Design and development of Optical flow based Moving Object Detection and Tracking (OMODT) System

Ms. Shamshad Shirgeri[1], Ms. Pallavi Umesh Naik[2], Dr.G.R.Udupi[3], Prof.G.A.Bidkar[4]

[1,2]Student of M.Tech in Industrial Electronics, [3]Principal, [4]Asst.prof & HOD E&C Dept KLS's VDRIT, Haliyal affiliated to VTU, Belgaum, and Karnataka, India.

ABSTRACT:

Moving object detection and tracking is often the first step which has attracted a great interest from computer vision researchers due to its applications in areas, like video surveillance, traffic monitoring and image recognition. Moving object detection involves identification of an object in consecutive frames where as object tracking is used to monitor the movements with respect to the region of interest. We propose, Optical Flow Based Lucas - Kanade algorithm using different smoothing techniques for a single and multiple object detection and tracking have been developed. Lukas – Kanade algorithm with Sobel, Sobel and Gaussian smoothing techniques is used in this paper to compute Optical Flow vectors. Single object and multiple object movements in an frame with respect to the computed vectors are segmented with the help of Threshold which is specified depending on the value mentaioned. The extracted movements are tracked using Sobel edge and Centroid information. This paper describes an smoothing algorithm to estimate Moving object detection using image processing technique using Matlab Software.

Keywords *- Image Pyramid Segmentation, Optical Flow Method, Sobel edge detection, Thresholding value, tracking.*

I. INTRODUCTION

Motion detection and tracking has attracted a great interest from computer vision researchers due to its promising applications in areas, like video surveillance, traffic monitoring and image recognition. Motion detection can be used to study a large variety of motions like motion with respect to moving observer and static objects, static observer and moving objects or movement with respect to both [1]. There are several techniques for moving object detection, commonly used approaches are based on Optical Flow and background subtraction techniques. Based on existing work [1] suggests that the method by Lucas - Kanade is consistent in computing Optical Flow vectors. In this work analysis on Lucas - Kanade algorithm based on smoothing techniques has been performed for better accuracy in computed Optical Flow vector. The computation time has been reduced using image pyramid concept.

II. BLOCK DIAGRAM OF MOVING OBJECT DETECTION AND TRACKING

Figure1 depicts the block diagram of a method.

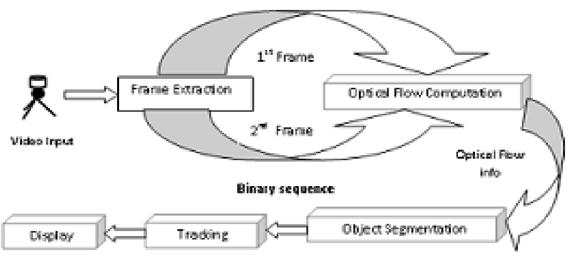


Figure 1 Optical Flow based Moving object detection and tracking method

Figure 1 contains mainly three parts they are:

- **Optical Flow Computation**
- **Object Segmentation**
- **Object Tracking**

In Optical Flow computation frame to frame Optical Flow vectors can be calculated. Object Segmentation includes multiple Object Segmentation in which computed Optical Flow Vectors are used to determine whether the pixels in the frame belong to movement or not. The Object Tracking part involves overlapping of edge information or building Boundary box over the segmented image to highlight the movement has been carried out.

2.1. The steps involved in motion detection and tracking system are as follows

- Extraction of image sequences from the input video
- Finding the moving objects for consecutive frames using Lucas - Kanade and background subtraction algorithm.
- Segmenting the regions where there is movement using thresholding operation
- Enhancing the segmented result using morphological operations.
- Highlighting the multiple objects tracking using edge or boundary box over centroid.

III. LITERATURE REVIEW

The following points has been summarized by referring journals, manuals and related documents

- The Lucas - Kanade Optical Flow works with the assumption of local flow at constant rate and the intensity of each point is constant between frames.
- The first order local differential methods are the most reliable ones that produce accurate vectors.
- The differential method does not generate Optical Flow in case of stationary moving objects (same intensity) with respect to stationary camera.
- The filtering and segmentation algorithm needs to be improved with respect to computation time suitable for real time applications.
- Use of multi resolution techniques such as image pyramid concepts, the computation time can be reduced.
- The work with respect to moving background with moving object (dynamic) has not been discussed in the most of literatures.
- Software's used with respect to the development of Optical Flow based application are MATLAB, SIMULINK, Visual C++ and Open CV.

