Control System Design and Simulation for Video Tracking

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Abstract

In this paper, a proposed video tracking system is introduced. The proposed system consists of two parts: motion estimation and tracking. Motion estimation is carried out by computing the difference between two successive images. The difference is dark image contains small relatively brightness at the region of existence the moving object. The average location of the moving object in the difference image is the target location, the tracking aims to make the head of camera facing the target location. Such that, the relation between the head of the camera and the target location relative to camera location is modeled to computes the deflection in the head. The tracking part depends on the head deflection, which make the control of camera motion toward the target location is modeled depending on the head deflection with regarding continual and soft motion of the camera. Such motion is made by constraint the rate of changing the head of camera at each control interval. The simulation results show reality and acceptable motion of the camera, this ensures the efficiency of the tracking method and correct proposed model.

تصميم ومحاكاة منظومة السيطرة لتعقب الاجسام بواسطة التصوير الفديوي

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الخلاصة

يُعرض في هذا البحث نظام مقترح لتعقب الاجسام المتحركة بواسطة التصوير الفيديوي. يتكون النظام المقترح من جزأين هما: تقدير الحركة والتعقب. يتم تقدير الحركة باحتساب الفرق بين الصورتين المتعاقبتين. الفرق هو صورة مظلمة تحتوي على بياض صغير نسبيا في منطقة تواجد الجسم المتحرك في الصورتين. ان معدل موقع تواجد الجسم في صورة الفرق يمثل الموقع المراد توجيه الكاميرا نحوهُ. تم نمذجة العلاقة بين وجهة الكاميرا الحالية والموقع المحدد بالنسبة لموقع الكاميرا من اجل حساب الانحراف بوجهة الكاميرا. ان عمل جزء التعقب يعتمد على انحراف الوجهة، ولذلك تم نمذجة منظومة سيطرة تعمل على تحريك الكاميرا بأتجاه الوجهة المطلوبة. تم مراعاة ان تكون حركة الكاميرا مستمرة وميسرة، وهذا يتم بتقييد المعدل الزمني لتغيير وجهة الكاميرا لكل فترة تحكم. اظهرت نتائج المحاكاة ان حركة المحاكي كانت واقعية ومقبولة، وهذا يؤكد كفاءة عملية التعقب وصحة النموذج المقترح.

1. Introduction

Video tracking is the process of locating a moving object (or multiple objects) over time using a camera. It has a variety of uses, some of which are: human-computer interaction, security and surveillance, video communication, augmented reality, and traffic control. Video tracking can be a time consuming process due to the amount of data that is contained in video. Adding further to the complexity is the possible need to use object recognition techniques for tracking [1]. The objective of video tracking is to associate target objects in consecutive video frames. The association can be especially difficult when the objects are moving fast relative to the frame rate. Another situation that increases the complexity of the problem is when the tracked object changes orientation over time. For these situations video tracking systems usually employ a motion model which describes how the image of the target might change for different possible motions of the object [2]. In order to perform video tracking, an algorithm analyzes sequential video frames and outputs the movement of targets between the frames. There are a variety of algorithms, each having strengths and weaknesses. Considering the intended use is important when choosing which algorithm to use. There are two major components of a visual tracking system; target representation and localization, and then filtering and data association [3]. Target representation and localization is mostly a bottom-up process. These methods give a variety of tools for identifying the moving object. Locating and tracking the target object successfully is dependent on the algorithm. For example using blob tracking is useful for identifying human movement because a persons profile changes dynamically [4]. Typically the computational complexity for these algorithms is low. Filtering and data association is mostly a top-down process, which involves incorporating prior information about the scene or object, dealing with object dynamics, and evaluation of different hypotheses. These methods allow the tracking of complex objects along with more complex object interaction like tracking objects moving behind obstructions [5]. There are many literatures published in the field of interest. New developed method for object tracking using laser camera was used to track any moving object in close range irrespective to its color. Edge detection is used for motion estimation and camera modeling employed to determine the object location [6]. Another method for real time tracking moving objects was developed in [7], this method uses the wavelet decomposition to perform multi-resolution analysis and edges extraction. In [8], a probabilistic center voting method for subsequent object tracking is introduced. The object tracking was accomplished via center voting and back projection. The center voting has every pixel in new frame to cast a vote on where about the object center is. The back projection segment the object from the background, which provides information about object size and orientation.

