for tracking fast-moving objects, by adjusting the control signal rate to once every three frames, and increasing the size of the control data. Figure 4 shows the result of tracking a target object that has been positioned in the center of the images using two methods explained. In Figure 6(a), the maximum pan/tilt data has been set to be 40/40, and the tracking result shows that the camera was controlled to place the target object in the center of the images with equivalent intervals. In Figure 6(b), however, the maximum pan/tilt data has been set to 200/200, and the tracking result shows that the object was moved to the image center in the unit of three frames with a static pattern. In this case, the first and second movements were small, as it was in the former case. However, third movement was larger, which was caused by the acceleration. As a result, the target spot was approached faster. According to the result, the speed has been doubled, which enables the tracking of fast-moving objects.

![Image of tracking results](image)

Figure 6. Fast-moving Object Tracking

3.5. Pan/tilt Data Modification

When the object is far away from the center of the image and cannot be moved to the center with a pan/tilt operation, the pan/tilt data that has been proposed is used as the control signal. In this case, the movement of CCD camera becomes awkward, because of the pan or tilt moves to the center discussed earlier. Figure 7 shows the position of an object on the image when the object is moved to the image center using the maximum pan/tilt data. In case of object (1), the object position is nearer to the image center in the vertical direction than in the horizontal direction. So, when the camera is moved based on pan/tilt data of identical size, the object reaches the center earlier in the vertical direction than in the horizontal direction. In case of object (3), unlike object (1), it was positioned nearer to the image center in the horizontal direction than in the vertical direction. The object reaches the image center in the horizontal direction, and then the vertical position is simply adjusted to the center. When the maximum pan/tilt data is simply used to track the object, images on the camera look very awkward to viewers. In this paper, modified maximum pan/tilt data in accordance with the object position is calculated to remove this awkwardness.
Figure 7 shows the object tracking result after modifying the maximum pan/tilt data based on the object position. The object in the image moves almost straight to the image center. These movements look natural to viewers.

3.6. Limit of Object Tracking

Since the CCD camera requires a certain amount of time to receive the control signal and to operate, the camera is restricted to tracking the moving object. Focusing on the horizontal movements, which are the major motions of CCD images, the limit of object tracking is considered while the pan data of the CCD camera is applied. Under the assumption that the object is at a distance from the CCD camera as far as 10 m, Table 1 shows the limits of general tracking in Figure 7(a), and fast tracking in Figure 7(b).

Table 1. Limit of Object Tracking

<table>
<thead>
<tr>
<th>Control Signal</th>
<th>15Hz</th>
<th>5Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>① Angle of View [°]</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>② Image Width [m]</td>
<td>10x640/656=9.7561</td>
<td></td>
</tr>
<tr>
<td>③ Length/pixel [m]</td>
<td>9.7561/640=0.01524</td>
<td></td>
</tr>
<tr>
<td>④ Pan Data/1°</td>
<td>Pan(D(360)/360)=40</td>
<td></td>
</tr>
<tr>
<td>⑤ Pixel/1°</td>
<td>640/52=12.308</td>
<td></td>
</tr>
<tr>
<td>⑥ Max Pan Data/frame</td>
<td>40</td>
<td>200</td>
</tr>
<tr>
<td>⑦ Max Pan Movement[°/frame]</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>⑧ Max Pan Movement[pixel/frame]</td>
<td>12.308</td>
<td>61.538</td>
</tr>
<tr>
<td>⑨ Max Pan Velocity[pixel/sec]</td>
<td>184.62</td>
<td>307.69</td>
</tr>
<tr>
<td>⑩ Max Pan Velocity[m/sec]</td>
<td>2.8136</td>
<td>4.6892</td>
</tr>
<tr>
<td>⑪ Max Pan Velocity[km/h]</td>
<td>10.1289</td>
<td>16.881</td>
</tr>
</tbody>
</table>

3.7. Object Tracking of CCD Camera

Figure 8 is the result of object tracking. Figure 8(a) is processed from the original image, and Figure 8(b) has been enlarged twice, and considers long distance object tracking. In both experiments, out of the entire range of pixels from (0,0) to (640,480), the object is kept mostly in the pixel range of (±80, ±60). This means that an object
moving in the pan/tilt field of view of 52°/40° is maintained in the pan/tilt range of 13°/10°. The error of object tracking is not affected by zooming, but by momentary speed.

This test detects an object from images obtained through the CCD camera to identify the location, generates pan/tilt data using the proposed algorithm based on the location of the object, and controls the camera to perform object tracking. A simple red square was used as the object. Figure 8 shows the results of tracking the freely moving object using the frame frequency of 15Hz, determined as discussed earlier, with pan/tilt data of 40/40 for maximum movements.

4. Conclusion

CCD cameras that monitor moving objects are generally fixed or move in certain patterns. Therefore, moving objects disappear from the fields of vision of CCD cameras within a short time. This paper suggested a method to generate signals to automatically control CCD cameras in order to continuously monitor moving objects. Important variables were determined for object tracking, and tracking tests with an object were performed to identify the effectiveness of the proposed algorithm. The control signal generation tests were performed by marking a location within an image and moving the location to the center of the image by the proposed method, and by a manual method in order to compare between the methods for evaluation. The difference between the two methods was negligibly small, thus the effectiveness of the proposed method was confirmed. Also, through the object tracking test, it was identified that the method could hold the moving object with in a pan/tilt of around ±13°/±10°, thus, it was confirmed that the proposed algorithm was effective.

Acknowledgements

This work was supported by 2013 Hanseo University research grants.

References


Author

Jin-Tae Kim, received his B.S., M.S., and Ph.D. degree in Electronics Engineering from Chung Ang University, Seoul, Korea, in 1987, 1989, and 1993, respectively. He worked at Institute of Industrial and Technology at Chung Ang University from 1993 to 1995. Since 1995 he has been a faculty member of Department of Aerospace Software Engineering, Hanseo University. From January 2008 to January 2009, he was a visitor professor at the University of North Carolina at Charlotte. His research interests include image compression, augment reality, face recognition, and digital watermarking.