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Moving Object Detection, Tracking, Object Counting and Speed Measurement

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Abstract: Detection and tracking of the moving object, people counting and speed measurement are important tasks of many computer vision applications. In this paper, the optical flow system is used for moving object detection. The pyramidal approach of Lucas-Kanade algorithm is used to estimate motion vectors. Because of this technique, there is a reduction in computational burden. Tracking of a moving object is performed using Kalman filter. This technique can track single or multiple moving objects. The number of detected moving objects is counted. People counting useful for the management of the public places. After that, speed measurement is performed. For the traffic management, this technique can be used.

Keywords: Optical flow (O.F.), Lucas-Kanade (L.K.) algorithm, Motion vectors, Kalman filter

I. INTRODUCTION

Moving object detection and tracking is the fundamental step of computer vision systems. Moving object detection involves extraction of the moving object from the image. Moving object detection is widely used in video inspection, monitoring of security at airports, law enforcement and authentication system related applications. Automated systems are helpful in some areas such as airports, railway-stations, shopping malls and university campus to maintain security and management. Computer vision systems are becoming very popular for such automated system. Recognition, motion analysis and image restoration are the basic tasks of computer vision systems [6].

There are different methods used for the moving object detection like background subtraction, mean shift method, continuously adaptive mean shift method, block motion estimation, temporal differencing method, statistical methods, active contour model and O.F. method.

The motion analysis can be used for tracking and to calculate optical flow. Motion vector estimation is the basic step of moving object detection. The different techniques used to obtain O.F. vectors are Gradient method, Horn-Schunck algorithm and L.K. algorithm [7]. The Horn-Schunk algorithm computes optical flow vectors accurately, but because of iterations, it consumes more computational time. L.K. algorithm solves this problem by using least square method [8].

Tracking is widely used in the automated system. A single person cannot observe multiple cameras simultaneously, at that time tracking technique is helpful. There are different methods for moving object tracking such as an adaptive color filter, particle filter, camshaft and Kalman filter. Tracking is useful for security and traffic management applications [1].

The numbers of challenges are present for moving object detection and tracking. Sometimes the camera and object motion are mixed together, due to this, the system is unable to catch the object motion. Occlusion creates a problem in detection and low resolution does the same. Some methods fail to detect whole relevant pixels of the same object and sensitive to instantaneous changes in the external environment while some method needs static background. But the O.F. method provides accurate results in these conditions also [8].

People counting can be used for the management in the areas like shopping mall, traffic. Different techniques of people counter are neural-based analysis and blob analysis. Neural based technique is more complex [8]. Using speed information, we come to know the speed of faster vehicles. This technique can be used for traffic monitoring.

In this paper, using pyramidal approach of L.K. algorithm O.F. vectors are calculated and using that moving object is detected. Optical flow was invented by James in 1940. Using pyramidal technique, there is a reduction in computational burden. The purpose behind the selection of the O.F. algorithm is to get fast and accurate results. For moving object tracking, Kalman filter is used. Then for people counting and speed estimation, the centroid of the people is helpful. The centroid is calculated by using blob analysis.

II. LITERATURE SURVEY

The working of the O.F. method is improved by adding two averaging filters before calculating the velocity field constraint equation [9]. A new technique is based on RGB color space along with edge ratio that allows determining moving object and shadow separately [5]. To improve the accuracy, combination of the kirsch operator and the O.F. method can be used [2]. The kirsch operator is used to compute the contour of the moving object and O.F. method is used to establish motion vector field for moving object.

Sometimes overlapping creates a problem for tracking. To solve this problem, the tracking system uses a combination

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of camshift and Kalman filter algorithm [3]. The block matching algorithm can be used for tracking in which binary component connected method is used to get an individual vehicle count [4].

For small object counting, neural-based system is used where the center positions of small patterns of known shape, size and orientation are located in an input image, in order to be finally counted [10]. The centroid and corner properties can be used to measure crowd density and speed [11].

III. PROPOSED ALGORITHM

For moving object detection, tracking, people counting and speed measurement following steps used. For O.F. motion analysis, which is an important task of moving object detection, frame-to-frame optical flow vectors are calculated.
For this, pyramidal implementation of L.K. algorithm is used. After detection, tracking is performed using Kalman filter. At the same time, blob analysis is used to compute some features which are necessary to maintain continuity of people counting and tracking. Speed measurement is also performed.

