SURVEILLANCE SYSTEM FOR SUSPICIOUS VEHICULAR MOVEMENT

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ABSTRACT

The use of video surveillance for security purposes had received significant attention as a result of its versatility and compactness of usage in places like stores, malls, banking halls, and schools among others. Recently, the increase in insurgence and the use of vehicles as ammunition payloads, especially to soft targets have given rise to the need for automatic detection and tracking of suspicious vehicular movements. This paper presents a method for detecting suspicious vehicular movement. In this approach, the pixels of moving vehicles were extracted in wavelet subband differencing of video clips. The system uses field measurements and surveillance camera parameters to detected suspicious vehicular movements. As a result, the presented system provides a reliable automatic suspicious detecting machine. The experimental results were validated with speed limiters installed vehicles. Thus, the system is suitable for detecting suspicious movement.

INTRODUCTION

Motion is necessary on daily basis to make progress. Movements are inevitable, as commuters need to move from one place to another for different activities. With the freedom of movement is the perpetuation of many criminals' activities like banditry, looting, pickpocketing among others.

Security is the state or feeling of being safe and protected. Security is everybody's business which influences the state of social activities, economic growth, and harmony within the globe. Insecurity with various movements of vehicles such as cars, buses, and motorbikes are the major challenges facing many societies. Logically an acceptable range of vehicular speed is considered normal at different locations but if the response of a vehicle deviates from this range, the behavior is considered suspicious. Earlier studies on security prove that stolen vehicle escape, armed robber escape, implementation of bombing activities by insurgence among others, attract suspicious movements such as unexpected slowing, unexpected stopping, sudden acceleration, or moving with high speed particularly near checkpoints, banking areas, marketplaces, churches, mosques, and government structures.

In recent times, visual surveillance has received significant attention due to its versatility and compactness of usage in places like stores, malls, banking halls, schools among others. The numerous application of visual surveillance to video-based intelligent transportation systems has also made it a great potential area of research.

Traffic surveillance is an application of video-based supervision systems, which are used to monitor the movement of vehicles on highways [1]. One important task in vehicular detection is identification and motion estimation. Motion identification involves the correct classification of moving vehicles into a desired different category.

Notable works have been done in this area of research using various methods of detection and tracking which include temporal differencing, background subtraction [2], Optical flow [3]. All of the aforementioned methods are good but have their shortcomings. The temporal difference method fails to detect a moving object when stopped in the scene [4]. Background subtraction fails to extract the whole relevant part of a moving object [5]. The optical flow method requires special hardware to be executed [6]. Researchers have also tried using a deep neural network to detect and track vehicular movements which work well, but a deep neural network requires a larger amount of data for training the network [12]. This paper develops a system capable of detecting suspicious vehicular movement through identification and speed estimation using the wavelet subband differencing method.

METHODOLOGY

Vehicular Detection

Accurate detection of vehicular movements is required for active vehicular surveillance. Wavelet transform is a signal processing algorithm that is useful in providing a time-frequency multi-resolution analysis that greatly detects the abnormal variation conditions based on a decomposed image in pattern recognition [8]. Wavelet transform is more efficient at high frequencies (small scales); in particular, for the detection of singularities in the signal [9]. Wavelets decomposition for image data is represented in "(1)" and "(2)". The vehicular images recorded on a personal digital Sony video recording camera were converted to frames and decomposed using 2D wavelets up to three levels for separation of approximation and details co-efficient [10]. The detailed decomposition of the 2D wavelet transform has higher frequencies more than the approximation part. The approximation part of the wavelet decomposition was suppressed for both background modeling and background subtraction images. The First decomposed frame goes into background initialization to modeling the background images while Subsequent frames, update the modeled background images. "Equation (3) and (4) was used to detect vehicular movement."
2D discrete wavelet transform is as follow;
The image f(x, y) wavelet is

$$\Psi_f\left(s,t_x,t_y\right)=\left\{f\left(x,y\right)\cdot\varphi_s\left(x,y\right)\right\} \tag{1}$$

where $\varphi_s(x,y)$ is wavelet function

$$\varphi_{s,t}\left(x,y\right)=\frac{1}{\sqrt{s}}\cdot\varphi\left[\frac{x-t_x}{s},\frac{y-t_y}{s}\right] \tag{2}$$

Where, s is the scale parameter, (t_x, t_y) are translation parameters, and (x,y) is image intensities.

$$B_{n+1}(x,y)=\begin{cases}\alpha B_o(x,y)+(1-\alpha)I_n(x,y) & (x,y) \text{ is not moving}\\ B_n(x,y) & \text{if } (x,y) \text{ is moving}\end{cases} \tag{3}$$

$$\left|I_n\left(i,j\right)-k_{(n-1)}\left(i,j\right)\right|>T_n\left(i,j\right) \tag{4}$$

where $I_n(i,j)$ $k_{(n-1)}(i,j)$ and are assumed to be the wavelet coefficient of the current and updated background images respectively, $T_n(i,j)$ is recursively updated threshold [11]. Finally, moving vehicles were detected and encapsulated by their minimum bounding box.