IV. OPTICAL FLOW MOTION ANALYSIS

Optical Flow methods can be computed by using two images taken at time t and t + δt; since they deal with the Taylor series, they're also called as differential methods, as they work with the spatial I(x, y) and temporal I(t) derivatives. Assume that the image intensity of each visible scene point is unchanging over time.

$$I(x, y, t) = I(x+\delta x, y+\delta y, t+\delta t) \quad (1)$$

Assuming that the movement is small , the image constraint at I(x, y, t) with Taylor series can be derived to give:

$$I(x+\delta x, y+\delta y+t+\delta t) = I(x,y,t) + \frac{dI}{dx}\delta x + \frac{dI}{dy}\delta y + \frac{dI}{dt}\delta t + H.O.T \quad (2)$$

From equation (2), by ignoring high order terms, we will get

$$\frac{dI}{dx}\delta x + \frac{dI}{dy}\delta y + \frac{dI}{dt}\delta t = 0 \quad (3)$$

Dividing equation (3) by δt results in

$$\frac{dI}{dx}(\delta x/\delta t) + \frac{dI}{dy}(\delta y/\delta t) + \frac{dI}{dt} = 0 \quad (4)$$

Rewriting the equation (4)

$$\frac{dI}{dx}Vx + \frac{dI}{dy}Vy + \frac{dI}{dt} = 0 \qquad (5)$$

The obtained equation (5) is the Optical Flow constraint equation , which expresses a constraint on the components Vx and Vy of the Optical Flow lying on the X axis and on the Y axis respectively and (dI/dx), (dI/dy), (dI/dt) are the derivatives of the image at (x,y,t). The Optical Flow constraint equation can be rewritten as shown in equation (6 and 7):

$$Ix.\ Vx + Iy.\ Vy = -It \qquad (6)$$

Or, equivalently

$$[Ix\ Iy]\begin{bmatrix} Vx \\ Vy \end{bmatrix} = -It \qquad (7)$$

The Optical Flow algorithms are mostly based on correlation, gradient and frequency information respectively. Some common algorithms for computing Optical Flow vectors are block matching for correlation, Lucas-Kanade and Horn –Schunck for gradient and phase- based filtering for frequency. Barron et al. In their wirk compared the accuracy of different Optical Flow techniques both real and synthetic method based on Lucas and Kanade method is consistent in producing accurate depth maps with good noise tolerance. Hence we will delve into Lucas-Kanade algorithm.

V. LUCAS KANADE OPTICAL FLOW ALGORITHM

The Lucas-Kanade algorithm assumed that motion vectors in any a given region do not change but merely shift from one position to another. Assuming that the flow (Vx, Vy) is constant in a small window of size m×m with m>1, which is centered at (x, y) and numbering the pixels as 1...n, a set of equations can be derived [1].

$$\begin{aligned} I_{x1}V_x + I_{y1}V_y &= -I_{t1} \\ I_{x2}V_x + I_{y2}V_y &= -I_{t2} \\ &\vdots \\ I_{xn}V_x + I_{yn}V_y &= -I_{tn} \end{aligned} \qquad (8)$$

It is seen from equation (8); the system is over-determined since there are more than three equations for the three unknowns [1]. Hence equation can be rewritten as;

$$\begin{bmatrix} I_{x1} & I_{y1} \\ \vdots & \vdots \\ I_{xn} & I_{yn} \end{bmatrix}\begin{bmatrix} V_x \\ V_y \end{bmatrix} = \begin{bmatrix} -I_{t1} \\ \vdots \\ -I_{tn} \end{bmatrix} \qquad (9)$$

Or

$$A\vec{V} = (-b) \qquad (10)$$

To solve the determined system of equations, the least squares method is used [1].

$$(A)^T A\vec{V} = (A)^T(-b) \qquad (11)$$

$$\vec{V} = (A^T A)^{-1} A^T(-b) \qquad (12)$$

Or

$$\begin{bmatrix} \sum Ix * Ix & \sum Ix * Iy \\ \sum Ix * Iy & \sum Iy * Iy \end{bmatrix}\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} \sum Ix * It \\ \sum Iy * It \end{bmatrix} \qquad (13)$$