2. Proposed Tracking Camera System

The proposed control system of tracking camera consists of two main parts: motion detection and tracking. Both are contains several stages within as Figure (1) shows. The following sections explain each stage in details:

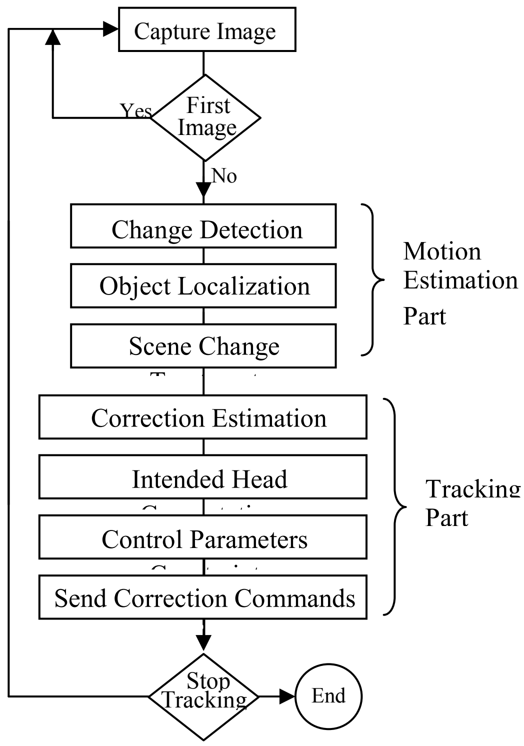


Figure 1- Block Diagram Shows The Proposed Tracking Camera System.

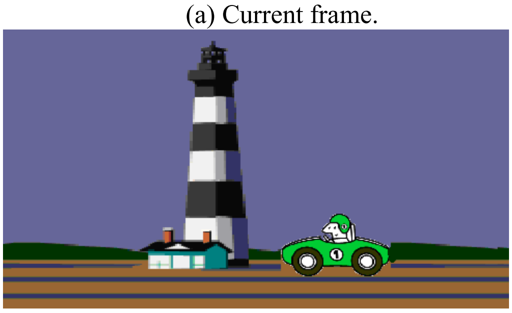
3. Motion Detection Part

Motion detection is a process contains three stages within; change detection, object localization, and scene change treatment. Each of them performs a specific function. The following sub sections explain the mathematical modeling of them.

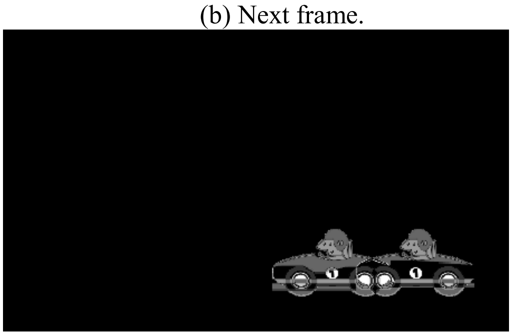
3.1 Change Detection

The changes happen in the two frames are detected in this stage by computing the absolute difference between the current image and the previous image. The result of the difference is an image contains expanded dark regions except the region of the moving object appearance. Figure (2) shows the difference image.

(a) Current frame.



(b) Next frame.



(c) Difference image.

Figure 2- The Difference Image.

The dark regions refer to that the difference between the corresponding regions in the two meant frames are very small approach to zero, due to the same background is appearing the two frames. Whereas, the difference in the different corresponding regions (such as the regions of moving object) be greater in comparison with dark regions. Such regions appeared relatively lighter.

3.2 Object Localization

This stage includes the determination of the object location in the two successive frames. HB is used to determine the location in the x-coordinate, and VB is used for y-coordinate. HB is a curve of length equal to the width of the image, each element in the HB represents the average of its corresponding column. While VB is a vector of length equal to the height of the image, each element represents the average of the corresponding row in the image as Figure (3) shows.

