Motion Detection Based on Image Intensity Ratio

Pham Bao Quoc[1(✉)] and Nguyen Thanh Binh[2]

[1] Faculty of Information of Technology,
Ho Chi Minh City University of Technology, HUTECH, Ho Chi Minh City, Vietnam
nationpham@hotmail.com
[2] Faculty of Computer Science and Engineering,
Ho Chi Minh City University of Technology, VNUHCM, Ho Chi Minh City, Vietnam
ntbinh@cse.hcmut.edu.vn

Abstract. Motion detection is the first important step in large applications of computer vision. Motion detection extracts moving objects from the background. There are many methods to do that. However, in most methods, if the input video has noise and light change, moving objects will not be extracted accurately. In this paper, we propose the method for motion detection which extracts moving objects from the background based on the image intensity ratio concept that is not affected by light change; therefore, the sensitivity with light change is overcome. The image intensity ratio is computed by the average intensity of current frame and the intensity of every pixel in that frame. The intensity ratio of a pixel is nearly unchanged between two frames. We apply the Lucas-Kanade optical flow method based on that image intensity ratio. Our proposed algorithm has good noise tolerance and is not affected by light change. For demonstrating the superiority of the proposed method, we have compared the results with the other recent methods available in literature.

Keywords: Motion detection · Intensity ratio image · Moving object

1 Introduction

Real-time object tracking is a popular application of computer vision. It faces up to complex problems. Although the algorithms have to do a lot of manipulation, they must be fast enough to finish processing a video frame in the extremely short time between two frames. The motion detection is a very important and complex step in the real-time object tracking system. In this step, moving objects will be extracted from the background. It is not easy to extract moving objects. In the input video, there is a lot of noise and light change because of the effect of the outdoor environment, which makes the moving object extraction inaccurate and some parts of the background become moving objects.

In the past, there are many methods to extract moving objects from the background. In image subtraction methods [1], the current frame will be subtracted with a reference frame. The reference frame may be the background frame (background subtraction) or the previous frame (frame difference). This method is very sensitive with noise and light change. Noise and light change makes the current frame different

P.C. Vinh et al. (Eds.): ICTCC 2014, LNICST 144, pp. 350–359, 2015.
DOI: 10.1007/978-3-319-15392-6_33

from the reference frame. These different pixels become the foreground and make the moving object extraction inaccurate. In Gaussian mixture model [2], Stauffer has proposed a probabilistic approach using a mixture of Gaussian for identifying the background and foreground. This method is not affected by noise and sudden light change. However, if the light changes continuously, some parts of the background will become foreground objects. In Lucas-Kanade optical flow method [4, 5, 6, 7, 8], two continuous frames are used to compute the velocity of moving objects by the spatial and temporal derivatives. This method has good noise tolerance. However, if the light changes suddenly and continuously, some parts of the background will become moving objects.

In this paper, we propose the method for motion detection extracts moving objects from the background based on the image intensity ratio concept that is not affected by light change; therefore, the sensitivity with light change is overcome. The intensity ratio image is computed by the average intensity of current frame and the intensity of every pixel in that frame. The intensity ratio of a pixel is nearly unchanged between two frames. Then, we apply the Lucas-Kanade optical flow method based on that image intensity ratio. Our proposed algorithm has good noise tolerance and is not affected by light change. It is suitable for the real-time object tracking system. For demonstrating the superiority of the proposed method, we have compared the results with the other recent methods available in literature.

The rest of the paper is organized as follows: in section 2, we described the basic of Lucas-kanade optical flow; details of the proposed method are given in section 3; the results of the proposed method are presented in section 4 and our conclusions in section 5.

2 Lucas-Kanade Optical Flow

The Lucas-Kanade optical flow method is proposed by Lucas and Takeo [4]. This optical flow method is used to compute the velocity of moving objects between two continuous frames by the spatial and temporal derivatives. It is fast and has a low computational cost, and good noise tolerance [5]. It tries to compute the motion between two continuous frames at time t and $t + \Delta t$. Assuming the intensity of a pixel does not change between two frames, we have equation:

$$I(x, y, t) = I(x + \Delta x, y + \Delta y, t + \Delta t) \tag{2.1}$$

Assuming the movement between two frames is small, the equation (2.1) with Taylor series can be derived to give:

$$I(x + \Delta x, y + \Delta y, t + \Delta t) \approx I(x, y, t) + \frac{\delta I}{\delta x}\Delta x + \frac{\delta I}{\delta y}\Delta y + \frac{\delta I}{\delta t}\Delta t \tag{2.2}$$