Equation (13) is written as

$$A^T A = \begin{bmatrix} \Sigma\, Ix_i^2 & \Sigma\, Ix_i Iy_i \\ \Sigma\, Ix_i Iy_i & \Sigma\, Iy_i^2 \end{bmatrix} \qquad (14)$$

VI. IMAGE ACQUISITION

First stage of vision system is the image acquisition stage.After the image has been obtained, some processing methods can be applied to the image to perform different vision tasks . if the image has not been acquired satisfactorily then the intended tasks may not be achievable, even with some form of image enhancement Video Signal must be digitised. Digitises the incoming video signal Samples signal into discrete pixels at appropriate intervals -- line by line. Samples signal into a (8 bit) digital value. Stores sample frame own memory.

Frame easily transferred to computer memory or a file.

VII. COMPUTATION OF SPATIAL AND TEMPORAL DERIVATIVE

In this section we discusses about the methods used to compute derivatives needed in order to estimate Optical Flow vectors. Sobel operator are used here to compute the spatial and temporal derivative.

7.1. Sobel Operator

A widely used technique for spatial derivatives computing is the convolution by using the Sobel Operator. It is a differential operator computing an approximation of the gradient of the image intensity and it's very fast to apply since it's based on a small window (3x3 kernels) to convolve with the full image. Which is also used to detect edges of a image, because by using it we'll obtain some white where the intensity changes abruptly and black when it does not have any changes. We refer to two matrices, on for the gradient over the X axis, and one for the gradient over the Y axis; consider an image I, convolving it two times in order to obtain Gx and Gy,that are the images containing the approximation of spatial derivatives. The temporal derivative (It) is calculated by subtracting the frame taken at time t + δt (second frame) from t (first frame) [1].

$$Gx = \begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix} * A \;\&\; Gy = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} * A \qquad (15)$$

VIII. OPTICAL FLOW VECTORS COMPUTATION

The spatial and temporal derivatives I(x, y, t) using Sobel operator are found. The Optical Flow vectors with the components 'u' and 'v' for each region are calculated by applying windowing concept over these Since Lucas - Kanade hypothesis assumes that all the pixels in an m×m window have the same velocity components, this parameter allows us to choose how big is the windows size and as direct consequence, the density of Optical Flow vectors. To achieve good results and to avoid noise, neighborhood window must be tuned in both Least squares windowing approach. Figure 2 shows block diagram of Lucas - Kanade Optical Flow computation.

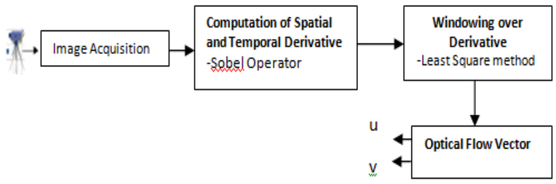


Figure 2 Figure shows the block diagram of Optical Flow based Lucas – Kanade computation

8.1. Least Square method

After finding the derivatives that is spatial and temporal I(x; y; t) from Sobel edge detection. The optic flow vectors with the components u and v for each region are calculated using equation 19 (Least squares method) and equation is as follows:

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} \sum Ix*Ix & \sum Ix*Iy \\ \sum Ix*Iy & \sum Iy*Iy \end{bmatrix}^{-1} \begin{bmatrix} \sum Ix*It \\ \sum Iy*It \end{bmatrix} \qquad (16)$$

IX. IMAGE PYRAMID

Image pyramid is used for reducing the resolution of the image. By using the concept of Image pyramid , the size of the image gets reduced by $1/4^{th}$ and which helps in avoiding dense vectors resulting in smooth vector computation with reduction in computational time.

X. OBJECT SEGMENTATION

In order to segment the moving object, the resultant Optical Flow vectors are used to determine whether the pixels in the frame belong to movement or not. Thresholding over the Optical Flow vectors has been performed to separate the moving region. The threshold is a dynamic parameter and its value may change from one frame to the next due to several factors including weather, illumination and camera settings. The main challenge within the segmentation block is the handling of small Optical Flow vectors. These may be associated with either background noise or with slow moving, but relevant objects. The threshold equation is given by

$$of_n = \left(\left| \sqrt{u^2} + \sqrt{v^2} \right| \right) \qquad (17)$$

Where "ofn" is the absolute value for Optical Flow and threshold is set as mean(mean(abs(of))); to eliminate background noise or with slow moving, median filter and morphologic processing is used, and the segmented object is given to tracking [2].

$$y_n = \begin{cases} 255 \ldots\ldots\ldots if\,(of_n > threshold) \\ 0 \ldots\ldots\ldots\ldots\ldots\ldots otherwise \end{cases} \quad (18)$$

XI. OBJECT TRACKING

Optical Flow vectors are used for tracking. Objects trajectories are represented by edges and Centroid based object tracking. In multiple objects tracking part, the overlapping of edge information or building of boundary box over the segmented image to highlight the movement has been carried out.

