Real Time Automatic Object Tracking by Pan-Tilt-Zoom cameras in an IP-Surveillance System

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Abstract:
Pan-tilt-zoom (PTZ) cameras are one of the advanced security cameras in the market. These cameras have the ability to cover a very far field and can acquire high resolution of images. These cameras are deployed mainly for perimeter surveillance applications where the security guards have to monitor the intruders from a long distance. Although there are intrinsic advantages of using pan-tilt-zoom cameras, their application in automatic surveillance systems is still scarce. The difficulty of creating background models for moving cameras and the difficulty of optical geometrical projection models are key reasons for the limited use of pan-tilt-zoom cameras. Geometric calibration is a useful tool to overcome these difficulties. Once developed the background and projection models, it is possible to design system simulators and surveillance methodologies similarly to the ones commonly available for fixed cameras. In this paper, the proposed system can automatically track moving objects. More specific, it is investigated how a system comprised of one pc and a PTZ camera installed within an indoor and outdoor settings can track objects in poor illumination conditions as well. The tracking and calibration results with several image processing techniques in a segmentation framework are combined, through which camera can track the target in real time.

Keywords: IP- surveillance system; PTZ Camera; tracking object

1. Introduction

Moving object detection and tracking is one of the key technologies for the surveillance environment. The aim is to track objects using an IP PTZ camera (a network based camera that pans, tilts and zooms). An IP PTZ camera responds to command via its integrated web server after some delays. Tracking with such camera implies: 1) irregular response time to control command, 2) low irregular frame rate because of network delays, 3) changing field of view and object scaling resulting from panning, tilting and zooming [13]. These cameras are deployed mainly for perimeter surveillance applications where the security guards have to monitor the intruders from a long distance. One problem in video surveillance is how to identify and recognize events. The advantage of using PTZ cameras over the static cameras is that they can cover a larger area as compared to passive cameras. Passive cameras only cover a specified field of view and multiple cameras are required to track a person in a particular area. Such multi-camera systems are very costly to use. Therefore, a system utilizing a single pan-tilt-zoom (PTZ) camera can be much more efficient if it is properly designed to work well.

Many methods have been proposed to detect motion of moving object using an active camera. To detect motion of moving object, frame difference method with several post-processing techniques has been proposed [1, 2]. Furthermore, tracking moving objects has been a challenging task in applications of video surveillance [19]. In several literatures, tracking of moving object continuously require tracking of the object in the video stream till the object goes out of the field of view of the camera. Generally, single camera is used to control the pan and tilt movements for tracking after the target detection [15]. In several papers, contour-based people tracking is proposed [11, 20]. It is assumed that the background motion between two consecutive images could be approximated by an affine transformation. Their methods are time consuming for IP camera. In addition, they cannot track temporarily stopping objects.

Motion detection and tracking of target at the same time is an important issue. In this paper, detection of motion with respect to position of the object and tracking in real time is proposed. The paper is structured as follows. Section II presents the architecture of the study used in this paper. In Section III, the proposed system is developed. Experimental results and discussions are given in section IV. Finally, in section V, conclusions of the work done are made and some useful future research is suggested.

2. Architecture of PTZ Camera

A PTZ camera tracking surveillance framework which includes camera tracking algorithm and camera calibration is proposed. The proposed framework uses a PTZ camera to capture the video data and detect the human location. Figure 1.1 shows the software and hardware architecture of the PTZ camera based tracking system. The infrastructure includes the PTZ camera, video and location analysis components, and user interface component. The video analysis component retrieves live video stream from the camera and the location component retrieves the object information and estimates the position of the object. Finally, the user interface component displays information.

