Detection and Tracking of Intruding Objects based on Spatial and Temporal Relationship of Objects

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Abstract. Recently, intelligent surveillance systems based on video analytics have been used in many places. In this paper, we propose an intrusion detection algorithm based on spatial and temporal relationship of neighboring objects and region of interest (ROI). Information of objects such as position, size, and distances to neighboring objects are updated every frame. To track intruded objects remaining within a frame, the intrusion flag of the intruding object is transferred to the corresponding object in the next frame based on the object tracking information in temporal direction. The detection accuracy and execution speed of the proposed intrusion detection algorithm were verified with real surveillance sequences.

Keywords: intrusion detection, surveillance system, object tracking, region of interest.

1 Introduction

Video surveillance systems have become popular with the rapid development of video coding and IP network technologies. Video surveillance systems can support real-time remote display of captured video signals while recording them in digital compressed formats. Real-time video monitoring is a process to detect surveillance events by humans or video analysis. As the cost of manual monitoring increases rapidly with the fast increment of monitoring channels, solutions of automated video analytics have been considered to reduce the cost.

Most of museum, historical sites, public institutions and private land require intrusion detection systems. Although tracking of intruding objects can contributes to the accuracy of detection or various event configurations, it is in the early stage to consider the tracking of objects into the detection of surveillance events [1, 2].

In this paper, we propose an intrusion detection algorithm for embedded systems which detects objects in restricted areas based on spatial relationship of objects and ROIs, and tracks the intruding objects with intrusion flag transfer throughout video sequences. Most intrusion detection systems adopt multiple video channel and some of them are implemented on embedded platform. To save memory in embedded platform, only luminance component of input video sequences are considered for video analytics.

2 Detection and Tracking of Intruding Objects in Restricted Area

To detect objects existing in restricted areas, it is necessary to extract objects in video frames. Object extraction consists of background generation with GMM [3], configuration of region of interest (ROI), extraction of object candidates based on background subtraction and contour labeling, noise elimination, and calculation of object information such as size and position. Figure1 shows the block diagram for the proposed intrusion detection algorithm.

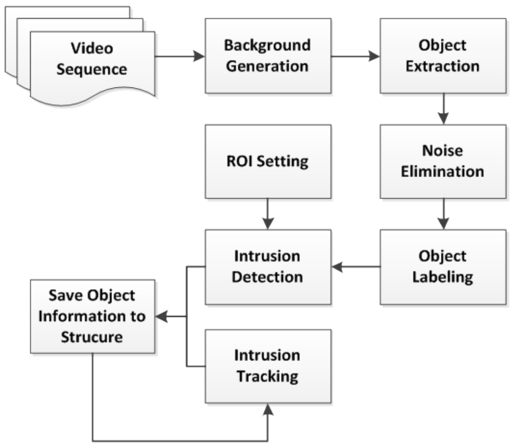


Fig. 1. The block diagram of Intrusion detection and tracking

2.1 Contour Labeling and Object Tracking

To extract objects from the foreground images with the foreground mask, contour labeling is used, which requires less memory and no additional process of merging the label number. Also, to eliminate erroneous blobs after the labeling, an object is defined as the blobs consisting of certain number of connected pixels.

Because the locations and the number of objects in the frame are changing with time, the information of all objects should be stored and managed throughout the video sequence. Thus, center of gravity, label number, and size of each object are computed and saved to the memory every frame. Using positions of objects, each object is traced based on minimum distance to neighboring objects in previous frames.

2.2 Detection and Tracking of Intruding Objects based on Location and Temporal Relationship of Objects

In this section, we propose to detect an intrusion if the center of gravity of an object is inside the ROI.

An intruding object is tracked throughout the video sequence until its disappearance. The object with the same label with any intruding object in previous frame is also determined to be the intruding object as follows.

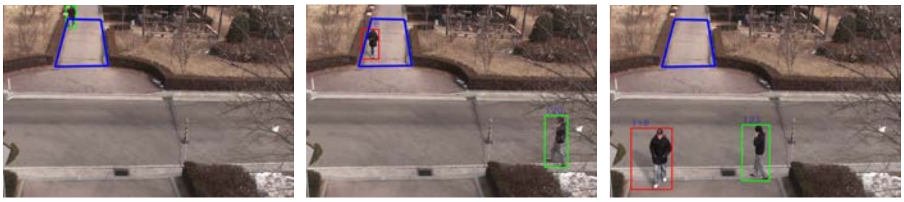
$$I(o_t^n) = \begin{cases} 1, & I(o_{t-1}^{L(o_t^n)}) \equiv 1 \\ 0, & otherwise \end{cases} . \quad \textbf{(1)}$$

where o_t^n is the n_{th} object in the t_{th} frame, $I(o_t^n)$ is the intrusion flag of o_t^n and $I(o_{t-1}^{L(o_t^n)})$ is the intrusion flag of the object, which has same label with o_t^n in previous frame.

In the process of an object tracking, a label of a moving object is sometimes changed to other one due to wrong or incomplete foreground masks. In this case, the moving object is determined to be a new object, losing the intrusion information. For this case, a label changing object in current frame is determined whether the object intruded or not, using the distances from the neighboring objects in recent frames.

$$I(o_t^{changed}) = \begin{cases} 1, & I(o_R^m) \equiv 1, \ \min_{m \in G_{t'}, t' \in R} dist(o_t^{changed}, o_{t'}^m) < T_{dist} \\ 0, & otherwise \end{cases} . \quad \textbf{(2)}$$

where $o_t^{changed}$ is the object whose label is changed in the t^{th} frame, R is the index group of reference frames, G_t is the group of objects in the t^{th} frame.



(a) **(b)** **(c)**

Fig. 2. The result of intrusion detection and tracking: ROI (blue box), intruder (red box), non-intruder (green box)
(a) before the intrusion, (b) intrusion detection (c) tracking of intruded objects

3 Experimental Results

To evaluate the performance of intrusion detection and tracking, the proposed algorithm is tested with five video sequences in D1 (720x480). In every sequence, all of intruders are detected in ROI. However, when a traced intruder is close to a pedestrian outside ROI, they are recognized to be single object in the process of object detection. For that reason, the intrusion flag from the intruder is shared with the pedestrian, which results in the failure of intruder tracking. The proposed algorithm shows 94.74% of true positive rate (TPR).

Table 1. The result of intruder tracking and processing speed

Sequence	no. of frames	no. of objects	no. of intruders	Detected no. of intruders (TP)	Speed of processing(fps)
STUDENT	17577	143	125	118	63.06
DOOR	6729	19	17	16	69.37
KAU	7865	28	9	9	67.17
LIBRARY	9931	14	5	5	66.38
STREET	9366	34	15	14	69.36
Total		238	171	162	

The experiments were carried out on a single thread i7-3517U @ 1.90-GHz laptop on with 4 GB of memory. The proposed algorithm can be easily implemented in a real time system since the processing speed for embedded systems.

4 Conclusion and Further Work

In this paper, we proposed the intrusion detection algorithm based on extracted information of objects and ROI for embedded surveillance systems. For each extracted object, center of gravity, pixel area, and distance to the closest objects in previous frame are calculated and used for object tracking and intrusion detection. For the tracking of intruding objects, the information of intruding objects are updated every frame until their disappearance.

Although the proposed intrusion detection algorithm showed quite accurate intrusion detection performance for real surveillance sequences, there still remain the problem of wrong merging of an intruder and its neighboring pedestrians and ghost objects generated from shadow. These problems should be resolved together with enhanced background generation method.

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