# Optical Flow Based Object Movement Tracking

**A. Balasundaram, S. Ashok Kumar, S. Magesh Kumar**

*Abstract: Object detection and tracking is one of the key tasks performed in video surveillance. The objects present in the area under surveillance is studied and analyzed with reference to the context. This plays a pivotal role in detecting and predicting anomalies based on the behavioral traits of objects observed under the surveillance region. Optical flow is one of the computer vision based approaches that is used for tracking the precise movement of objects. Several optical flow algorithms have been used to track and study the movement of objects. This work is motivated towards carrying out a thorough study different optical flow techniques and comparing the features of different optical flow approaches and implementing them for real time detection and tracking of objects in real time environment.*

*Keywords: Optical Flow, Object Detection, Object Tracking, Anomaly detection, Vision Based Object Tracking*

## I. INTRODUCTION

Video surveillance is one of the evolving and upcoming areas which have high degree of social relevance in current age. One of the primary tasks accomplished during video surveillance is object detection and tracking. It is highly significant to identify several objects prevailing in the area under surveillance. This is accomplished using different object detection techniques. Once the objects are detected, it is important to study the behavior of objects and track the movement of objects under surveillance. Several real time object detection and tracking techniques are available for effective object tracking. These algorithms have been modeled based on certain attributes of objects such as edges, flow of movement, texture of objects etc. Figure 1 shows the taxonomy of model based object tracking approaches. The tracking objects can be broadly classified into recursive tracking that involves repeated tracking of object across each frame and tracking of object based on object detection.
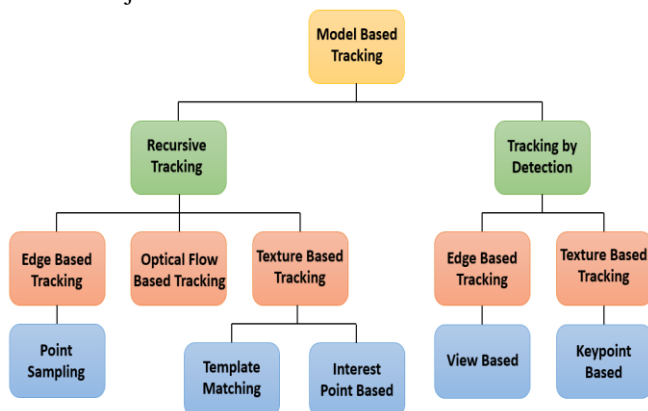


**Figure 1: Taxonomy of Model based Object Tracking approaches**

**A. Balasundaram,** Assistant Professor, Department of CSE, Saveetha School of Engineering, email: balasundaram2682@gmail.com
**S. Ashok Kumar,** Assistant Professor, Department of CSE, Saveetha School of Engineering, email: ashokkumars.sse@saveetha.com
**S. Magesh Kumar,** Associate Professor, Department of CSE, Saveetha School of Engineering, email: mmce6450@gmail.com

This work is focused towards studying and understanding the different methods of tracking objects using optical flow. Optical flow is one of the efficient approaches to track the movement of objects. Optical flow studies the relative motion of objects across different frame sequences based on the velocity of movement of objects and illumination changes. Optical flow techniques can be classified into two types namely sparse optical flow techniques and dense optical flow techniques. Sparse optical flow techniques select a significant subset of interesting features of objects under study such as corners, edges etc and based on these select set of features the tracking is carried out. Some examples of sparse optical flow algorithms are Lucas-Kanade method, Horn-Schunck method, Buxton-Buxton method and so on.

While sparse optical flow is focused towards using selected features for tracking using optical flow, dense optical flow is focused towards computing the optical flow for each and every pixel present in a video frame. Farneback optical flow is a typical example of dense optical flow method. Figure 2 shows the taxonomy of different optical flow methods. Table 1 performs a detailed comparison of the various features of sparse and dense optical flow methods. It can be seen from the comparison that though dense optical flow incurs more processing time than sparse optical flow, dense optical flow yields better results in terms of higher accuracy and density.
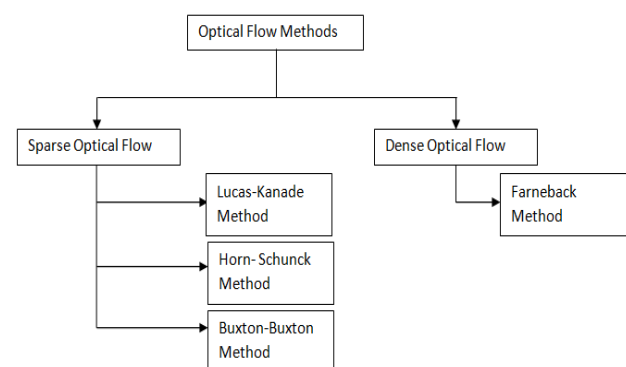


