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A Survey on Detection and Tracking of Objects in Video Sequence

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Abstract— Object tracking is a process of segmenting a region of interest from a video scene and keeping track of its motion, position and occlusion. The tracking is performed by monitoring objects' spatial and temporal changes during a video sequence, including its presence, position, size, shape, etc. Object tracking is used in several applications such as video surveillance, robot vision, traffic monitoring, Video inpainting and Animation. Also, tracking of an object mainly involves two preceding steps object detection and object representation. Object detection is performed to check existence of objects in video and to precisely locate that object. The detected object fall into various categories such as humans, vehicles, birds, floating clouds, swaying tree and other moving objects. This paper presents a brief survey of different object detection, object representation and object tracking algorithms available in the literature including analysis and comparative study of different techniques used for various tracking stages.

Keywords— Object detection, Object representation, Object tracking, Background subtraction, Background Modelling, Point based tracking, Kernel based tracking, Silhouette based tracking.

1 INTRODUCTION

Object detection and tracking is an important task within the field of computer vision. The proliferation of high-powered computers, the availability of high quality and inexpensive video cameras, and the increasing need for automated video analysis has generated a great deal of interest in object tracking algorithms. There are three key steps in video analysis: detection of interesting moving objects, tracking of such objects from frame to frame, and analysis of object tracks to recognize their behavior [17].

Actually videos are sequences of images, each of which called a frame, displayed in fast enough frequency so that human eyes can percept the continuity of its content. It is obvious that all image processing techniques can be applied to individual frames. Besides, the contents of two consecutive frames are usually closely related [3].

An image, usually from a video sequence, is divided into two complimentary sets of pixels. The first set contains the pixels which correspond to foreground objects while the second complimentary set contains the background pixels. This result is often represented as a binary image or as a mask. It is difficult to specify an absolute standard with respect to what should be identified as foreground and what should be marked as background because this definition is somewhat application specific [4]. Generally, foreground objects are moving objects like people, boats and cars and everything else is background. Many a times shadow is represented as foreground object which gives improper output. The basic steps for tracking an object are described below:

a) Object Detection

Object Detection is a process to identify objects of interest in the video sequence and to cluster pixels of these objects. Object detection can be done by various techniques such as temporal differencing [16], frame differencing [5], Optical flow [4] and Background subtraction [6, 11].

b) Object Representation

Object representation involves various methods such as Shape-based representation[9], Motion-based representation[9], Color based representation[6] and texture based representation[14] where object can be represented as vehicles, birds, floating clouds, swaying tree and other moving objects.

c) Object Tracking

Tracking can be defined as the problem of estimating the trajectory of an object in the image plane as it moves around a scene. Point tracking, kernel tracking and silhouette tracking are the approaches to track the object.

The major issues in object tracking [17] are Loss of evidence caused by estimate of the 3D world on a 2D image, Noise in an image, Difficult object motion, Imperfect and entire object occlusions, Complex objects structures, Scene illumination changes and Real-time processing requirements.

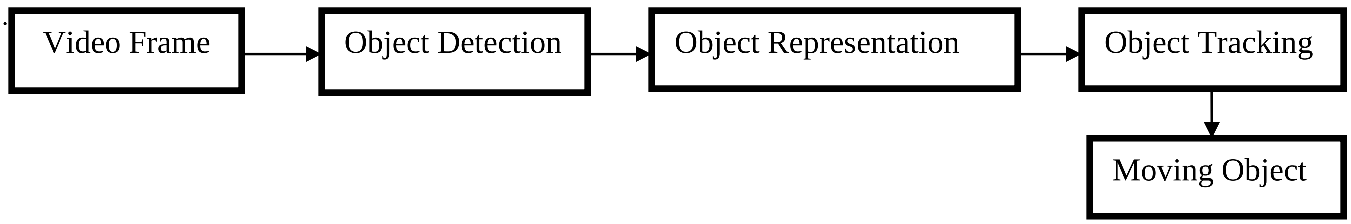

Fig 1: Basic steps in Object Tracking

In this paper, Section 2 provides brief explanation on several object detection methods. Section 3 consists of detailed study on object representation methods and Section 4 describes object tracking methods. Section 5 describes conclusion