From (2.1) and (2.2), we obtain the following:

$$\frac{\delta I}{\delta x}\Delta x + \frac{\delta I}{\delta y}\Delta y + \frac{\delta I}{\delta t}\Delta t = 0 \tag{2.3}$$

or

$$\frac{\delta I}{\delta x}\frac{\Delta x}{\Delta t}+\frac{\delta I}{\delta y}\frac{\Delta y}{\Delta t}+\frac{\delta I}{\delta t}\frac{\Delta t}{\Delta t}=0 \tag{2.4}$$

and the result is:

$$\frac{\delta I}{\delta x}V_x+\frac{\delta I}{\delta y}V_y+\frac{\delta I}{\delta t}=0 \tag{2.5}$$

where V_x and V_y are the x and y components of the velocity and $\frac{\delta I}{\delta x}$, $\frac{\delta I}{\delta y}$, $\frac{\delta I}{\delta t}$ are the spatial and temporal derivatives at x, y, t. Set I_x, I_y, I_t as those derivatives, we have equation:

$$I_xV_x+I_yV_y=-I_t \tag{2.6}$$

Assuming the neighboring pixels move at the same velocity with the pixel under consideration, we have the following:

$$\begin{cases} I_{x_1}V_x+I_{y_1}V_y=-I_{t_1} \\ \vdots \\ I_{x_m}V_x+I_{y_m}V_y=-I_{t_m} \end{cases} \tag{2.7}$$

The (2.7) can be written as:

$$\begin{bmatrix} I_{x_1} & I_{y_1} \\ \vdots & \vdots \\ I_{x_m} & I_{y_m} \end{bmatrix}\begin{bmatrix} V_x \\ V_y \end{bmatrix}=\begin{bmatrix} -I_{t_1} \\ \vdots \\ -I_{t_m} \end{bmatrix} \tag{2.8}$$

Set $A=\begin{bmatrix} I_{x_1} & I_{y_1} \\ \vdots & \vdots \\ I_{x_m} & I_{y_m} \end{bmatrix}$, $v=\begin{bmatrix} V_x \\ V_y \end{bmatrix}$, $b=\begin{bmatrix} -I_{t_1} \\ \vdots \\ -I_{t_m} \end{bmatrix}$, we have equation:

$$Av=b \tag{2.9}$$

Use the least squares method to solve equation (2.9), we have the following:

$$v=(A^TA)^{-1}A^Tb \tag{2.10}$$

And the result is:

$$\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{m} I_{x_i}^2 & \sum_{i=1}^{m} I_{x_i} I_{y_i} \\ \sum_{i=1}^{m} I_{y_i} I_{x_i} & \sum_{i=1}^{m} I_{y_i}^2 \end{bmatrix}^{-1} \begin{bmatrix} -\sum_{i=1}^{m} I_{x_i} I_{t_i} \\ -\sum_{i=1}^{m} I_{y_i} I_{t_i} \end{bmatrix} \tag{2.11}$$

We can use Gaussian function in computational derivative step and add a Tikhonov constant to (2.11) for the better result [8].

3 The Proposed Method

Real-time object tracking is a complex problem and a popular application of computer vision. In this section, we propose an approach for motion detection which extracts moving objects using an image intensity ratio based on Lucas-Kanade method (IRI-LK). We apply the Lucas-Kanade optical flow method based on the intensity ratio image. We propose the image intensity ratio concept because it is not affected by light change.

In input video, assuming the different pixels of actual interested moving objects between two frames is small. If the light does not change between two continuous frames, the average intensity of two continuous frames is different slightly. Else, the intensity of all pixels is changed and the average intensity is significant different between two continuous frames, which means the average intensity depends on the light change. Assumingly, the intensity of all pixels will change with a same coefficient λ when the light changes.

