Moving object tracking using optical flow and motion vector estimation

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Moving Object Tracking using Optical Flow and Motion Vector Estimation

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Abstract— **Moving object detection and tracking is an evolving research field due to its wide applications in traffic surveillance, 3D reconstruction, motion analysis (human and non-human), activity recognition, medical imaging etc. However real time object tracking is a challenging task due to dynamic tacking environment and different limiting parameters like view point, anthropometric variation, dimensions of an object, cluttered background, camera motions, occlusion etc. In this paper, we have developed new object detection and tracking algorithm which makes use of optical flow in conjunction with motion vector estimation for object detection and tracking in a sequence of frames. The optical flow gives valuable information about the object movement even if no quantitative parameters are computed. The motion vector estimation technique can provide an estimation of object position from consecutive frames which increases the accuracy of this algorithm and helps to provide robust result irrespective of image blur and cluttered background. The use of median filter with this algorithm makes it more robust in the presence of noise. The developed algorithm is applied to wide range of standard and real time datasets with different illumination (indoor and outdoor), object speed etc. The obtained results indicates that the developed algorithm over performs over conventional methods and state of art methods of object tracking.**

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Keywords— **Object Tracking, Optical Flow, Median Filter, Motion Vector.**

I. INTRODUCTION

The real time object tracking is one of the important issues in computer vision; it plays a vital role in various lines of research such as motion estimation, human and nonhuman activity recognition, 3D representation and 3D reconstruction, vehicle navigation, etc. The object tracking is more popular in automated surveillance applications because in surveillance systems single human operator cannot monitor the area under surveillance if number of cameras increases. In medical diagnosis, sometimes the physician cannot analyse video captured by the instrument; in such critical cases object detection and tracking system works more efficiently than human being.

The object tracking systems can track single or multiple moving objects in a dynamic environment. Tracking systems not only helps in tracking but it is useful in analysing the object behaviour. Due to this, it is popular choice in fighting against terrorism, antitheft systems, traffic management systems etc. Basically, real time object tracking involves the different stages like Object Detection, Object Classification (segmentation) and Object Tracking as shown in figure 1

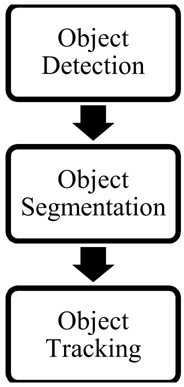


Fig. 1 Stages in object tracking

In the proposed system, optical flow is used in object detection stage. The optical flow provides accurate object detection over other methods like background subtraction and many more. The optical does not provide in motion trajectory instead it provides the information about object direction and movement in the form of vectors. Motion vectors estimation technique is used in object tracking stage. It eliminates the shortcomings in tracking due to conventional optical flow as mentioned in [6].

Since last few decades, many researchers have demonstrated the object detection and tracking algorithms but they have their own limitations. The object tracking can be done by using background cues [5], using Kalman filter and optical flow [3], using particle filter [4], using Lucas and Kanade optical flow [6]. However each method has its own limitations and developing robust tracker is challenging.

The algorithm described in [3] uses Kalman filter and optical flow. Here object detection is done by using optical flow and tracking is done by Kalman filter. The Kalman filter is linear approach which works on two main stages prediction and update. The tracker using Kalman filter is good in detecting moving object in similar background but it is not able to track low resolution object and it cannot track the objects with variation in speed of movement.

The algorithm described in [4] uses particle filter and optical flow for detection and tracking of object. The particle filter uses set of samples of detected object for object tracking. It is advanced version predict and update model. This algorithm requires large computation time. The particle filter cannot is not efficient tool for tracking in multiple moving object environment and low resolution input.

The algorithm described in [5] uses background cues for object tracking. Traditionally background cues are used as one of the important feature for object detection and tracking. Here the background confidence map is computed using target and reference cues. However this algorithm is sensitive to sudden illumination changes, camera motion, and occlusion.

Another novel approach is described in [6], which uses optical flow field vectors for the tracking of moving objects in traffic surveillance. The described algorithm uses blob analysis for object segmentation. But this algorithm is inefficient for multiple object tracking and sensitive to camera motion.