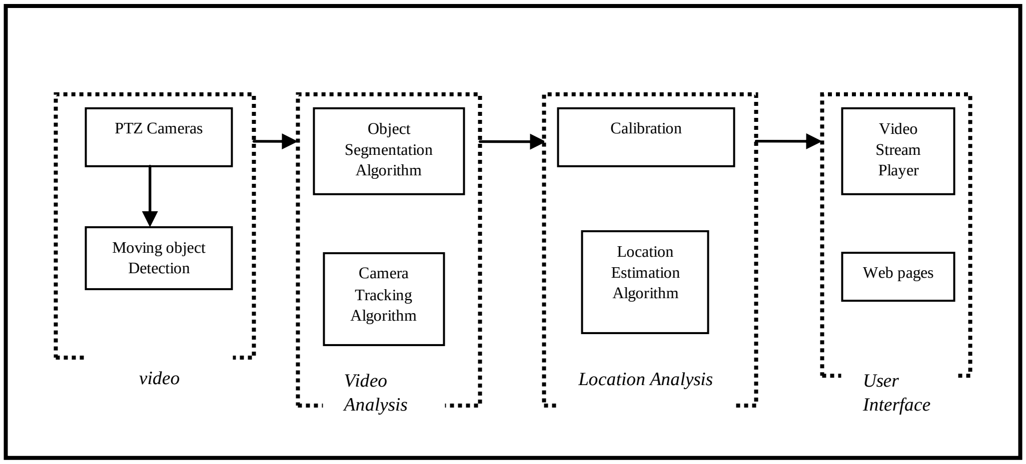

Figure 1. PTZ Architecture

3. PTZ Camera based object tracking system

In this paper, the proposed system tracks the person with the help of motion detection algorithm to detect the location of the person in the particular area. The position of the person is obtained and used to control the PTZ camera in the specified region.

3.1. Motion detection algorithm

Calibration, object detection in the image and passing control commands to cameras are three key modules in Auto-PTZ tracking algorithm. Object detection is done by using motion cue. Algorithm detects the moving object and obtains its coordinates and computes the pan, tilt and zoom values using calibration modules and these values are sent to servo motor, this in turn pans, tilts the camera accordingly and camera zooms as per the computed zoom value. The flowchart for camera tracking algorithm with object detection is given in figure 2.

The main challenge in detecting moving object in PTZ camera is non-availability of sufficient frames for background modeling. Algorithm has to detect the moving object with limited number of frames. In this work, an algorithm is developed to detect moving object with lesser number of frames with appropriate post processing techniques.

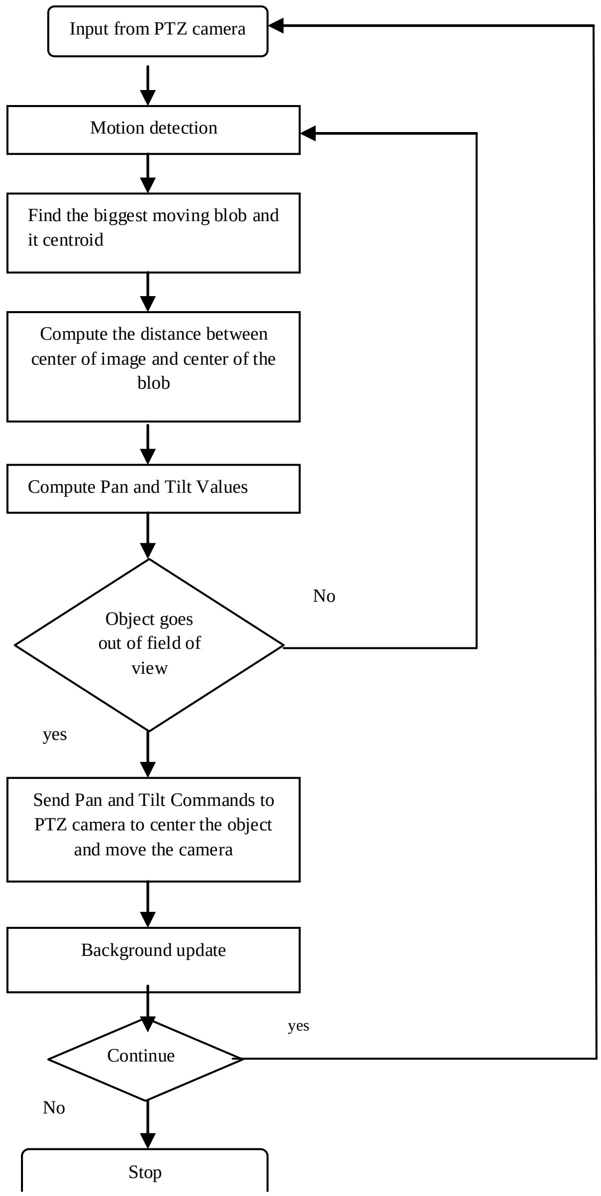

Figure 2. Flowchart of camera tracking algorithm

Motion detection is widely used real time method for identifying foreground moving objects in a video sequence. It is the first significant step in many computer vision applications, including traffic monitoring, video surveillance etc. Simple motion detection algorithms compare a static background frame with the current frame of a video scene, pixel by pixel. The aim is to segment the incoming image into background and foreground components, and use the components of interest in further processing. The three important attributes for detecting moving object are how the object areas are distinguished from the background; how the background is maintained over time; and, how the segmented object areas are post-processed to reject false positives, etc. Figure 3 shows the block diagram of motion detection algorithm.