IV. MOVING OBJECT DETECTION

The O.F. method computes optical flows for two successive frames. For these frames,

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

Where, I is an image sequence, δx and δy are the displacement vectors for the pixel. Ignoring higher order terms above equation can be written as-

$$IxOx + IyOy = -It \quad (2)$$

Where, Ox and Oy are O.F. vector components and Ix, Iy, It are the derivatives of image at x,y,t.
For the detection, we have used L.K. algorithm. The L_K obtains following equation using least square method.

$$\bar{V} = -(A^T A)^{-1} A^T B \quad (3)$$

Where, B = [I_1,I_2,…,I_n]
Where,

$$A^T A = \begin{bmatrix} \sum_{i=1}^{n} {I_{xi}}^2 & \sum_{i=1}^{n} I_{xi} I_{yi} \\ \sum_{i=1}^{n} I_{xi} I_{yi} & \sum_{i=1}^{n} {I_{yi}}^2 \end{bmatrix}$$

I_x , I_y represents the derivative of the image in x and y direction respectively. Above matrix must be an invertible matrix. Two more parameters are calculated. Those parameters are- 1) A=multiplication of the image derivative in x-direction with the difference of next frame and current frame and 2) B=multiplication of the image derivative in y-direction

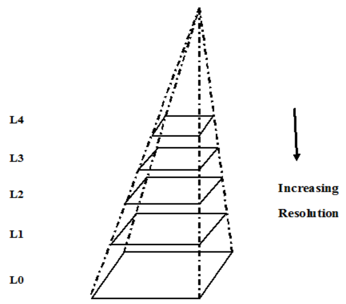

Fig.1:Pyramidal implementation

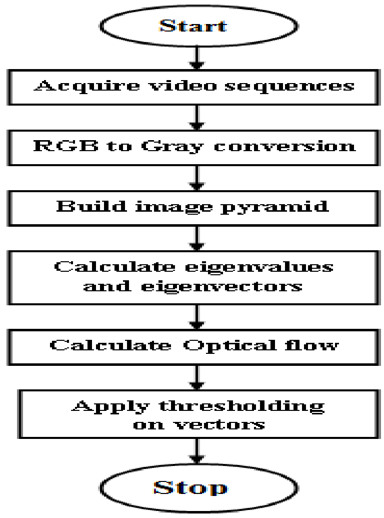

Fig.2:Agorithm of moving object detection

with the difference of next frame and the current frame. These parameters are necessary while finalizing the optical flow vector magnitude.
Pyramidal concept is used to create level in an image. The image represented at initial step is the original image. At step 0 (initial step), image size is same as the original image. At first step, image size is reduced by 2. Basically, hight and width of the original image are 2 raise to n times of the image at level n.
If an image is of size 640 X 360, then sizes of the images at each step will be 320 X 180, 160 X 90, 80 X 45 and 40 X 23 at step 1, step 2 ,step 3 and step 4 respectively.
The need of the pyramidal system for optical flow vectors is that the total number of pyramids has to define initially. Before starting the process, motion vector values are initialized to zero. Then start the process at first step. Here, partial derivatives of intensity of the image I are calculated which are Ix, Iy and It. Then, O.F. vectors Vx and Vy are updated using pyramidal based L.K. algorithm. Then these values are used as an input to calculate the next motion vectors. If the computed step is less than the total number of steps, which is defined initially, the whole process is repeated otherwise stop the process.
The concept of eigenvalues and eigenvectors is used to calculate the motion vectors. The concept of eigenvectors used here to calculate the motion vector pixel-wise. At the start, at step 4, by using the equations, we get the slice numbers. Using this information, we can calculate the

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eigenvalues and from them eigenvectors. And then using the threshold value, we can finalize the motion vector for step 4. These values are used to calculate the motion vectors at step 3. Do this process four times, which is equal to number of pyramid level.

Figure 2 shows the algorithm of moving object detection. If the images are color images, then RGB to gray conversion is necessary. To design a pyramid, convolution along with bilateral filtering is used. Because after image acquisition, the next step is image down sampling. By deleting a certain number of rows and columns will make a drastic variation in the image, which will degrade the quality of the image. To avoid such disturbances, convolution is used here. Bilateral filter has property of-edge preserving smoothing.