After reviewing the published research on object tracking it is found that object detection and tracking is a complex task due to dynamic tracking parameters like illumination variation, object speed variation, occlusion, scale variation, stationary objects, camera motion etc. Extending the previous work in optical flow based object tracker [6]; we have proposed robust object detection and tracking algorithm which is in fact a combination of two well-known computer vision techniques namely optical flow and motion vectors estimation. This system is insensitive to the many limiting parameters in object tracking like speed variation, scale variation, occlusion, stationary objects and multiple objects.

This paper is organized as follows. Section II describes proposed method. Section III describes experiments and results. And finally conclusion is drawn on the basis of those results in Section IV.

II. PROPOSED SYSTEM

The main objective of the object tracking is to trace the moving object in the video. However video is nothing but the sequence of consecutive frames, hence the object tracking algorithm should map the object from these successive frames. The figure 2 shows frame work of our proposed system. Before any operation initially the input video is captured by a camera. The effects of sudden environment intensity changes can be compensated by computing the mean of every frame on gray-scale format. The working on gray scale format reduces computation time and memory requirement.

A. Object detection using Optical flow

The principal objective of optical flow estimation is to separate the moving foreground objects from the background and generate optical flow field vector for the moving object. Optical flow calculates the motion between two frames which are taken at different time intervals for every pixel in the frame. It is discriminative method which pose object to be tracked is a binary classification problem in a local image region. Optical flow or optic flow is very popular techniques in the tracking of moving objects. This method is capable of providing complete movement information and detects the moving object from the background better than the other methods.[9]However this method is useful in object tracking when the captured frames are filtered by the noise filter. [1] [2]

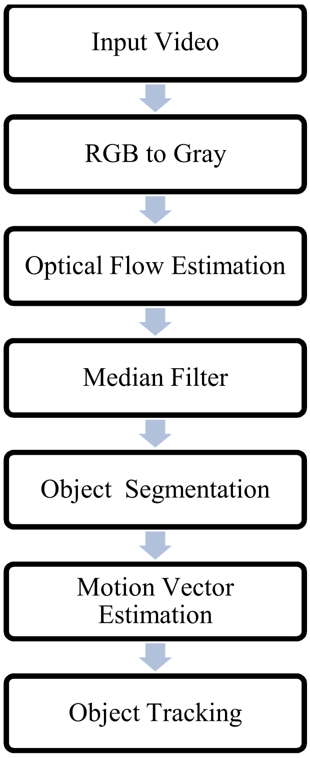


Fig. 2 Framework of Proposed Algorithm

Consider an object is displaced by a distance δx in the x-direction and δy in the y-direction in time δt. The brightness of background is assumed to remain constant. We will derive an equation that relates the change in image brightness at a point to the motion of the brightness pattern. Let the image brightness at the point **(x,** y) in the image plane at time r be denoted by I**(x,** y, t) [8]. Now consider what happens when the pattern moves. The brightness of a particular point in the pattern is constant, so that $\frac{di}{dt} = 0$

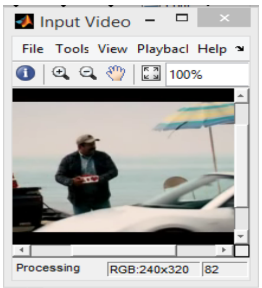
The following expression is a Taylor series expression which represents 2D dynamic brightness function of I (x, y, t),By using Taylor series expansion in the right side of expression and further simplification (1) we can write

$$I_x . v_x + I_y . v_y = -I_t \qquad (2)$$

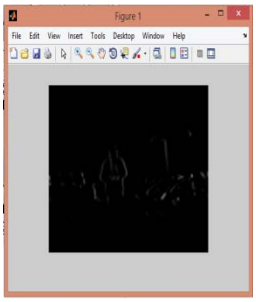
From equation (2), we can write

$$\nabla \mathrm{I} . \vec{v} = -I_t \qquad (3)$$

Here ∇I spatial gradient of intensity and $\vec{v}$ is optical flow field vector. The input frame and optical flow field vectors are shown in figure 3.