2 OBJECT DETECTION METHODS

Every tracking method requires an object detection mechanism either in every frame or when the object first appears in the video [17]. This step in the process of object tracking is to identify objects of interest in the video sequence and to cluster pixels of these objects. Since moving objects are typically the primary source of information, most methods focus on the detection of such objects. Detailed explanation for various methods is given below.

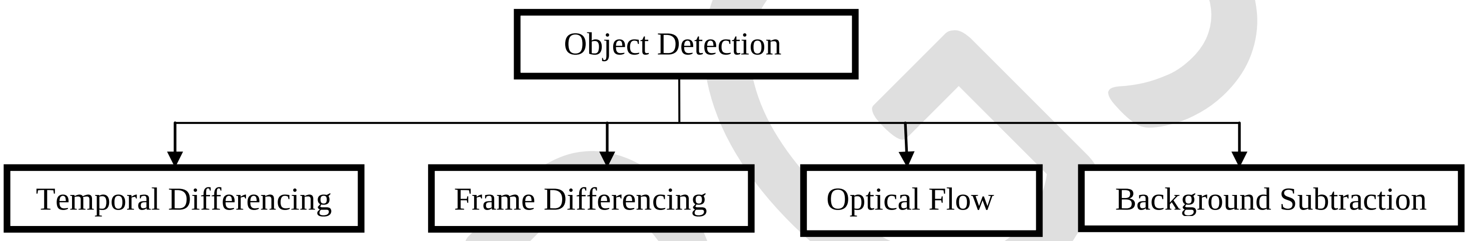

Fig 2: Methods involved in Object Detection

2.1 Temporal Differencing: Temporal differencing method uses the pixel-wise difference between two or three consecutive frames in a video imagery to extract moving regions from the background [16]. It has high adaptability with dynamic scene changes although it cannot always extract all relevant pixels of a foreground object mostly when the object moves slowly or has uniform texture [18, 19]. When a foreground object stops moving, temporal differencing method cannot detect a change between consecutive frames and results in loss of the object.

2.2 Frame Differencing: Some object detection methods make use of the temporal information computed from a sequence of frames to reduce the number of false detections. This temporal information usually in the frame differencing, highlights changing regions in consecutive frames. Given the object regions in the image, it is then the tracker's task to perform object correspondence from one frame to the next to generate the tracks. In this method, presence of moving objects is determined by calculating the difference between two consecutive images. Its calculation is simple and easy to implement. For a variety of dynamic environments, it has a strong adaptability, but it is generally difficult to obtain complete outline of moving object, as a result the detection of moving object is not accurate [5].

2.3 Optical Flow: Optical flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and the scene. Optical flow method is to calculate the motion between two image frames which are taken at times t and t+ δt at every position [4]. These methods are called differential since they are based on local Taylor Series approximation of the image signal; that is, they use partial derivatives with respect to the spatial and temporal coordinates. This method can get the complete movement information and detect the moving object from the background better, however, a large quantity of calculation, sensitivity to noise, poor antinoise performance, make it not suitable for real-time demanding occasions [4].