Then the O.F. calculation is done using pyramidal L.K. which has described earlier. To finalize the magnitude of O.F. vectors, the comparison is performed between two eigenvalues. A higher eigenvalue indicates the maximum amount of the variance. If $\lambda 1$ is higher than $\lambda 2$, then following conditions are checked.

i. if $\lambda 1 < 0.001$ then
$Ox = Oy = 0$

ii. if $\lambda 1 > 100 * \lambda 2$ then
$n = A * Ox1$;
$Ox = n*Ox1/\lambda 1$ and $Oy = n*Oy1/\lambda 1$

iii. Otherwise,
$n1=A*Ox1+B*Oy1$,
$n2=A*Ox2+B*Oy2$
$Ox=n1 * Ox1/\lambda 1 + n2 * Ox2/\lambda 2$
$Oy=n1 * Oy1/\lambda 1 + n2 * Oy2/\lambda 2$ (4)

The first condition shows that the motion is too small, that motion may represent the presence of noise. To skip noise interference, flow vector magnitude initialized to zero. The second condition shows that $\lambda 1$ is too large than $\lambda 2$, this means that the point is on the edge and method will suffer from aperture problem. To avoid this problem, the magnitude of the flow vectors is changed using variable n.

After finalizing the magnitude of the eigenvectors at fourth step, the expansion of the result takes place. It is necessary, as the eigenvectors produced at fourth step are used at the third step.

V. PEOPLE COUNTING

Blob analysis is very much helpful for people counting, tracking and speed calculation. The blob is the region of interest in a binary image. Blob analysis provides statistics of the interested region such as centroid and bounding box of the blob. Blob analysis scans the full image and based on the given condition, it provides the information.

Figure 3 shows the algorithm for object counting. At the start, we have initialized some variables which can store the processed values such as Object_count, frame number, centroid.

We have mentioned the minimum blob area in pixels for blob analysis. This information helps to extract the specified region from the background. Using that information, blob analysis provides the centroid of the blob and the co-ordinates of the bounding box around the blob if any object is present in the frame. After detection of an object, the corresponding object number, frame number and its centroid value are stored.

After storing the frame number and corresponding centroid values, assignment step starts. After getting the centroid values in the current frame, Kalman filter is used to predict the centroid coordinates. The Kalman filter works as a predictor. For the next frame, Euclidean distance is calculated between predicted centroid value and the detected centroid value. At the same time, the number of detections is stored.

One scalar value (S) is used for the comparison. This comparison is performed using assignDetectiontoTracks function. The calculated Euclidean distance and S are the inputs of assignDetectiontoTracks function. The outputs of this function are assignments, unassignedTracks and unassignedDetections.

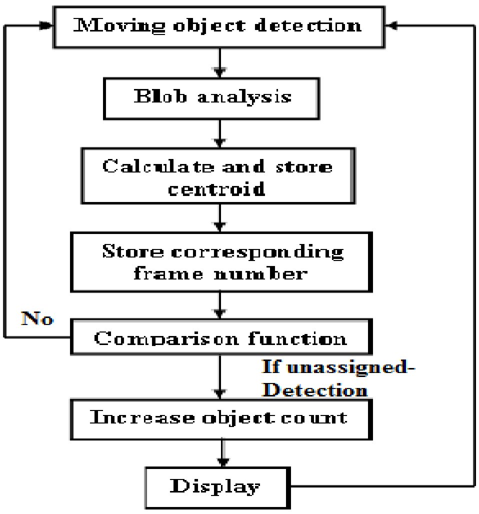

Fig.3:Algorithm of object counting

Assignment consists of a number of objects and corresponding tracks, detection values present in that frame. The value of the unassignedDetections shows the detection for which no track is assigned. This value helps us to create new object as it has no previous information. At that time, Object_count is increased by 1.

The unassignedTracks information is useful for tracking.

In the result of people counting, we get the frame number, corresponding object number and centroid values.

VI. TRACKING AND SPEED MEASUREMENT

This part of the paper consists of moving object tracking and speed measurement. For the moving object tracking, Kalman filter is used. Euclidean distance between the centroid position of the object for successive frames, helps to estimate the speed.

A)Those variables are used to store the number of the track, box number of the object, totalVisiblecount [the number of frames for which object is visible] and consecutiveInvisiblecount [the number of frames for which object was invisible]. The totalVisiblecount helps to

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reduce the short-lived tracks. When the totalVisiblecount of the detected object crosses the mentioned threshold value of frames, then only tracking results are shown. The consecutiveInvisiblecount helps to remove the track information of the detected object. This information is removed when the object is invisible for mentioned threshold value. Following figure shows the algorithm for tracking and speed estimation.