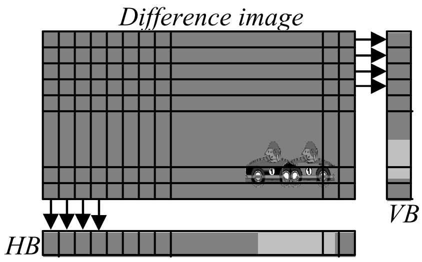


Figure 3- HB And VB Computations.

It is noticeable that the behaviors of the two curves contain two characteristics peaks as shown in Figure (4).

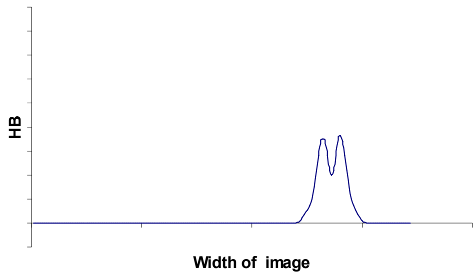


Figure 4- HB Versus Width Of The Image Same Behavior Is For VB Versus Height.

Each peak refers to the location of the object in one image. In order to determine the average location of the moving object, a smoothing process is done several times on HB (and VB separately) even reaching the case where the peaks are wedding with each other to compose a new one smoothed behavior peak. The location of such peak is determined to be X_o on the x-axis and to be Y_o on the y-axis. The location (X_o,Y_o) is the average motion of the object that the camera should track.

3.3 Scene Change Treatment

This stage is begun to be implemented when receiving the third frame, where there is a change in the scene due to camera moving. The scene change appears in the terminals of the difference image, which almost do not exceed five columns in the horizontal change or five rows in the vertical change. Scene change makes the behavior of HB and VB is high in one terminal equivalent to the direction of the camera motion. To overcome such problem, a part of image equivalent to the scene change can be cut from the difference image. The size of such part should be calibrated with the amount of the rotation angle of camera motion with newly appearance of the parts (measured by columns or rows) in the image background. The modeling of this calibration depends on the field of view (FOV) of the used camera as follows:

$$N_c = \frac{\theta_x}{FOV} \times W \quad \ldots (1)$$

$$N_R = \frac{\theta_y}{FOV} \times H \quad \ldots (2)$$

Where, θ_x and θ_y are rotating angles of camera motion in the directions x and y, N_C and N_R are the number of columns and rows should be cut from the difference image, W and H are the width and height of the image.

4. Tracking Part

The previous stages are preprocessing needed to implements the control task, whereas the tracking is the main function of the controller. In the tracking, the deflection in the object location is determined, and then commands are decided to move the camera toward the moving object. These commands are computed according to amount and direction of the detected change. The following sub section illustrates the sequential stages of the tracking task:

4.1 Correction Estimation

Since the camera moving with angular amounts, the motion parameters in the proposed tracking (control) model are assumed to be angular too. The suggested parameters expressed the head of the camera, which are: the actual head (H_A) and intended head (HI) of the camera. The difference between them (ΔH) represents the amount of error in the head that should be corrected during the control interval (Δt) given as:

$$\Delta H = H_I - H_A \quad \ldots (3)$$

Eq. (3) requires computing both H_A and H_I. By noting Figure (5), one can see that there is a modified setting for the amount of maximum reference angles. Greatest rotation angle on the right is +90^o and -90^o for the left. This setting is very important when determining the direction of the camera motion. That means, when ΔH is positive implies the direction of the correction is toward the positive x or y, and vice versa.