2.4 Background Subtraction: Background subtraction is a technique for segmenting a foreground object from its background. The main step in background subtraction is background modelling. It is the core of background subtraction algorithm. Background Modelling must be sensitive enough to recognize moving objects [1]. Background Modelling is to yield reference model. This reference model is used in background subtraction in which each video sequence is compared against the reference model to determine possible Variation. The variations between current video frames to that of the reference frame in terms of pixels signify existence of moving objects. Currently, mean filter and median filter are widely used to realize background modelling [6]. The background subtraction method is to use the difference method of the current image and background image to detect moving objects, with simple algorithm, but very sensitive to the changes in the external environment and has poor anti- interference ability. However, it can provide the most complete object information in the case background is known. Background subtraction has mainly two approaches [4]:

a) Recursive Techniques:

Recursive techniques do not maintain a buffer for background estimation. Instead, they recursively update a single background model based on each input frame. As a result, input frames from distant past could have an effect on the current background model. Compared with non-recursive techniques, recursive techniques require less storage, but any error in the background model can linger for a much longer period of time. This technique includes various methods such as approximate median, adaptive background, Gaussian mixture [6, 11].

b) Non-Recursive Techniques:

A non-recursive technique uses a sliding-window approach for background estimation. It stores a buffer of the previous L video frames, and estimates the background image based on the temporal variation of each pixel within the buffer. Non-recursive techniques are highly adaptive as they do not depend on the history beyond those frames stored in the buffer. On the other hand, the storage requirement can be significant if a large buffer is needed to cope with slow-moving traffic [11, 6].

The problem with background subtraction [20, 21] is to automatically update the background from the incoming video frame and it should be able to overcome the following problems: Motion in the background, Illumination changes, Memory, Shadows, Camouflage and Bootstrapping.

According to survey [5, 14, 16], Table 1 describes comparative study of detection methods using accuracy and computational time.

Methods		**Computational Time**	**Accuracy**	**Feedback**
Temporal Differencing		High	Moderate	✓Less complex and adaptives to dynamic changes in video. × Sensitive to threshold value that determines changes in video frames.
Frame Differencing		Low to Moderate	High	✓ Easy to implement and perform well for static background. × Requires a background without moving objects.
Optical Flow		High	Moderate	✓Complete Movement information of object is not produced. × Large amount of calculation is required.
Background Subtraction	Approximate Median	Low to Moderate	Moderate	✓ Does not require sub sampling of frames to create adequate background model. × A buffer with recent pixel values is required for computation.
	Gaussian of Mixture	Moderate	Moderate	✓ Huge memory is not needed. × Does not cope with multimodal Background.

TABLE 1: Comparative Study of Object Detection Methods

3 OBJECT REPRESENTATION METHODS

In a tracking scenario, an object can be defined as anything that is of interest for further analysis. Objects can be represented by their shapes and appearances [17]. The extracted moving object may be different objects such as humans, vehicles, birds, floating clouds, swaying tree and other moving objects [5]. Hence shape features are usually used to represent motion regions. As per literature survey, approaches to represent the objects are as follows:

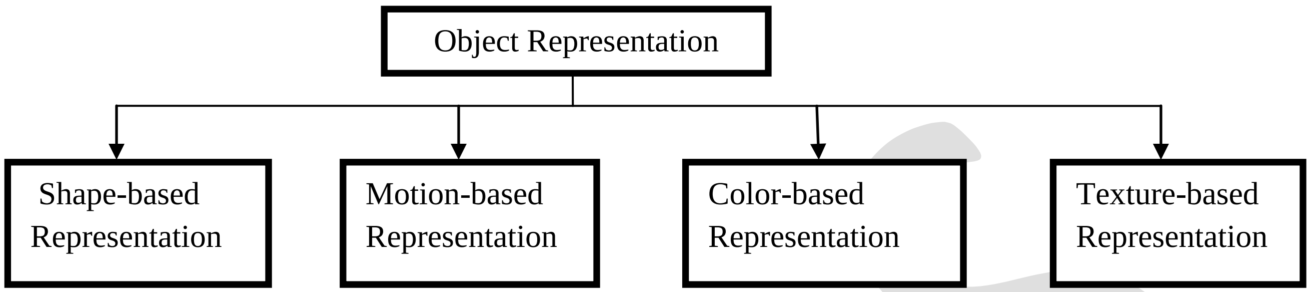

Fig 3: Methods involved in Object Representation

3.1 Shape-based Representation: Different shape information of motion regions such as representations of points, box and blob are available for representing moving objects. Input features to the network is a combination of image-based and scene-based object parameters such as image blob area, apparent aspect ratio of blob bounding box and camera zoom [9]. Representation is performed on each image blob at every frame and results are stored in histogram.