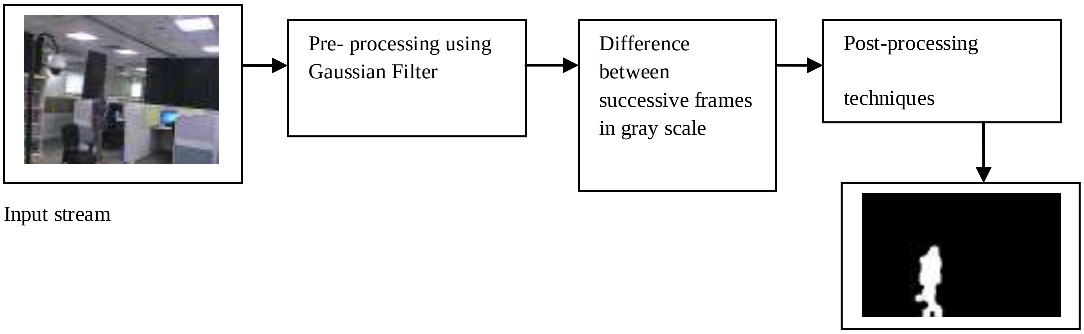

Figure 3. Block diagram of motion detection algorithm

The height and width of the moving blob from the motion detection algorithm is calculated. A typical object that is in interest is an intruder and hence a condition such that the height to width ratio should be greater than some scalar quantity is used. Only objects satisfying the condition are identified and the bounding box is drawn on the moving blob. The centroid of the moving blob is passed to the pan, tilt commands to move the camera keeping the object in the center.

3.2. Calibration model

The calibration is the process by which the different camera parameters are obtained. The task of calibrating a camera consists of finding the geometrical relationships and involved parameters between pixels and real world locations. To calibrate a camera, the proposed idea is to show the camera a set of scene points for which their 3D position is known. It is required to determine where on the image these points are projected. For the calibration purpose, we plotted checkboxes on a white board at certain distance and since the pattern was flat, we assumed that the board is located at Z=0 with the X and Y axes well aligned. Camera was moved manually to each location of the detected corner from the center position and we stored the corresponding pan, tilt values. Here is one example of calibration pattern image:

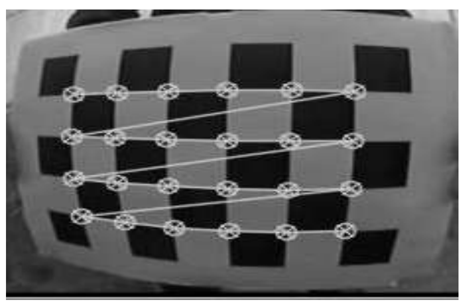

Figure 4. Calibration pattern

3.3. Camera tracking algorithm

The camera moves to the position of current centroid of the human. The distance between center of the current frame and the centroid of the moving blob is calculated in both the horizontal and vertical directions. As shown in the above calibration pattern, the pan, tilt values from one position to another are obtained manually and the same experiment is applied using the $pan, tilt$ equations thus calculated. dx, dy are the change in position of the moving blob from the centroid of the field of view.

$$dx = X_1 - A, \quad (1)$$

where,

X_1 = center of the frame size and A is the centroid of the moving blob

$$dy = Y_1 - B, \quad (2)$$

where,

Y_1 = center of the frame size and B is the centroid of the moving blob

The graphs below show the movement of camera with respect to centroid coordinates of the moving object. The horizontal axes denote the $pan, tilt$ values whereas the vertical axes of both the graphs denote the change in position of the moving blob from the centroid of the field of view.

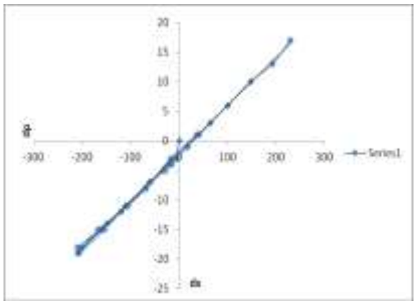

Figure 5. Graph between horizontal axes and pan values

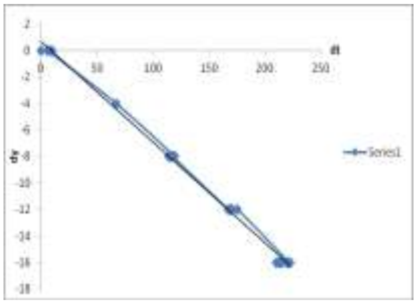

Figure 6. Graph between vertical axes and tilt values

The equations that are used to control the $pan, tilt$ values are as follows

$$dp = 0.059 * dx - 0.375 \qquad (3)$$
$$dt = -0.057 * dy - 0.25$$

where parameters dp, dt are change in pan and $tilt$ values; dx, dy are the change in position of the object from the center of the field of view. The above generated equations help to move the camera and to track the object. The centroid of the human is calculated from the motion detection algorithm.