(a) Input Frame



(b) Optical Flow Field Vectors

Fig. 3 Optical Flow of input frame

There are various methods available in optical flow estimation. Among these, phase based methods provides good results but they are complex to implement. Hence differential methods like Horn and Schunk, Lucas and Kanade are used. These methods are mean between computational complexity and cost. The differential methods provide robust results in dynamic environments. [9] The Lucas and Kanade method also called local flow estimation. In this method, the problem of global error propagation can be avoided. The local flow estimation is based on same brightness and smoothness assumptions. Each video frame is divided in small patches where these assumptions can be applied. The Lucas and Kanade method is more accurate and requires less computation time. [9]

B. Object Segmentation

The captured frames are often corrupted by noise. To eliminate the effect of noise the captured frames are filtered by using Median filter. The median filter is a averaging spatial filter which provides efficient noise filtering over different types of noises.

After filtering operation, the optical flow field vectors are given to the thresholding function to eliminate the unwanted objects from the detected objects. The morphological operations are performed on the thresholded frames. The morphological close operation removes holes generated in the processed frames during thresholding. The tracking window is drawn around the objects or region of interest using blob analysis.

C. Object Tracking Using Motion Vector Estimation

The accurate motion estimation is an essential part of moving object tracking. In most of the videos the frame to frame variations are very small; many times the significant part of the frame remains same. This property of videos is useful in determining the movement of object in the sequence of frames. It provides two-dimensional vector of the frame. These vectors can be used for the prediction of motion by comparing the two dimensional vectors of two successive frames. [10] The motion vector estimation technique operates on macro blocks of the reference frame. The frame is divided in macro blocks. After dividing the image in blocks the area of interest (Target Frame) is compared with reference area (Reference Frame).

The figure 4 shows the procedure for motion vector estimation. Any selected macro block from reference frame (R) is compared with selected macro block from the target frame. The Mean Absolute Difference (MAD) between those two frames is calculated by using expression

$$MAD = \frac{1}{N}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1} T(x+k+i, y+l+j) - R(x+k, y+l) \tag{4}$$

Where, N - Size of the macro block

k and l - indices for pixels in the macro block,

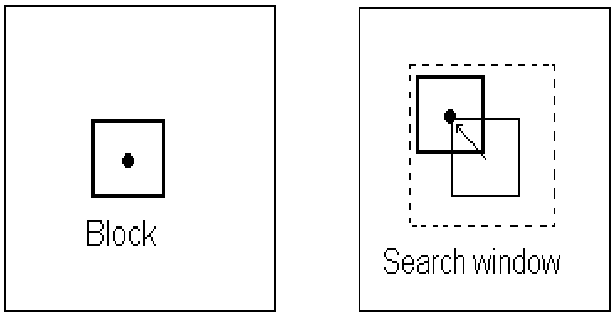
i and j - horizontal and vertical displacements,

$T(x + k + i, y + l + j)$ - pixels in macro block of Target frame,

$R(x + k, y + l)$ - pixels in macro block in Reference frame.

The macro block provides minimum value of MAD will be best matched block. This process is shown in the figure.3. The frame k is a reference frame and the frame k+1 is the frame in which there is movement of an object. The use motion vector estimation makes this algorithm more robust in presence multiple moving objects and also while working at low resolution input sequences. The limitations of optical flow estimation like sensitivity to lighting changes can be eliminated by using this technique. There are various methods of motion vector estimation:-

- Sequential search
- Hierarchical search
- Logarithmic search
- Block Matching



(a) Reference Frame (R) (b) Target Frame (C)

Fig.4 Motion estimation using motion vectors

Among these methods the sequential search (also called as dense search) provides good accuracy; but computational time and complexity more. Hence the hierarchical method provides accurate motion vector with less computational cost.[10]

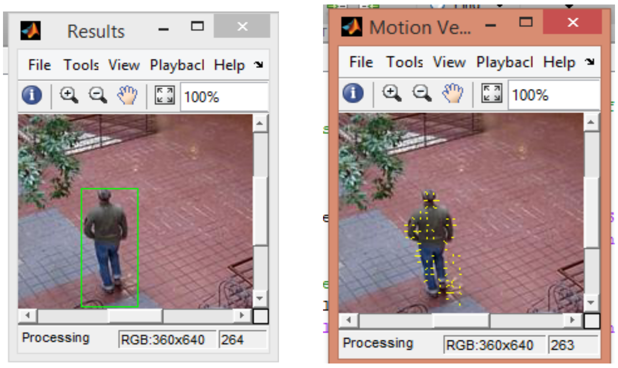
III. EXPERIMENTS AND RESULTS

This section represents experimental results of object detection and tracking system for standard data sets of traffic closed-circuit TV (CCTV) and real time videos to evaluate our system. The implemented system is tested by using input videos with different view point, object size and speed of movement of object in each case. The results of proposed tracking system are compared with the results of algorithm explained in [6].