3.2 Motion-based Representation: Non-rigid articulated object motion shows a periodic property. This method has been used as a reliable approach for moving object representation. Some optical flow methods such as residual flow can be used to analyze rigidity and periodicity of moving entities. Rigid objects typically present little residual flow where as a non rigid moving object has higher average residual flow and displays a periodic component [9].

3.3 Color-based Representation: Unlike many other image features color is relatively constant under viewpoint changes and easy to be acquired. Although color is not always appropriate as the only means of detecting and tracking objects, but the algorithms that have low computational cost makes color as an important feature to use when appropriate. To detect and track vehicles or pedestrians in real-time, among other techniques, color histogram based technique [23] is used. A Gaussian Mixture Model is used to describe the color distribution within the sequence of images. Object occlusion is handled using an occlusion buffer [6].

3.4 Texture-based Representation: Texture based technique [14] counts the occurrences of gradient orientation in localized portions of an image, then computes the data on a dense grid of uniformly spaced cells and uses overlapping local contrast normalization for better accuracy.

According to literature survey [13, 14], Table 2 describes comparative study of representation methods using accuracy and computational time.

Methods	**Computational time**	**Accuracy**	**Feedback**
Texture-based	High	High	✓ Improved quality is provided. × Additional computation time is required.
Color-based	High	High	✓ Low computational cost × Not always appropriate because of accuracy.
Motion-based	High	Moderate	✓Predefined pattern templates are not required. × Difficult to identify non moving human.

Shape-based	Low	Moderate	✓ Can be applied with appropriate templates. × Does not work with dynamic situations and unable to determine internal movements well.

TABLE 2: Comparative Study of Object Representation Methods

4 OBJECT TRACKING METHODS

Tracking can be defined as the problem of approximating the path of an object in the image plane as it moves in a scene. The purpose of an object tracking is to generate the route for an object by finding its position in every single frame of the video [11]. Object is tracked for object extraction, object recognition and decisions about activities. Object tracking can be classified as point based tracking, kernel based tracking and silhouette based tracking [1]. For illustration, the point trackers involve detection in every frame; while geometric area or kernel based tracking or contours-based tracking require detection only when the object first appears in the scene. Tracking methods can be divided into following categories [1]:

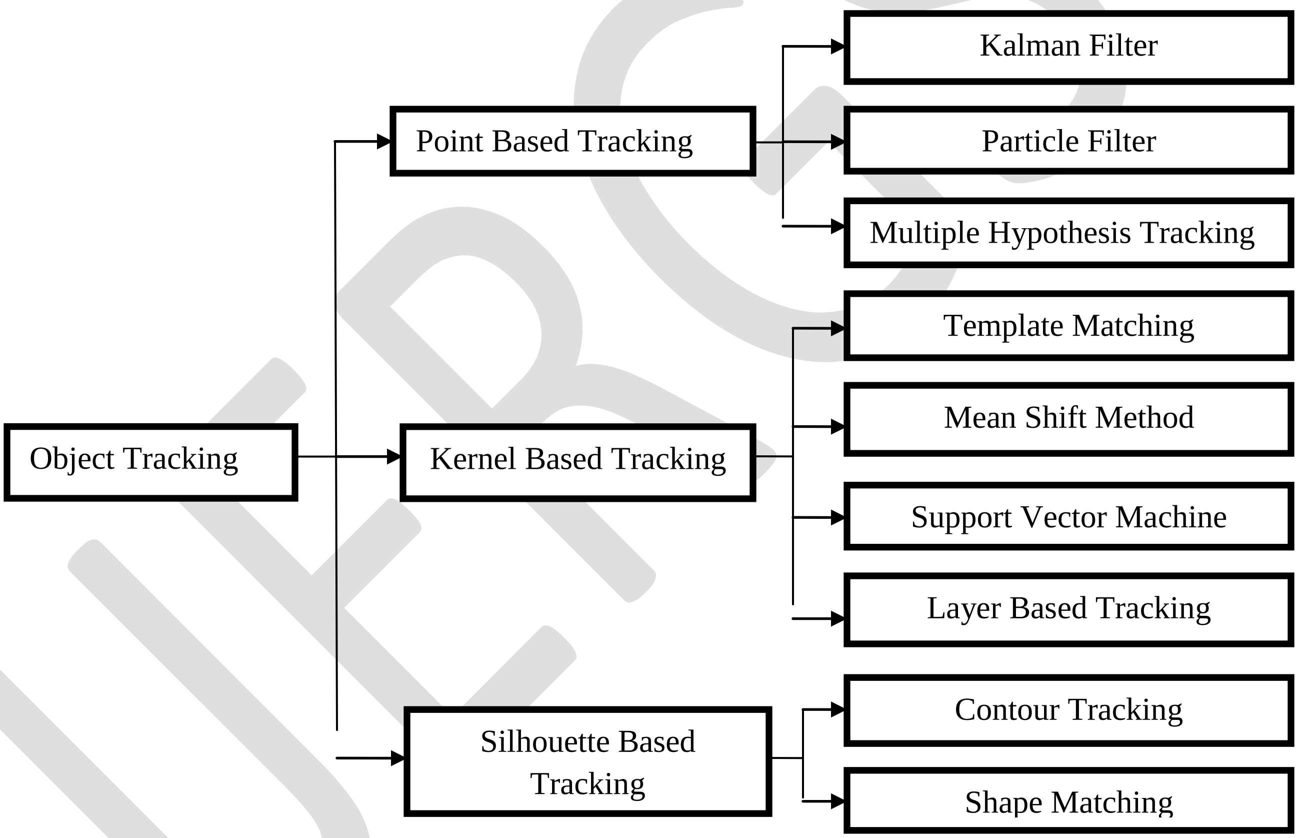

Fig 4: Methods involved in Object Tracking

4.1 Point based Tracking

In an image structure, moving objects are represented by their feature points during tracking. Point tracking is a complex problem particularly in the incidence of occlusions, false object detections. Recognition can be done relatively simple, by thresholding for the identification of these points. Point based tracking approaches [1] are described below:

1. Kalman Filter: They are based on Optimal Recursive Data Processing Algorithm. The Kalman Filter performs the restrictive probability density propagation. Kalman filter [10] is a set of mathematical equations that provides an efficient computational (recursive) means to estimate the state of a process in several aspects: it supports estimations of past, present, and even future states, and it can do the same even when the precise nature of the modelled system is unknown. The Kalman filter estimates a process by using a form of feedback control. The filter estimates the process state at some time and then obtains feedback in the form of noisy measurements. The equations for Kalman filters [10] fall in two groups: time update equations and measurement update equations. The time update equations are responsible for projecting forward (in time) the current state and error covariance estimates to obtain the priori estimate for the next time step. The measurement update equations are responsible for the feedback. Kalman filters always give optimal solutions.

2. Particle Filter: The particle filter [1] generates all the models for one variable before moving to the next variable. Algorithm has an advantage when variables are generated dynamically and there can be unboundedly numerous variables. It also allows for new operation of resampling. One restriction of the Kalman filter is the assumption of state variables are normally distributed (Gaussian). Thus, the Kalman filter is poor approximations of state variables which are not Gaussian distribution. This restriction can be overwhelmed by using particle filtering. This algorithm usually uses contours, color features, or texture mapping. The particle filter [1] is a Bayesian sequential importance Sample technique, which recursively approaches the later distribution using a finite set of weighted trials. It also consists of fundamentally two phases: prediction and update as same as Kalman Filtering. It is applied in developing area such as computer vision communal and applied to tracking problematic.