Set $I(x, y, t)$ and $I(x+\Delta x, y+\Delta y, t+\Delta t)$ as the intensity of pixel at time t and $t + \Delta t$, we have equation:

$$I(x, y, t) = \lambda I(x + \Delta x, y + \Delta y, t + \Delta t) \tag{3.1}$$

Set $\overline{I}(t)$ and $\overline{I}(t + \Delta t)$ as the average intensity of the frame with the size m x n at the time t and $t+\Delta t$, we have the following:

$$\overline{I}(t) = \frac{\sum_{y=1}^{n} \sum_{x=1}^{m} I(x, y, t)}{m.n} \tag{3.2}$$

and

$$\overline{I}(t + \Delta t) = \frac{\sum_{y=1}^{n} \sum_{x=1}^{m} I(x + \Delta x, y + \Delta y, t + \Delta t)}{m.n} \tag{3.3}$$

From (3.1), (3.2) and (3.3), we have equation:

$$\overline{I}(t) = \lambda \overline{I}(t + \Delta t) \tag{3.4}$$

Set $R(x, y, t)$ and $R(x+\Delta x, y+\Delta y, t+\Delta t)$ as the intensity ratio of pixel at time t and $t+\Delta t$, we have the following:

$$R(x, y, t) = \frac{I(x, y, t)}{\overline{I}(t)} \tag{3.5}$$

and

$$R(x + \Delta x, y + \Delta y, t + \Delta t) = \frac{I(x + \Delta x, y + \Delta y, t + \Delta t)}{\overline{I}(t + \Delta t)} \tag{3.6}$$

From (3.1), (3.4), (3.5) and (3.6), we have equation:

$$R(x, y, t) = R(x + \Delta x, y + \Delta y, t + \Delta t) \tag{3.7}$$

The equation (3.7) means the intensity ratio of pixels do not change when the light changes. Therefore, the intensity ratio image is not affected by light change. If the Lucas-Kanade optical flow method is based on the intensity ratio image, the sensitivity with light change of it is overcome.

The proposed method IRI-LK algorithm which we propose is depicted in figure 1. This model includes four steps. The two main steps are intensity ratio image computation and optical flow computation.

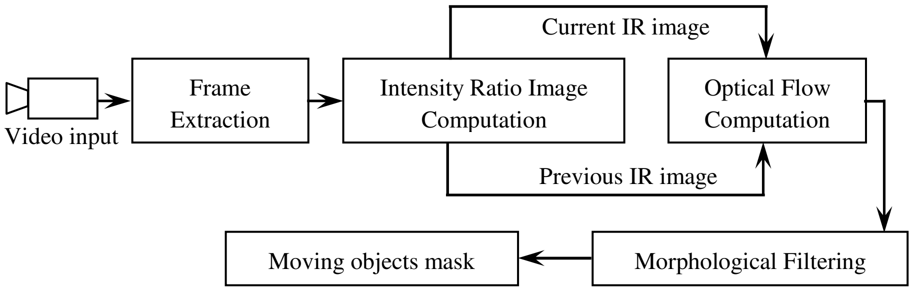

Fig. 1. Image Intensity ratio based on Lucas-Kanade model

Firstly, the frame extraction. Frame sequences are extracted from input video. Frame by frame are converted to intensity images. Then, the intensity image is standardized. The intensity value will be a real number between 0 and 1. In this step, we can use an image processing function to resize the frame in an appropriate size.

Secondly, the intensity ratio image computation. Each intensity image in turn is used to compute the image intensity ratio. We use the equation (3.2) to compute the average intensity of the current intensity image. Then, we use the equation (3.5) to compute the image intensity ratio. We can multiply the image intensity ratio with a coefficient α which depends on the highest intensity ratio. This makes the intensity ratio value always in a correct range.

Thirdly, optical flow computation. The Lucas-Kanade method is applied to compute the velocity of moving objects. The spatial and temporal derivatives are computed based on the current image intensity ratio and previous image intensity ratio using Gaussian function. We use the equation (2.11) to calculate the velocity vector $\begin{bmatrix} V_x \\ V_y \end{bmatrix}$ of moving objects. The velocity magnitude $V(x, y)$ is calculated by the following:

$$V(x, y) = \sqrt{V_x^{\ 2} + V_y^{\ 2}} \tag{3.8}$$

For returning binary foreground mask $B(x, y)$, the velocity magnitude $V(x, y)$ is taken threshold by the following:

$$B(x, y) = \begin{cases} 1 & (V(x, y) \geq Threshold) \\ 0 & (V(x, y) < Threshold) \end{cases} \tag{3.9}$$

Finally, we apply some morphological filtering to remove noise and small blobs such as morphological closing, image fill, and binary area open.