Before applying optical flow estimation on frames, the captured frame is filtered using median filter which removes the speckle noise present in the frame. Depends on methodology steps, the motion vector estimation and proper optical flow estimation (Lucas and Kanade) has been applied.

Experiment 1:For Single Object Tracking

The input video contains single moving object is with constant speed of movement. This input is given to our proposed tracker and tracker explained in [6]. Figure 5 (a) shows the results of optical flow tracker in [6] and figure 5 (b) shows the results of proposed tracker



(a) Optical flow tracker (b) Proposed tracker

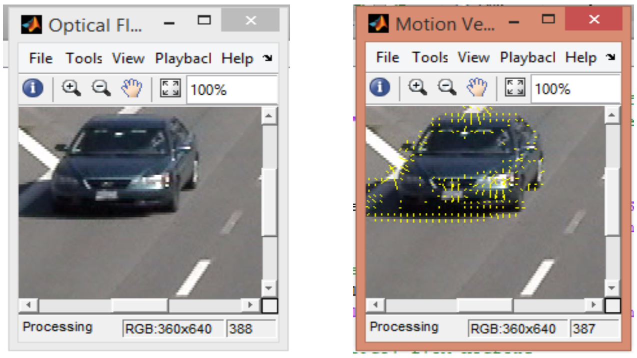
Figure.5 Results for single object tracking

Results: The results presented in figure 5(a) and 5(b) indicates the tracking of moving objects by using two different approaches. It is observed that both trackers have tracked single moving object from input successfully without any error in it.

Experiment 2: For Object Tracking with Speed Variations

Here the traffic video with speed variations is given to both trackers. The moving car in the input video changes its speed suddenly when it enters in the range of camera. Figure 6 (a) shows the results of optical flow tracker in [6] and figure 6 (b) shows the results of proposed tracker.

Results: The results presented in figure 6(a) and 6(b) indicates the tracking of moving objects by using two different approaches. It is observed that proposed tracker have tracked the moving object from input successfully without any error in it. But the optical flow tracker in [6] cannot detect the speed variations.

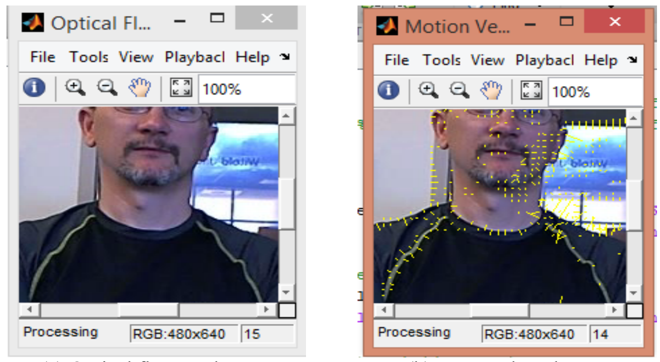


(a) Optical flow tracker (b) Proposed tracker

Figure.6 Results for Object Tracking with Speed Variations

Experiments 3: For Scale Variations

In this experiment both algorithms are tested for scale variations. When the camera focus changes the size of object appears to be larger in size. The results for input video with scale variations are represented in figure 7 (a) and 7 (b).



(a) Optical flow tracker (b) Proposed tracker

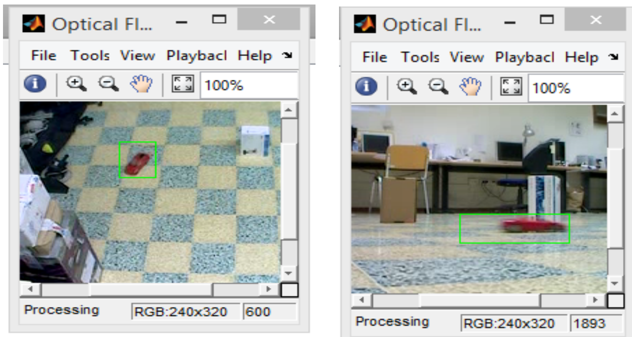
Figure.7 Results for Object Tracking with Speed Variations

Results: The results presented in figure 7(a) and 7(b) shows the response of tracker for input video with scale variation. It is observed that proposed tracker can track the moving object irrespective of scale variations successfully whereas optical flow tracker in [] fails in this case.