3. Multiple Hypothesis Tracking (MHT): In MHT algorithm [1], several frames have been observed for better tracking outcomes MHT is an iterative algorithm. Iteration begins with a set of existing track hypotheses. Each hypothesis is a crew of disconnect tracks. For each hypothesis, a prediction of object's position in the succeeding frame is made. The predictions are then compared by calculating a distance measure. MHT is capable of tracking multiple object, handles occlusions and Calculating of Optimal solutions.

4.2 Kernel Based Tracking

Kernel tracking [12] is usually performed by the moving object, which is represented by a embryonic object region, from one frame to the next. The object motion is usually in the form of parametric motion such as translation, conformal, affine, etc. These algorithms diverge in terms of the representation used, the number of objects tracked, and the method used for approximating the object motion. In real-time, illustration of object using geometric shape is common. But one of the restrictions is that parts of the objects may be left outside of the defined shape while portions of the background may exist inside. This can be detected in rigid and non-rigid objects .They are number of tracking techniques based on representation of object, object features ,appearance and shape of the object. Kernel based approaches are described below:

1. Template Matching: Template matching [12, 2] is a brute force method of examining the Region of Interest in the video. In template matching, a reference image is verified with the frame that is separated from the video. Tracking can be done for single object in the video and overlapping of object is done partially. Template Matching is a technique for processing digital images to find small parts of an image that matches, or equivalent model with an image (template) in each frame. The matching procedure contains the image template for all possible positions in the source image and calculates a numerical index that specifies how well the model fits the picture at that position. This method is capable of dealing with tracking single image and partially occluded object.

2. Mean Shift Method: Mean-shift tracking tries to find the area of a video frame that is locally most similar to a previously initialized model. The image region to be tracked is represented by a histogram. A gradient ascent procedure is used to move the tracker to the location that maximizes a similarity score between the model and the current image region. In object tracking algorithms target representation is mainly rectangular or elliptical region. To characterize the target color histogram is chosen. Target model is generally represented by its probability density function (pdf). Target model is regularized by spatial masking with an asymmetric kernel.

3. Support Vector Machine (SVM): SVM is a broad classification method which is termed by a set of positive and negative sample values. For SVM, the positive samples contain tracked image object, and the negative samples consist of all remaining things that are not tracked. It can handle single image, partial occlusion of object but necessity of physical initialization and training is must [8].

4. Layering based tracking: This is another method of kernel based tracking where multiple objects can be tracked. Each layer consists of shape representation (ellipse), motion (such as translation and rotation,) and layer appearance (based on intensity). Layering is achieved by first compensating the background motion such that the object's motion can be estimated from the rewarded image by means of 2D parametric motion. Every pixel's probability is calculated based on the object's foregoing motion and shape features [8]. It can be capable of tracking multiple images and full occlusion of object.

4.3 Silhouette Based Tracking

Some object will have complex shape such as hand, fingers, shoulders that cannot be well defined by simple geometric shapes. Silhouette based methods afford an accurate shape description for the objects. The aim of a silhouette-based object tracking [12] is to find the object region in every frame by means of an object model generated by the previous frames. This method is capable of dealing with variety of object shapes, Occlusion and object split and merges. Silhouette based tracking approaches are described below:

1. Contour Tracking: Contour tracking methods [12], iteratively progress a primary contour in the previous frame to its new position in the current frame. This contour progress requires that certain amount of the object in the current frame overlay with the object region in the previous frame. Contour Tracking can be performed using two different approaches. The first approach uses state space models to model the contour shape and motion. The second approach directly evolves the contour by minimizing the contour energy using direct minimization techniques such as gradient descent. The most significant advantage of silhouettes tracking is their flexibility to handle a large variety of object shapes.