4 Experimental Results

In this section, we illustrate the results of IRI-LK algorithm. The implementation of developed algorithm has been tested under MATLAB platform. The input video is captured by a static camera with the resolution of 160 x120 pixels, at the frame rate of 15fps. We choose coefficient $\alpha = 6$ and Tikhonov constant = 0.005. We tested many video clips. In here, we present some frames. In the input video, there are many frames having light change. Video clips for testing are taken from standard datasets and some clips from cameras on the streets. For demonstrating the superiority of the proposed method, we have compared the results with the Lucas-Kanade (LK) method, and Gaussian Mixture Model (GMM) method.

In figure 2, we show three input frames that have light change. The light is darker from frame 39 to frame 41. For the Lucas-Kanade optical flow method, we receive a flash at frame 40 and frame 41. For the Gaussian mixture model method, we receive a flash at frame 41. For the proposed method, the segment result is very good.

Table 1 compares the motion segment error between LK method, GMM, and the proposed method (IRI-LK). Look at table 1, we have the percentage of the motion segment error is LK: 12.40%, GMM: 8.26%, IRI-LK: 0.00%. The LK gets the motion segment error when the light changes suddenly and continuously. The GMM gets the motion segment error when the light changes continuously. The IRI-LK is very good for this input video.

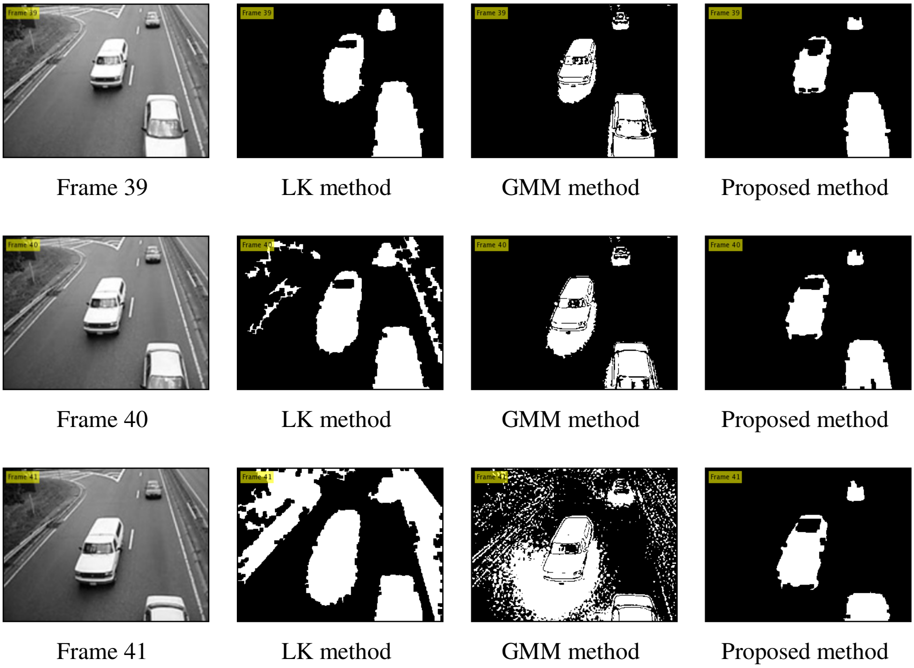

Fig. 2. The segment of Car video compared the proposed method with the other methods

Table 1. Comparing the motion segment error of LK, GMM, and IRI-LK

Frame	Average Intensity	LK method	GMM method	Proposed method
1	0.5220			
…				
21	0.5030			
22	0.5056			
23	0.4628	Error		
24	0.4717			
25	0.4854			
…				
38	0.5165			
39	0.5035			
40	0.4643	Error		
41	0.4166	Error	Error	
42	0.3714	Error	Error	

Frame	Average Intensity	LK method	GMM method	Proposed method
43	0.3922		Error	
44	0.3374	Error	Error	
45	0.3814	Error	Error	
46	0.4026	Error	Error	
47	0.4345	Error		
48	0.4829	Error		
49	0.4818			
50	0.4809			
…				
76	0.4764			
77	0.4975			
78	0.4472	Error	Error	
79	0.4056	Error	Error	
80	0.4237		Error	
81	0.4068		Error	
82	0.4551	Error		
83	0.4925	Error		
84	0.4890			
85	0.4892			
…				
98	0.4790			
99	0.4677			
100	0.4200	Error		
101	0.4282			
102	0.4330			
103	0.4267			
104	0.4704	Error		
105	0.4875			
106	0.4872			
…				
121	0.4891			

In another test, the input video is captured by a static camera with the resolution of 640x360 pixels, at the frame rate of 29fps. We choose coefficient $\alpha = 6$ and Tikhonov constant = 0.001. We add 10% brightness at frame 160 and 20% brightness at frame 161 for testing. Three input frames are shown in figure 3.