4. Results and discussions

To evaluate the performance of the proposed algorithm, we tested it on both offline and real-time data captured from PTZ camera. The results are presented in this section.

4.1. Offline system results of tracking

The simulation result is shown in Figure 7.

Frame 7 Frame 17 Frame 23 Frame 29

Figure 7. Offline experimental result of moving person

The person is detected and tracked while his position and movement is changing.

4.2. Real-time system results of tracking

The algorithm was implemented in a real-time object detection and tracking system using a Panasonic camera. It has 22x optical zoom. The video is captured at 640 x 480 at 10 frames per second. The camera tracks the person while keeping it in the center of the field of view. It gives good results with the blob estimation and then accordingly, the camera moves. The complete tracking procedure a long with motion detection in shown in Figure 8.

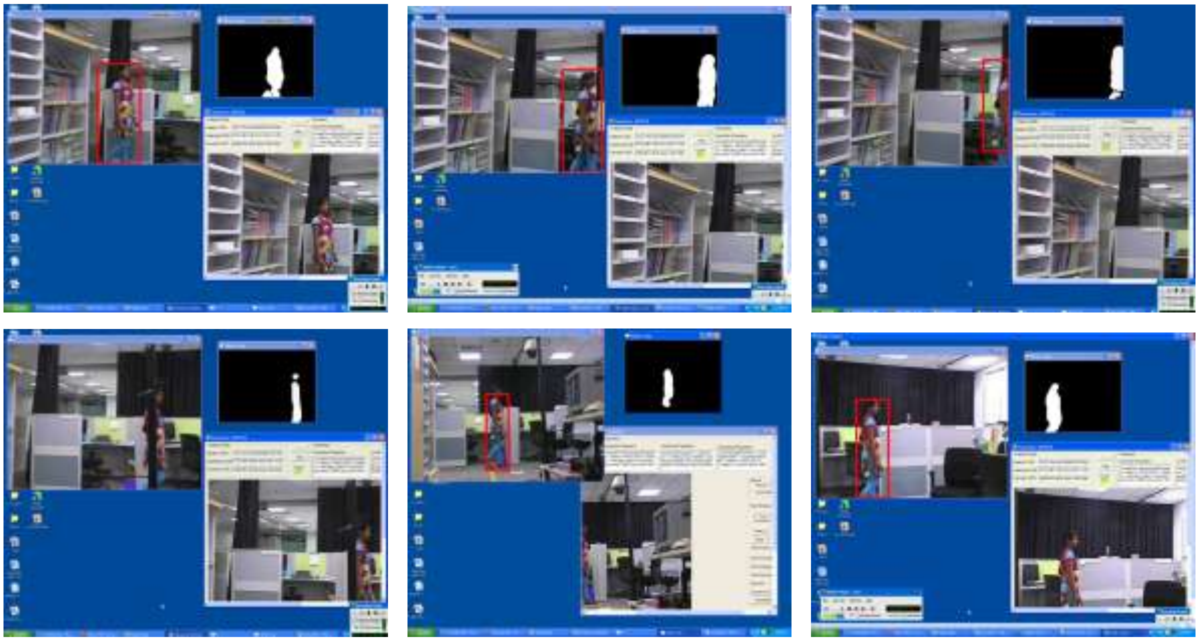

Figure 8. Real-time tracking sequence performed in indoor environment

5. Future improvements

The Auto-PTZ tracking method implemented in this project allows following the object in the scene by automatically moving the camera. The frames are processed, centroid of the foreground mask is obtained and the command is sent to the PTZ camera. The motion detection algorithm used in this project is computationally very fast but sometimes, the performance can be quite poor, especially with fluctuating illumination conditions. In order to manage changes in illuminations, more complex background subtraction algorithms for video analysis are to be developed in future.

The framework developed for automatic pan-tilt-zoom tracking needs further improvements:

- Use the bounding boxes of the blob and extract color template of the blob
- Appearance model is computed for the template and is used to detect the same object in next frame
- Appearance model is updated regularly
- A simple tracker has to be implemented for tracking the object continuously. This will be helpful for smooth and robust tracking

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