**Figure 2: Taxonomy of different Optical flow methods**

**Table 1: Comparison of Sparse and Optical Flow Algorithms**

| S. No | Feature | Sparse Optical Flow | Dense Optical Flow |
|---|---|---|---|
| 1. | Feature Set | Minimal | Vast |
| 2. | Features | Edges, corners, size etc | Complete image |

| 3. | Time Complexity | Less | More |
|---|---|---|---|
| 4. | Space Complexity | Less | High |
| 5. | Execution Time | Lesser Execution Time | Greater Execution Time |
| 6. | Accuracy | Less Accurate | Highly accurate |
| 7. | Depth of analysis | Lesser depth | Greater depth |

Optical flow is best suited for tacking the motion of objects in free space. The movement of brightness patterns observed defines the direction of movement of the object under study. Figure 3 shows the optical flow vector direction of a ball that rotates about its vertical axis in clockwise direction.
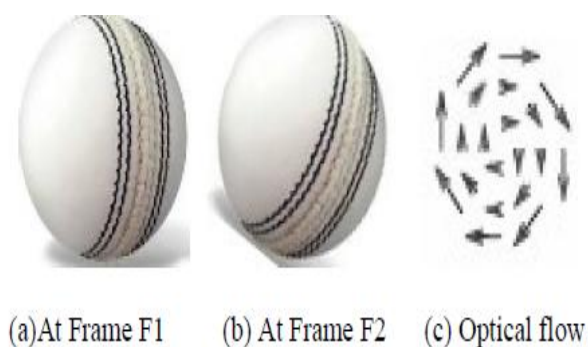


Figure 3: Optical flow for a ball rotating about its vertical axis in clockwise direction

It can be seen from the above figure that the ball has rotated about its vertical axis in clockwise direction from frame 1 to frame 2 and the corresponding optical flow vector direction is shown in figure 3.c. This work is focused towards developing an optical flow based object tracking mechanism in real time video sequences.

## II. LITERATURE REVIEW

Several works have been carried out towards studying the different means of applying optical flow towards tracking of different objects across several application areas. Optical flow analysis is used to study the behavior of objects in sonar images as discussed by D.M. Lane et al [1]. Optical flow finds extensive use in transport system analysis as illustrated in the work carried out by Chung-Wei Liang et al [2] where the system classifies the moving objects into four classes namely cars, pedestrian, bicycles and motor cycles. The movement of objects can be easily tracked using optical flow by the variations observed in velocity and location description as illustrated in [3] by A.G.Bors et al. The real challenge in optical flow will be in estimating the location motion of objects and several works like Tobias Senst et al [4] have been carried out on this front to efficiently gauge the movement of objects locally. Also, several works related to the performance of density based

optical flow has been performed like Juan David Adarve et al [5].

Optical flow finds greater use in vehicle motion tracking to judge if proper lane is followed and also optical flow is used as a potential concept to make lane changing decisions as discussed by Javier Diaz Alonso et al [6]. Optical flow based spatio temporal analysis discussed by Hidetomo Sakaino et al [7] has also gained significant ground. Another approach related to optical flow analysis is contour based optical analysis as discussed by Kanagamalliga et al in [8]. Optical flow has also been combined with other mathematical models such as Markov models as discussed in [9] to achieve better results with respect to better detection and tracking. Optical flow can also be used to track the movement of persons and animals as discussed in [10].

It can be seen from the above works that the need and significance of optical flow in determining the movement of objects and tracking their trajectories is prominent. This work is motivated towards understanding the different methods of using optical flow and develops a system that automatically adjusts itself to optical flow changes.

## III. PROPOSED SYSTEM:

The proposed system is developed by using four existing algorithms for optical flow namely Lucas-Kanade algorithm, Horn-Schunck algorithm, Buxton-Buxton method and Farneback method. The proposed system is smartly designed to gauge the conditions and automatically perform a switch between the algorithms according to the conditions. The block diagram of the proposed system is shown in figure 4.
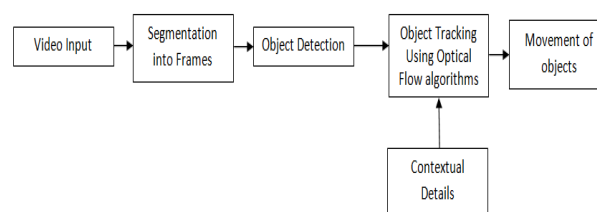


Figure 4: Block Diagram of Optical Flow based Movement Tracking System

As seen from figure 4, the input video is segmented into video frame sequences and individual objects present in each frame are detected. Based on the different types of contextual inputs the most suitable optical flow algorithm is selected for tracking the flow of object. The nature of optical flow vector depends on the type of algorithm selected. Table 2 shows the comparison of Lucas-Kanade algorithm and Horn-Schunck algorithm as discussed in [11] and [12].