Detection of suspicious vehicular movement

In this section, the speed per frame of vehicles passing through the surveillance area is exhibited to detect suspicious movement. To realize the proposed system, some measurements were carried out on the field which includes the height of the camera from the ground, the distance between the camera and the possible locations of moving vehicles, the vertical dimension of all experimented vehicles at all possible locations of the road; were also carried out for pixel to kilometers conversion. The information about the used camera was the focal length and the frame rate. Thus, the perpendicular distance between the surveillance camera and the moving vehicles was determined by "(5)" and "(6)".

$$P=2D\tan\left(\frac{\phi}{2}\right) \tag{5}$$

$$\phi=2ar\tan\left(\frac{v}{2f}\right) \tag{6}$$

where ν is the vertical dimension of the image format of the vehicles, f is the focal length of the camera, is angle inclined between the moving vehicles and the stationary camera, is the real distance between the camera and the moving object which is shown in "(7)"

$$D=\sqrt{\left(\left(H-h\right)^2+\left(K\right)^2\right)} \tag{7}$$

Where is the height of the camera to the ground, is the height of the moving vehicles, and is the horizontal distance between the camera and moving vehicles. In this work, intrusion lines and the assumption of constant speed throughout the surveillance scene as proposed by [12] were eliminated.

To know more information about the vehicle detected, each detected vehicle's length and breadth were encapsulated and trained by a backpropagation algorithm into their different predetermined classes. The three categories of vehicular movement in this work include car, bus, and motorbike. In this work all detected vehicles were assumed to travel on a straight line; therefore, the equation of motion was employed to estimate the moving speed per frame. Using "(8)" the distance traveled per frame was determined. The speed at which the vehicle moves from frame to frame was realized using "(9)".

$$d = \sqrt{\left(x_1^i - x_i\right)^2 + \left(y_1^i - y_1\right)^2} \quad (8)$$

$$s = \frac{\Delta d}{\Delta t} \quad (9)$$

Where is changed in distance, and are the plane differences of change in location of the foreground image between two processed frames, s is the instantaneous speed from frame to frame, is the time used to process each frame.

The acceleration per frame of each vehicular movement was also estimated using "(10)".

$$S = \frac{1}{2} a t^2 \quad (10)$$

Where s is the speed, acceleration, and t time taken to process the frame. Figure 1 shows the flow chat design to realize the proposed system.

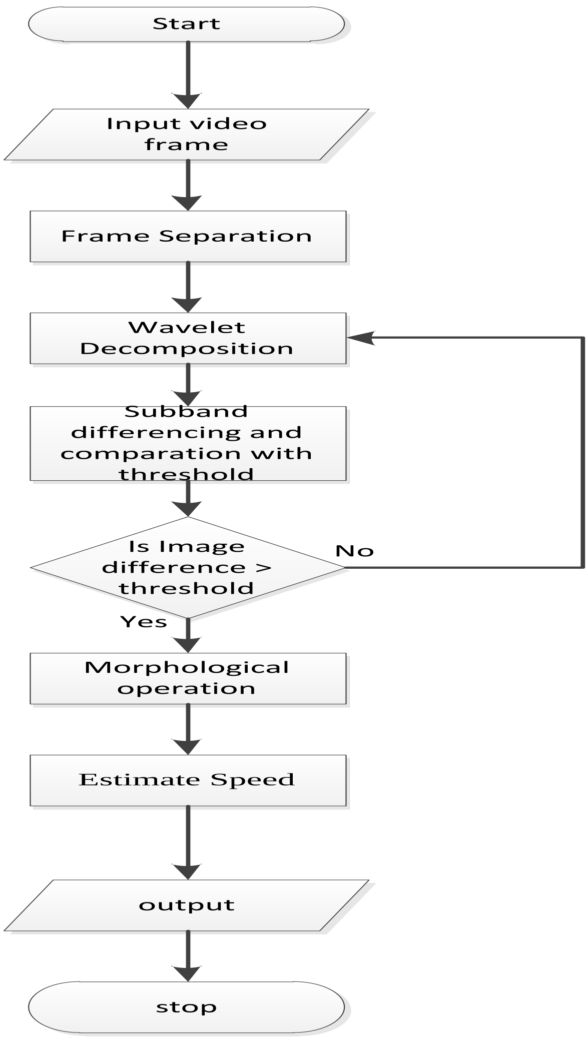

Figure 1: Flow chart of the proposed suspicious system.

Performance Evaluation of the System

The accuracy and completeness of the references is the responsibility of the author. References to personal letters, paper presented at meetings, and other unpublished material may be included.

References in 12-point type should be listed alphabetically at the end of the paper using an unnumbered style with a hanging indentation (see below).