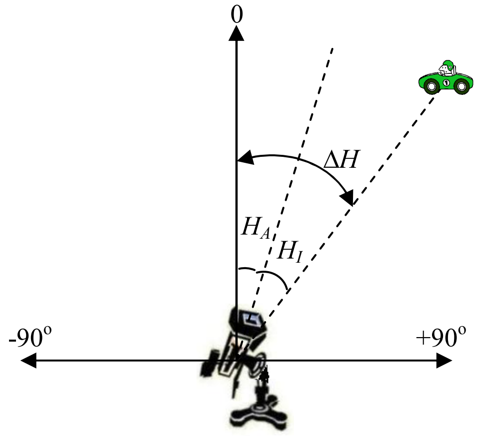


Figure 5- The Relationship Between The Control Parameters (H_A And H_I)

4.2 Intended Head Computation

The computation of the intended head (H_I) is depending on the new location of the object (X_o,Y_o), also the concept of FOV is contributed in the lateral direction as follows;

$$H_I = \frac{X_P}{(W/2)} * FOV \quad \ldots (4)$$

And for the vertical direction is given as:

$$H_I = \frac{Y_P}{(H/2)} * FOV \quad \ldots (5)$$

Where, X_P and Y_P are the modified new location of the object with respect to the camera location. In case when the camera located at the center of the coordinates, the modified new location is given as:

$$X_P = X_o - (W/2) \quad \ldots (6)$$

And

$$Y_P = Y_o - (H/2) \quad \ldots (7)$$

4.3 Control Parameters Constraints

To credit the soft motion of the camera, the amount of the variation in the head correction should be don't exceeded a predefined value called the maximum change of the head (ΔH) at any control interval (Δt). This assumption can be carried out by applying the following two conditions:

If $\Delta H > H_{MC}$ then set $\Delta H_C = H_{MC}$ otherwise $\Delta H_C = \Delta H$

and,

If $\Delta H < -H_{MC}$ then set $\Delta H_C = -H_{MC}$ otherwise $\Delta H_C = \Delta H$

where, H_{MC} refers to the maximum amount of the constraint change in the head of camera, ΔH_C is the constraint change of the head. The first condition restricts camera motion in the positive direction, and the second restrict the camera motion in the negative direction. Later, ΔH_C is used to compute the correction commands.

4.4 Correction Commands

The correction commands in simply is the amount of the last value of ΔH_C decided to change the actual head of the camera during the interval Δt, which can be formulated as follows:

$$H_{Com} = \Delta H_C \times \Delta t \quad \ldots (8)$$

5. Simulator Modeling

There are two functions done by the simulator to simulate the camera tasks, they are: (1) capture (load) the successive images from the video file, and (2) emulate the camera motion graphically according to the controller commands. Since the parameter H_A is only the one that tells the camera situation, the emulation of camera motion needs to model the camera head depending on the parameter H_A. Such that, the simulator's motion is continually drown graphically at each control interval, the head of the simulator begin with H_A head angle at time t and become (H_A+H_{Com}) at time (t+Δt). That means the change in the simulator's head is accumulated during all the control intervals as given:

$$H_A = H_A + H_{Com} \quad \ldots (9)$$

Eq.(9) state that the current value of HA is the summation of all the correction commands during all control intervals.

6. Simulation Results

In the simulation test, the maximum rate of head change was set to be H_{MC}=5 degree, several test movies are prepared for testing the proposed system, each one contains one moving object assumed to be imaged with a video camera specifies a frame rate of 5 fps and frame resolution 320*240. This makes the control interval is $\Delta t = 0.2$ sec. The first test was including a video frames contains an object moves at small region. Through 20 successive frames (during 4 sec) the control parameters behaves as shown in Figure (6). Another test, at which the moving object wander at large expanded region. The resulted paths were shown different, but same behavior of the control parameters are noted as shown in Figure (7).

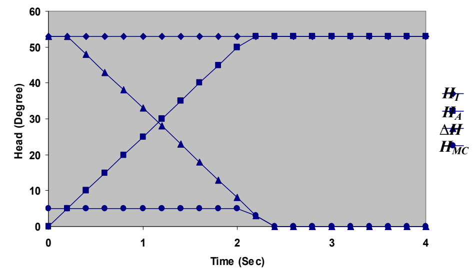


Figure 6- The Behaviors Of The Control Parameters When The Target Object Moves Slowly At Small Region.