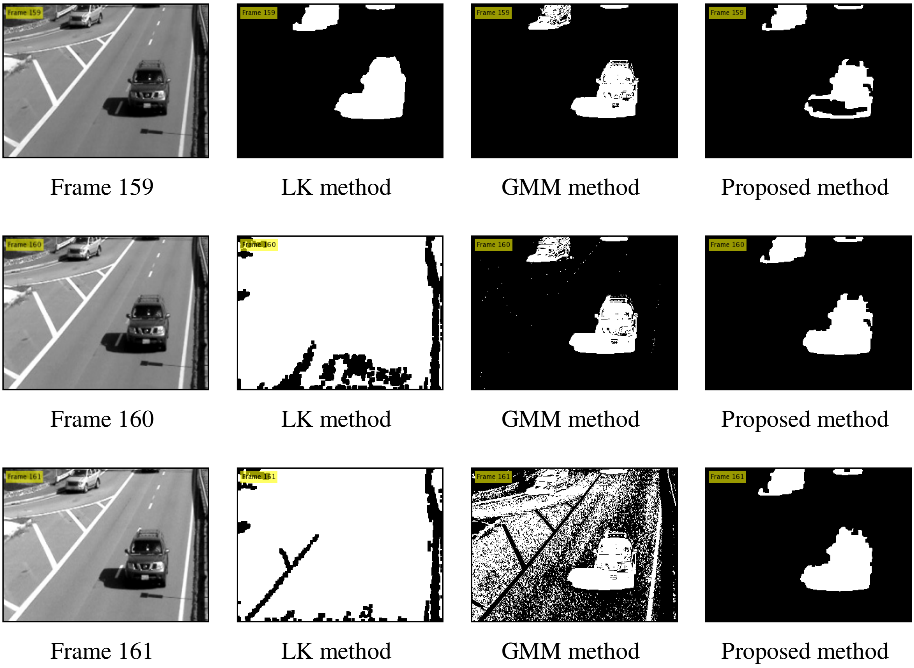

Fig. 3. The segment of clip, which was captured by a static camera, compared the proposed method with the other methods

In figure 3, we also show three input frames that have light change. For the Lucas-Kanade optical flow method, we receive a flash at frame 160 and frame 161. For the Gaussian mixture model method, we receive a flash at frame 161. For the proposed method, the segment result is also very good.

5 Conclusion

In motion detection, the noise and light change makes moving object identification inaccurate because the Lucas-Kanade optical flow method works well with the assumption that the intensity of pixels does not change. We propose the image intensity ratio concept that is not affected by light change in accordance with the Lucas-Kanade optical flow method. The proposed method has good noise tolerance and is not affected by light change. It is good for the real-time object tracking system. In fact, the light does not change with the same coefficient λ at all pixels. The intensity ratio of a pixel has a small difference between two continuous frames. It makes the segment result not good in all cases. Despite that, our proposed method greatly improves the result of motion detection in the light change.

References

1. Moeslund, T.B.: Introduction to video and image processing: Building real systems and applications. Springer (2012)
2. Rout, R.K.: A survey on object detection and tracking algorithms. Diss (2013)
3. Stauffer, C., Grimson, W.E.L.: Adaptive background mixture models for real-time tracking. In: IEEE Computer Society Conference on Computer Vision and Pattern Recognition, vol. 2. IEEE (1999)
4. Lucas, B.D., Takeo, K.: An iterative image registration technique with an application to stereo vision. In: IJCAI, vol. 81 (1981)
5. Lu, N., et al.: Motion Detection Based on Accumulative Optical Flow and Double Background Filtering. World Congress on Engineering (2007)
6. Frantc, V.A., et al.: Video inpainting using scene model and object tracking. In: IS&T/SPIE Electronic Imaging. International Society for Optics and Photonics (2013)
7. Shirageri, M.S., Udupi, G.R., Bidkar, G.A.: Design and development of Optical flow based Moving Object Detection and Tracking (OMODT) System. vectors 2.4 (2013)
8. Karlsson, S.M., Josef, B.: Lip-motion events analysis and lip segmentation using optical flow. In: 2012 IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops (CVPRW). IEEE (2012)