XII. EXPERIMENTAL RESULTS

This section provides the details about the results of motion detection and tracking. It also describes the use of image pyramid concept in real time applications like video surveillance. Implementation of developed algorithm has been tested under MATLAB platform.

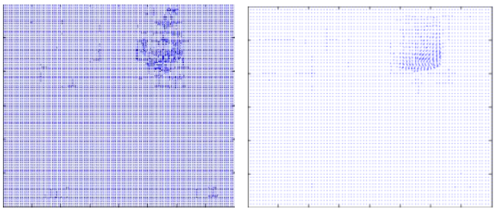
12.1.Test Input and results for with and without Image Pyramid

Image pyramid is used for reducing the resolution of the image. By using the concept of Image pyramid , the size of the image gets reduced by $1/4^{th}$ and which helps in avoiding dense vectors resulting in smooth vector computation with reduction in computational time. Figure 2 shows input sequences of car, captured by static camera with resolution of 160x120 pixels and frame rate of 15fps.

Frame (a) Frame (b)

Figure 3 Input sequence of car

The expected Optical Flow vectors of the car will be as in the direction of car rotation, as camera and the background is static.



(a) (b)

Figure 4 Optical Flow vectors for with and without image pyramid.

Figure 4 (a) shows the Optical Flow vectors obtained using Lucas – Kanade without using image pyramid over the input sequence. Figure 4 (b) shows Optical Flow vectors obtained using Lucas – Kande algorithm with 2 level image pyramid respectively. The Optical Flow vectors obtained without image pyramid has more density, which leads to overlap of the information's and increase the computation time. Image Pyramid results to overcome these problems and provide smoother vector results with less density, high accuracy and better computation time.

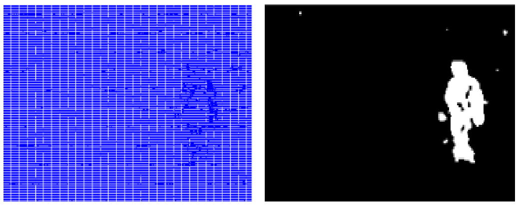
XIII. MATLAB IMPLEMENTATION FOR MOVING OBJECT DETECTION AND TRACKING USING STATIC CAMERA WITH STATIONARY BACKGROUND

A test case Image sequence with 360x240 pixel resolution has been taken. This has movement with respect to a person with static background and stationary camera. The two image sequences with respect to test case are shown in Figure 5.

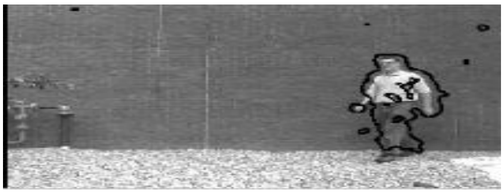
Frame (a) Frame (b)

Figure 5 Input sequences of man

Optical Flow vectors will be in the direction of movement of the person. The identified movements have been segmented by using Thresholding operation. The segmented movements are tracked using edge based method.The Optical Flow vectors using Sobel based Lucas – Kanade approach without image pyramid is shown in the Figure 6.



(a) Optical Flow vector (b) Segmentation

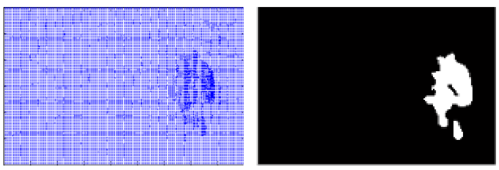


(c) Sobel Edge based tracking system

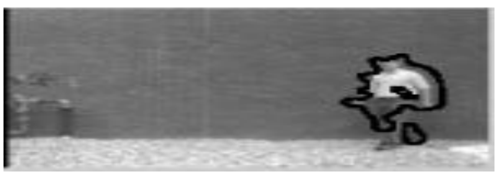
Figure 6 Detection and Tracking of moving object using Sobel Operator based Lucas – Kanade Optical Flow based algorithm without image pyramid implemented on MATLAB.