Mean and standard deviation of the developed system were determined to evaluate the performance of the system.

Mean is the average value for a finite set of replicate measurements on a sample. The mean value for this proposed work was determined by finding the mean value of 200 frames' estimated speed on each detected vehicular movement. Mean

$$\mu = \frac{1}{n}\sum x_i \tag{11}$$

The standard deviation is the average amount of variability in your dataset. It tells you, on average, how far each value lies from the mean. Standard deviation

$$\sigma = \sqrt{\frac{\Sigma(x-\mu)^2}{N}} \tag{12}$$

where,

σ = standard deviation, ∑ = sum of, x = each value, μ = mean value, N = number of values of the estimated speed.

RESULTS AND DISCUSSION

The three different locations used to experiment with the developed system are residential premises, highways, and campus drives. The videos were captured with a digital Sony camera with 16.1 megapixels, 25 mm wide-angle lens at a frame rate of 29 frames per second. The sizes of the input frame were 480 x 640 pixels. This experiment was carried out in three different locations where videos of different vehicular movements were covered for an hour each. Matlab version 8.1 software package installed on a laptop configuration of 2.6 gigahertz processor speed and 8-gigabyte ram was used to process the recorded videos. A camera tripod stand was used to mount the camera when residential premises and campus drive data were being taken. The recording camera was mounted on the arm of an overhead bridge when data for the highway scene was taken. The measurements carried out for pixel conversion varies and it all depends on the location of the experiment.

The distance and height measurement of 30 meters and 2.0 meters was used to experiment a residential building compound vehicular movements surveillance. Plate 1 to 4 shows the result of a normal vehicular movement while plate 5 shows the result of a suspicious vehicular movement. Since a moving car changes its position across a video scene, the speed estimated by the developed system also changes per frame because a static measurement was used; therefore, an estimated speed of 200 frames for detected vehicular movements per scene was used to evaluate the performance of the surveillance system developed.

Plate 1 shows a car under surveillance on the highway traveling with the speed estimated as 72.468 km/hr by the vehicular surveillance system developed. The speed range at which the car travels also falls within the range of speed considered to be normal on highways that is 0-100km/hr. Plate 2 shows a motorbike under surveillance on the highway traveling with the speed estimated by our system to be 21.314 km/hr.

Plate 1: A car under surveillance on highway

Plate 2: A motorbike under surveillance on highway

Plate 3: A bus under surveillance on a campus drive

Plate 4: A car under surveillance on a residential premise

Plate 5: Suspicious movement of a motorcycle

To validate the speed estimated by the developed surveillance system, commercial vehicles with speed limiters installed were used. The speed limiter was set at different values to validate the performance of the proposed system. 15km/hr was set to be the maximum vehicular movement speed limit in residential premises, while 25km/hr, 65km/hr, and 100km/hr were set to be the maximum vehicular movement speed limits for all other locations where the experiments were carried out.

100km/hr speed limit was used to detect suspicious vehicular movement in this work. Plate 5 shows a detected suspicious vehicular movement. The speed at which the motorcycle moves was above 100km/hr earlier set as the maximum speed to detect normal vehicular movement, hence the bounding box changed to red color to indicate suspicious movement.

Also, the speed limit set on an installed speed limiter vehicle was used to compare with the speed values estimated by our system. Table 1 shows the speed evaluation performance of the developed surveillance system for vehicular movements as compared with speed limiter installed vehicles. The mean and standard deviation of the estimated speed for the surveillance system developed in two decimal places is also shown on the Table 1.

Table 1. The performance evaluation of the developed surveillance system compared with speed limiter installed vehicles.

S/N			**Speed estimated by the surveillance system developed (km/hr)**			
	Locations	**Speed limiter value km/hr**	**Mean and standard deviation values**	**Bus**	**Car**	**Motorbike**
1	Residential premises	15	Mean	12.88	11.83	12.49
			Standard deviation	1.00	0.59	0.83
2	High way	25	Mean	23.27	24.23	23.48
			Standard deviation	3.09	2.19	2.19
3	Campus drive	65	Mean	64.43	63.59	64.34
			Standard deviation	3.08	2.39	2.21

CONCLUSION

A system for detecting suspicious vehicular movements has been presented in this paper. In this work suspicious vehicular movement system was implemented by detecting vehicular movements with a surveillance camera using the wavelet subband differencing method. The system detects vehicular movement speed at different locations where vehicles are used to commit atrocities. The speed estimation of this system was developed through pixels to kilometer conversions. The result of this work has been tested and compared with that of the speed limiter installed vehicular movements, which work well with just a difference of ± 3km/hr. The difference was a result of changes in the position of the moving vehicles under surveillance which makes the field measurements also vary. From the experimental findings, it is confirmed that the system detects suspicious vehicular movement in residential premises, on highways, and on on-campus drives. Also, the system can be used as an image-based speed limiter, which is needed on highways to reduce accidents due to overspeeding.

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