**Table 2: Comparsion of Lucas-Kanade Algorithm and Horn-Schunck Algorithm**

| S.No | Aspect of Comparison | Lucas-Kanade Algorithm | Horn-Schunck Algorithm |
|---|---|---|---|
| 1. | Coverage | Local space | Global space |
| 2. | Optical flow method | Differential | Differential |
| 3. | Methodology | A small sliding window is moved across to determine the optical flow directions. | Global energy function is computed and this is minimized using differentiation |
| 4. | Sensitivity to noise | This method is less sensitive to noise as this is a local method. | More sensitive to noise than Lucas - Kanade algorithm |
| 5. | Time complexity | Linear | Quadratic |
| 6. | Application scope | This method is applicable for tracking objects with moderate operating speed. | Applicable for tracking objects with high speed movement |
| 7. | Density of optical flow vectors generated | Less when compared to Horn-Schunck method. | More when compared to Lucas-Kanade method |
| 8. | Addressing aperture problem | No | Yes |
| 9. | Dependencies | The performance of this system is highly dependent on the size of the sliding or moving window that is selected. | The video should be cleared or smoothened by removing noisy data before applying this algorithm |
| 10. | Advantages | Sliding window size is small and hence takes less computational time. Less sensitive to noise. | More sensitive to noise. Dense optical flow vectors generated as output. Highly effective even in uniform surfaces |
| 11. | Limitations | This method is less effective when applied across uniform surfaces. | Higher time complexity and sensitivity to noise. |

Optical flow is predominantly computed based on Image Intensity (I). This image intensity is represented as a function time (t) and space coordinates (x,y). Initially the first object in a frame at time t is represented as I(x,y,t). After a certain time dt, the object is displaced over a certain duration and this displacement is denoted as dx and dy respectively. The image intensity of the new location is given by I(x+dx, y+dy, t+dt). This denotes the typical optical flow diagram.
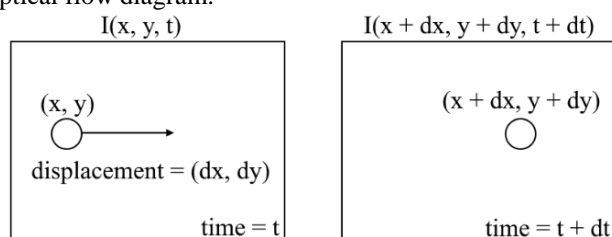


**Figure 5: Typical Optical Flow Depiction**

The revised intensity is given by:

$$I(x,y,t) = I(x+dx, y+dy, t+dt) \qquad (1)$$

The first order Taylor series expansion of the above equation is given by

$$I(x, y, t) + \frac{\partial I}{\partial x} dx + \frac{\partial I}{\partial y} dy + \frac{\partial I}{\partial t} dt \qquad (2)$$

The above equation (2) can be represented in terms of $I_x$, $I_y$, $I_z$ as

$$I_x dx + I_y dy + I_t dt = 0 \qquad (3)$$

The above equation is divided by dt and accordingly written as

$$I_x u + I_y v = -I_t \qquad (4)$$

where u = $dx/dt$ and v = $dy/dt$.

The above equation is used to compute the intensity variations across the pixels and hence enables to perform effective optical flow.

## IV. EXPERIMENTAL RESULTS

The above optical flow algorithms namely Lucas-Kanade, Horn-Schunck, Buxton-Buxton and Farneback method have been implemented using python programming and the results have been shown. Figure 6 represents the sparse optical flow motion tracking. Figure 7 represents the sparse and dense optical flow motion for a traffic sequence.



**Figure 6: Sparse Optical Flow Representation**



**Figure 7: Spare and Dense optical flow motion tracking in a crowded traffic sequence**

The above diagram shows the direction of motion of objects in the above case the various vehicles commuting on the road. The optical flow intensity in turn can be used to compute the speed of moving objects. This is depicted in figure 9. It can be seen that the length of the displacement vector plays a pivotal role in determining the speed of motion of vehicle as shown in figure 8.
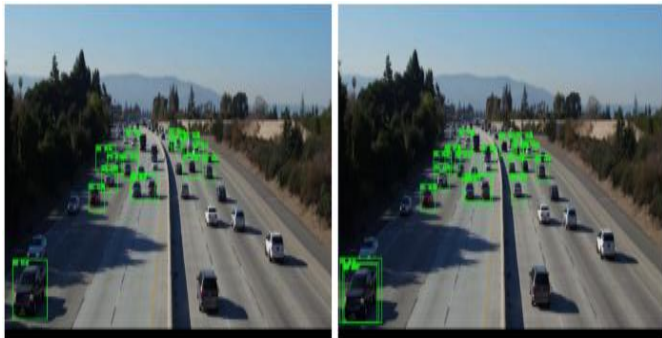


**Figure 8: Speed Prediction using Optical Flow**

## V. CONCLUSION AND FUTURE WORK

The above work discusses in detail the significance of optical flow and its role in tracking the movement of objects. As part of this paper a comprehensive study on the different types of optical flow techniques such as sparse and dense optical flow has been studied. Also, a comparative analysis of different types of optical flow algorithms namely Lucas-Kanade, Horn-Schunck and Buxon-Buxon has been carried out. Finally, the sparse and dense optical flow algorithms have been implemented and tested using a traffic video sequence. Also, using the optical flow vector length, the speed of the commuting vehicle is also computed and reported.

Future work will be directed towards using these optical flow algorithms across several real time environments to track the movement of objects under study and use them across multiple domains for effective object tracking and predictions.

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