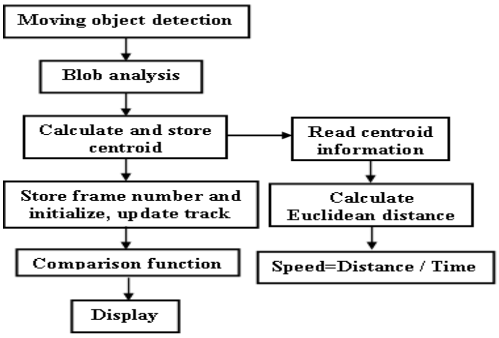

Fig.4: Algorithm for tracking and speed measurement

The outputs of the assignDetectiontoTracks function– unassignedTracks , assignedTracks used for tracking. The value of the unassignedTracks shows the tracks which are not related to any detection. By using unassignedTracks information, consecutiveInvisiblecount variable is increamented by 1. The assignedTracks value helps to maintain continuity in tracking by updating totalVisiblecount and bounding box. If consecutiveInvisiblecount is grater than the mentioned threshold value or if totalVisiblecount is less than mentioned threshold value, then corresponding tracking data is deleted.

B) We are using avi file format for the project. The standard frame rate of avi is 15 frames per second. Therefore, while calculating the speed we used centroid values of 15 frames. By using these 15 values, we calculated the distance traveled by that person.

$$\text{Distance}=\sqrt{(x_{i+1}-x_i)^2+(y_{i+1}-y_i)^2} \quad (5)$$

The calculated distance unit is in millimeters. Dividing it by 1000, we can convert it into meters. By dividing that value by 15, we will get the speed of the person in meters per second.

Distance of first person = 0.081842 meters
Speed = 0.005456 meters/second

After reading the complete video, we will display the total number of objects in the full video.

The output for the first video is –
Total objects =7

VII. RESULTS

We have used two videos of avi format. For the detection, we have used two successive frames – current frame and next frame. Results of tracking, people counting are related to current frame. For speed measurement we have used 15 frames.

A) Pedestrian video :

Figure 5 shows the frame number 13 and 14.

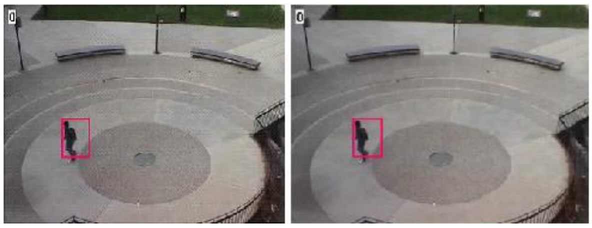
Fig.5: Extracted frames from input video

Following figure shows the detection and tracking results of the moving object.

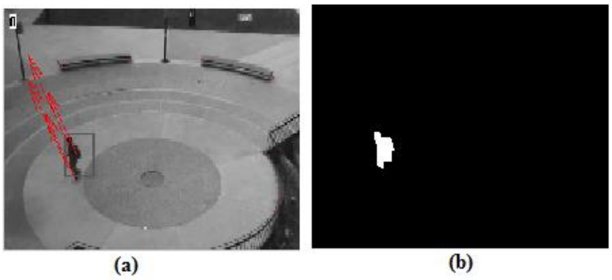

Fig.6: a) Object Detection b) Tracking


Fig.7: Object counting

Above figure shows the object counting over frame number 13.
FrameNumber=13 and Detected objects in the frame =1 ;
Object Number=1, centroid_x=77.949896,
centroid_y =146.098121
By using centroid values of the moving object from frame 13 to 28, we have calculated the speed.

Speed=0.024978 meters/second

B) Vehicle video :

Figure 8 shows the frame number 91 and 92.


Fig.8: Extracted frames from input video

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Following figure shows the detection of the moving object.

Fig.9: Object Detection

Fig.10 shows the moving object tracking results.

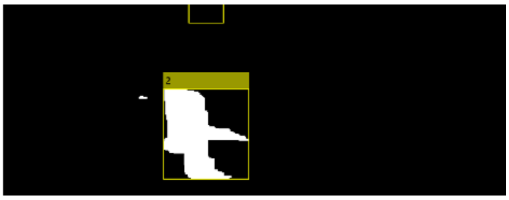

Fig.10: Tracking

Fig.11: Object counting

Above figure shows the object counting over frame number 91.
FrameNumber=91 and Detected objects in the frame =1 ;
Object Number=1, centroid_x=560.449473,
centroid_y =167.774523
By using centroid values of the moving object from frame 91 to 106, we have calculated the speed.

Speed=0.001532 meters/second

VIII. CONCLUSION

We have implemented a system for moving object detection, tracking, people counting and speed measurement. Optical flow method is tested on different videos to successfully detect moving objects – pedestrians as well as vehicles. Number of moving objects are also counted correctly, provided that there is no overlapping or occlusion of objects. The results are found to be inaccurate due to the presence of shadow, also. Calculation of speed of objects is carried out at the last step. But, these results are not very accurate as speed also dependant on camera parameters, which are not available.

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