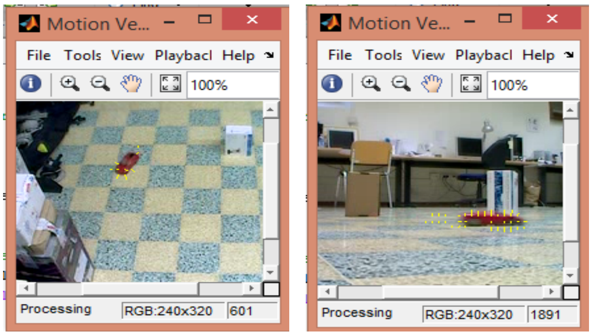
Experiment 4: For View Point Variation

The view point variation may cause the changes in the output of tracker. Here we have tested both tracking algorithms for input sequences with different viewpoints. The results of both trackers are shown in figure 8 (a) and 8 (b).

Results: The performance of optical flow tracker and proposed tracker good for view point variations. Both can detect the moving objects successfully irrespective of view point variations.



(a) Results of optical Flow tracker for view point variation



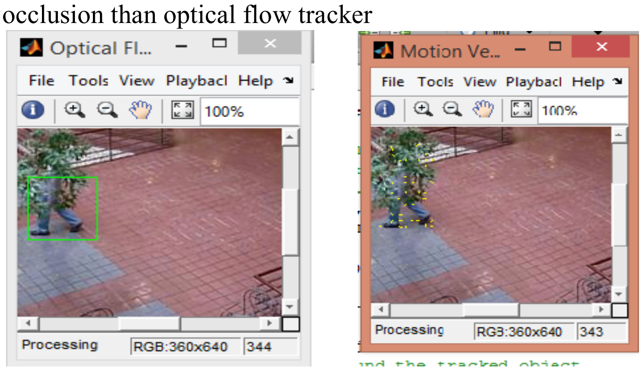
(b) Results of proposed tracker for view point variation

Figure.8 Results for Object Tracking with view point variations

Experiment 5: For Occlusion

The occlusion is the most challenging problem while designing the object detection and tracking system. Many tracker fails due to occlusion in the object to be tracked. The tracking systems using Kalman filter cannot predict the accurate location of an object in the further frames of the video. The input sequence with partially occluded object is given as input to both trackers. The results are represented in figure 9(a) and 9(b).

Results: The results in figure 9 (a) and 9(b) shows that both trackers are capable detecting and tracking a partially occluded object. But our proposed tracker can handle more occlusion than optical flow tracker

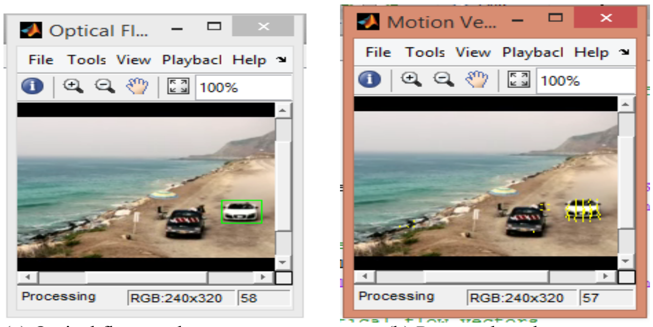


(a) Optical flow tracker (b) Proposed tracker

Figure.9 Results for Object Tracking with partial occlusion

Experiment 6: For Input with moving and stationary objects

Another important issue in object tracking is detection and tracking of moving object from the video contains both stationary and moving objects. The input video with stationary and moving objects is given to both trackers. The results of this experiment are shown in figure 10 (a) and 10 (b).