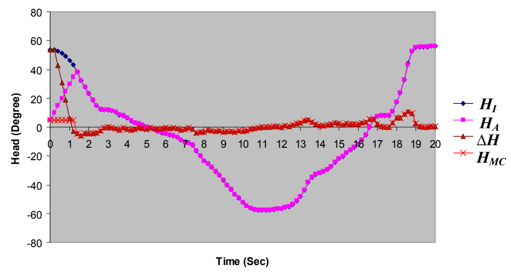


Figure 7- The Behavior Of The Control Parameters When The Target Object Wander At Large Expanded Region.

7. Results Analyses

In the case of Figure (6), it shown that the H_I takes approachly same value during all control intervals. Whereas the H_A increases from zero up to H_I with slightly soft behavior. The behavior of ΔH was maximum at starting, and then it decreased due to continually corrections even became zero when H_A identify H_I. At same time, ΔH_C takes values equal to the maximum rate of the change in the head when ΔH is greater than H_{MC}, and this situation of constraint ΔH is released when ΔH is equal or less than H_{MC}. This test shows clearly the instantaneous changes in head of the camera toward the target object due to the wise correction of the controller.

In the second test, the results shown in Figure (7) demonstrate that there was a variation in the H_I values due to the change of the object location in the successive frames, which ensures the correct estimation of object localization. Also, it was shown that H_A of zero initial value had been varied toward H_I during the control intervals, which refers to the camera motion toward the object.

During each control interval, the amount of time rate of changing the simulator head was varied according to the amount of the difference (ΔH) between H_I and H_A. It is noticeable the intervals that have ΔH greater than the allowed maximum change in the head (H_{MC}), the restricted change in the head ΔH_C is equal to constant value is H_{MC}. This situation has been continued until reaching a point when ΔH is equal to H_{MC}. At this time, ΔH_C begin to be decreased under H_{MC} till reaching the zero when H_A identifying H_I. The H_A is remained identifying H_I as well as the speed of moving the camera is greater than that of the object motion.

It should be mentioned that the control interval was set according to surveillance camera manufacturing standards. But such interval regarded long relative other applications (such as automobile controlling). This lightly affect the H_A values when identified H_I, and may produce an overshot in the H_A value. This case is quickly corrected in the next interval by the controller. Several movies were used to test the performance of the proposed system, the tracking results were behavioral acceptable, which ensure the correct path of the suggested algorithm and the accuracy of tracking.

8. Conclusions

The behavior of the control parameters concludes that the proposed system exhibit video tracking system. The proposed system was successful to govern the camera movement to ward the instantaneous location of the moved object.

9. References

[1] Peter, M., Danail S and Guang Z. Y. **2010**. "Three Dimensional Tissue Deformation Recovery and Tracking: Introducing techniques based on laparoscopic or endoscopic images", IEEE, 27 (4): 14-24.

[2] Mihaylov, A. , Lyudmila J. , Paul B., Nishan C., and David B., **2011**. "Object Tracking by Particle Filtering Techniques in Video Sequences". IEEE, 22 (2): 87-95.

[3] Kato, M., Hirokazu B., and Mark B., **2005**"Marker Tracking and HMD Calibration for a Video-based Augmented Reality Conferencing System",. Jornal of computer vision and signal processing, 5 (3): 42-50.

[4] Kang, S. M., Paik J., Koschan A., Abidi B., and Abidi M., **2003**. "Real-time video tracking using PTZ cameras," Proceeding of SPIE 6th International Conference on Quality Control by Artificial Vision, 5132 (3): 103-111.

[5] Black, C. B., James L., Ellis T., and Rosin P., **2009**"A Novel Method for Video Tracking Performance Evaluation.", , Journal of computer vision and signal processing, 19 (6): 43-54.

[6] Arulampalam, M. K., Maskell S., Gordon N., and Clapp T., **2002**. "A Tutorial on Particle Filters for Online Nonlinear/Non-Gaussian Bayesian Tracking", IEEE Trans. on Signal Processing, 50 (2): 67-76.

[7] Foresti, G. L., **1999**"Object Recognition and Tracking for Remote Video Surveillance",. Transaction of Circuit Systems and Video Technology, 97 (2):1045-1062.

[8] Yaov, R. N., and Michael W., **2003**. "Real time object Tracking from a Moving Video Camera", Journal of Computer Science Institute, 5 (3): 211-219.