Figure 6 (a) shows Optical Flow vector of person movement. Figure 6 (b) shows selecting suitable threshold over the Optical Flow vector result. The Edge based information for the input sequence is shown in Figure 6 (c).

The Optical Flow vector using Sobel based Lucas – Kanade approach with image pyramid is shown in the Figure 7.



(a) Optical Flow vector (b) Segmentation



(c) Sobel Edge based tracking system

Figure 7 Detection and Tracking of moving object using Sobel Operator based Lucas – Kanade Optical Flow based algorithm with image pyramid implemented on MATLAB.

The Optical Flow vectors with image pyramid has more density, leads to overlap of the information and increases computation time.

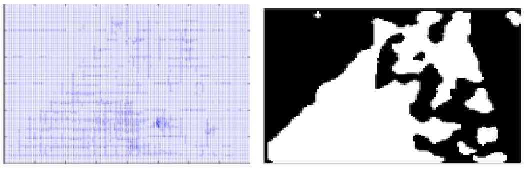
10. MATLAB MPLEMENTATION OF MULTIPLE MOVING OBJECTS DETECTION AND TRACKING USING STATIC CAMERA WITH STATIONARY BACKGROUND

A test case Image sequence with 160x120 pixel resolution has been taken. This has movement with respect to a car with static background and stationary camera. The two image sequences with respect to test case are shown in Figure 8.

Frame (a) Frame (b)

Figure 8 Input sequences using static camera with static background

Optical Flow vectors will be in the direction of movement of the person. The identified movements have been segmented by using Thresholding operation. The segmented movements are tracked using edge based method.The Optical Flow vectors using Sobel based Lucas – Kanade approach without image pyramid is shown in the Figure 9.



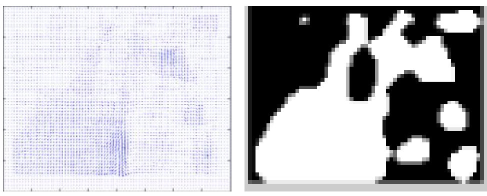
(a) Optical Flow vector (b) Segmentation

(c) Sobel Edge based tracking system

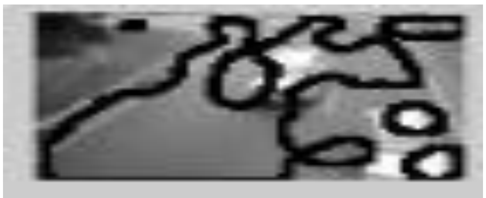
Figure 9 Detection and Tracking of moving object using Sobel Operator based Lucas – Kanade Optical Flow based algorithm without image pyramid implemented on MATLAB.

Figure 9 (a) shows Optical Flow vector of person movement. Figure 9 (b) shows selecting suitable threshold over the Optical Flow vector result. The Edge based information for the input sequence is shown in Figure 9 (c).

The Optical Flow vector using Sobel based Lucas – Kanade approach with image pyramid is shown in the Figure 10.



(a) Optical Flow vector (b) Segmentation



(c) Sobel Edge based tracking system

Figure 10 Detection and Tracking of moving object using Sobel Operator based Lucas – Kanade Optical Flow based algorithm with image pyramid implemented on MATLAB.

The Optical Flow vectors with image pyramid has more density, leads to overlap of the information and increases computation time. The Optical Flow vector result using Sobel operator based Lucas Kanade approach is shown in Figure 10(a) gives the details of cars movement. Figure 10(b) is obtained by selecting suitable threshold value over the Optical Flow result obtained. The extracted edge information with respect to the segmented movement is overlapped over the input sequence and shown in Figure10(c).

XIV. Conclusion

The obtained Optical Flow vectors without image pyramid has more density, which leads to overlap of the information's and increases the computation time. Image pyramidal results overcome these problems and provide smoother vector results with less density, high accuracy and better computation time Image pyramid in low resolution test sequence results in loss of information because the input image size is two small and contains very low resolution data. Hence the application of image pyramid should be selected always based on the input image resolution. The obtained results using Sobel operator based Lucas Kanade approach gives better accuracy in vectors with reduced computation time.

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