(a) Optical flow tracker (b) Proposed tracker

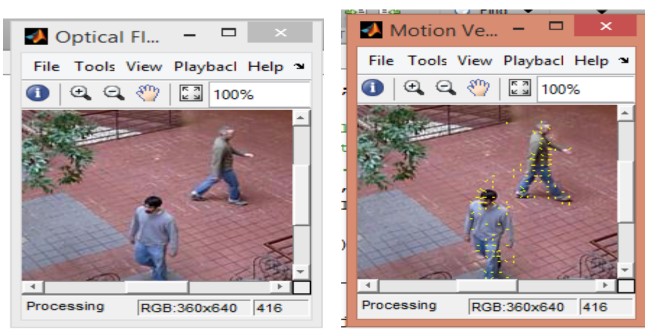
Figure.10 Results for moving and stationary objects

Results: The performance of optical flow tracker and proposed tracker are shown in figure 10 (a) and 10 (b). The results indicate that the optical flow tracker can detect and track moving object from input video with moving and stationary objects. But the accuracy is less because it cannot detect the small movement of a person standing nearer to the stationary black car or cars moving slowly behind the tracked car. Whereas the proposed tracker can detect and track all moving objects from input video irrespective speed and size.

Experiment 7:- For Multiple Object Tracking

Multiple objects tracking usually faces three challenges: object witch during overlapping, new object initialization and recognition of re-entering objects. In this experiment, the performance of object tracking system is tested by using input video with multiple moving objects. The results of both tracking algorithms are shown in figure 11.

Results: The results shown in figure 11 indicate multiple object tracking. The input video with multiple moving objects is given to system under evaluation. The optical flow tracker cannot detect and track multiple moving objects accurately. However as shown in figure 11 (b), the proposed tracker can detect multiple moving objects successfully.



(a) Optical flow tracker (b) Proposed tracker

Figure.11 Results for Multiple Objects Tracking

Experiment 7: Accuracy of the tracker

The accuracy of the tracker is another performance measure in object tracking. The accuracy of the object detection and tracking system can be computed by using following expression.

$$\text{Accuracy} = \frac{\text{Number of moving objects detected by the tracker}}{\text{Total no of moving objects presemt in input}}$$

Results: The both tracking algorithms are tested with different over multiple input videos with different types of scenarios to evaluate their accuracy. The table shown below indicates the accuracy of proposed tracker and optical flow tracker in different input scenes.

TABLE I

ACCURACY OF TRACKER IN PERCENTAGE

Parameter	Optical Flow Tracker in [6]	Proposed Tracker
Single Human	90	100
Speed Variation	10	90
Scale Variation	10	90
View point variation	90	90
Partial occlusion	90	90
Stationary objects	70	90
Multiple objects	20	90

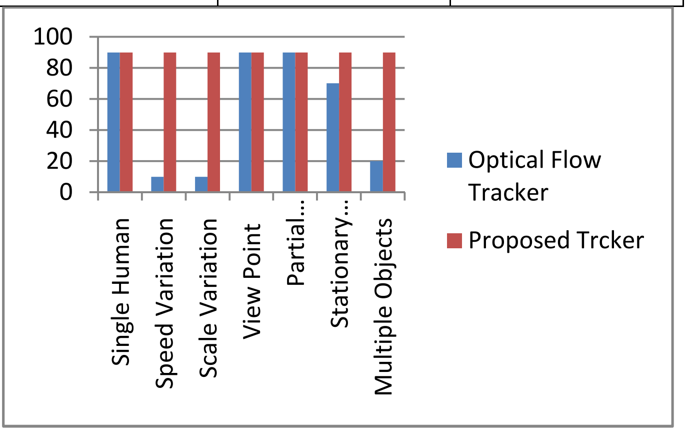


Chart1. Accuracy of tracker in percentage

IV. CONCLUSION

The presented tracking system combines the optical flow and motion vector estimation for moving object detection and tracking. This proposed algorithm is capable of detecting and tracking multiple moving objects in the video. The combination of optical flow and motion vector estimation gives accurate and robust results over different types of real time and standard inputs as shown in the section. The figure7.(c) and figure 7.(d) proves the accuracy and robustness the proposed algorithm. As the conventional optical flow tracker is not capable of detecting the moving human nearer to black car having very small size and small movement. The conventional tracker is also not capable of detecting the moving cars at longer distance from the camera. The accuracy of proposed tracker is also proved in figure.5.(c) and figure 5.(d) as theproposed tracker detects the human with small movement and precisely the moving shadow of the same person as a moving object. Thus the motion vector based approach to optical flow estimation is robust and it over performs in the situations like view point, anthropometric variations, object movement, distance from the camera etc over the conventional and state-of-art techniques.

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