2. Shape Matching: These approaches examine the object model in the existing frame. Shape matching performance is similar to the template based tracking in kernel approach. Another approach to Shape matching [1] is to find matching silhouettes detected in two successive frames. Silhouette matching, can be considered similar to point matching. Detection based on Silhouette is carried out by background subtraction. Models object in the form of density functions, silhouette boundary, object edges capable of dealing with single object and Occlusion handling will be performed in with Hough transform techniques.

According to the literature, performance metrics are implemented on the datasets available at *cmp.felk.cvut.cz/~vojirtom/dataset/,www.iai.uni-bonn.de/~kleind/tracking, clickdamage.com/.../cv_datasets.php.* Qualitative comparison of object tracking methods for different challenging situations is presented in the Table 3.

Tracking Methods	**Type of Tracking**	**Tracking Algorithm**	**Number of objects tracked**	**Occlusion Handling**	**Performance metrics**	**Feedback**
Kalman Filter[17,25]	Point tracking	Kalman Filtering Algorithm	Single	No	Efficiency in terms of total time elapsed for processing certain Frames.	✓ Used to track points in noisy images × State space variables are normally Gaussian distributed
Particle Filter[17]	Point tracking	Particle Filtering Algorithm	Multiple	Yes	Minimum variance estimate & average processing time/frame	✓Robust tracking when Image content is evaluated at hypothesis object positions ×Limited to linear system and require the noise to be Gaussian.
Multiple Hypothesis Tracking[17]	Point tracking	MHT Algorithm	Multiple	Yes	Distance measure	✓Able to deal with entries of new object and exit existing object ×Computationally exponential in both time and memory
Template Matching [2,24,27]	Kernel tracking	Exhaustive search template matching Algorithm	Single	Partial	Correlation measure & Intensity difference measure	✓Simple to implement × Sensitive to noise and time interval of movements
Mean Shift Method[23]	Kernel tracking	Histogram based Method	Single	Partial	Mean error & standard deviation error	✓ Runs very fast, suitable for models having dominant colors × Spatial information is lost and performance is not good when target and background are similar

Support Vector Machine[22]	Kernel tracking	SVM classifier & optic flow based tracker are integrated to perform support vector tracking	Single	Partial	Error surface & average Image plane motion	✓ Performs real time tracking over long periods of time × It is not designed to handle momentary disappearance & reappearance.
Layer Based Tracking[26]	Kernel tracking	Background stabilization combined with layer representation	Multiple	Full	Multiple object tracking accuracy & avg. Miss detection /frame	✓ Applicable for video matting and layer extraction × limited to binary labelling
Contour Tracking[17]	Silhouette tracking	Gradient descent Algorithm	Multiple	Full	Region statics is calculated using grid points	✓ Object shape is implicitly modelled × limited to sensitivity of contour model
Shape Matching[17]	Silhouette tracking	Hough Transform	Single	Partial	Temporal Spatial Velocity in 4D(x,y,u,v) image /frame is calculated	✓ Less sensitive to appearance variations × It requires training

TABLE 3: Comparative Study of Object Tracking Methods

5 CONCLUSION

In this survey paper all the major aspects of object detection, object representation and object tracking have been addressed. Various methods in these aspects have been explained in brief and a number of merits and demerits were highlighted in each and every technique. Different object detection methods are temporal differencing, frame differencing, optical flow and background subtraction. It can be summarized as background subtraction is a simplest method providing complete information about object compared to other methods. Among the different methods of object representation, most of the researchers prefer texture based and color based object representation. Object tracking can be performed using various methods based on point, kernel, and silhouette. Advance study may be carried out to find efficient algorithm to reduce computational cost and to decrease the time required for tracking the object for variety of videos containing diversified characteristics.

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