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# Color Particle Filter Based Object Tracking using Frame Segmentation in CIELab* and HSV Color Spaces

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*Abstract*— **Object tracking is a significant process used in many application areas. This paper presents a color based particle filter algorithm used for object tracking in video sequences for CIELab and HSV color space. Initial state of particles represents the position of pixels in the object to be tracked. The initial state is updated and weights are assigned to the particles depending on the value of the likelihood distance. Likelihood is computed based on color similarity with target region. The process leads to particle degeneracy and it is handled by using resampling stage. The method provides reliable and effective tracking results for many indoor and outdoor video sequences.**

*Index Terms*— **CIELab; HSV; object tracking; particle degeneracy; particle filter; resampling**

## I. Introduction

Object tracking is an important task in many application areas like automated surveillance, human computer interfacing, vehicle navigation, traffic control, etc. [1]. The term object tracking is referred to estimate trajectory of the object through video sequence.

Two basic approaches for object tracking are deterministic method and stochastic method. The deterministic method is based on target representation and localization. The stochastic method is based on filtering and data association techniques [2]. Various features like color, edges, optical flow, texture, etc. can be considered for object tracking. Point tracking, kernel tracking, contour tracking are different methods for object tracking.

The filtering approach is a probabilistic approach where state space model is used and the tacking process is considered as state estimation problem. Basically Kalman filter is used as a traditional approach of tracking. It provides nice tracking results for linear systems with Gaussian noise. In nonlinear systems, the nonlinear function is linearized over small region around predicted value. This approach is known as extended Kalman filter and utilized to solve the problem of nonlinear tracking. The unscented Kalman filter can approximate second order Taylor series expansion whereas extended Kalman filter can achieve only first order Taylor series expansion. Thus unscented Kalman filter have better performance in estimation using Gaussian distribution but still it cannot deal with multimodal noise distribution [2].

Particle filter is a probabilistic method for object tracking based on posterior probability density. Particle filter is a point tracking method that has been proven successful for nonlinear and non-Gaussian estimation. They approximate a posterior probability density of the state such as the object position by using samples which are called particles. Particle filtering uses sequential importance sampling. It estimates the posterior distribution of target state using set of weighted particles. The weight of the particle represents the likelihood of particle properties with the target properties [3]. A single color or local color distribution can be used as an observable feature for deciding weight of particle [4].

In conventional particle filters like condensation algorithm, the latest observation from the current frame in the image sequence is only used in the weighting step and not in the sampling step. As a result, a large number of particles are often required to approximate the posterior probability density properly. Large number of particles improves the tracking accuracy but increase computational requirement. This limitation is overcome in particle filter algorithm which requires less number of particles and thus computations get reduced [5].

` The process of object tracking involves object detection and tracking the detected object. The flowchart showing complete tracking process is shown in Fig. 1. Section II describes object detection in brief. Section III describes the process of particle filtering. The experimental results and conclusions are given in sections IV and V respectively.

## II. Object Detection

Object detection can be done in every frame or when the object first appears in the video. Detecting object in every frame leads to increased accuracy but it also increases the computational cost as well as time consumed for tracking process. Thus here object is detected only once in the video frame.

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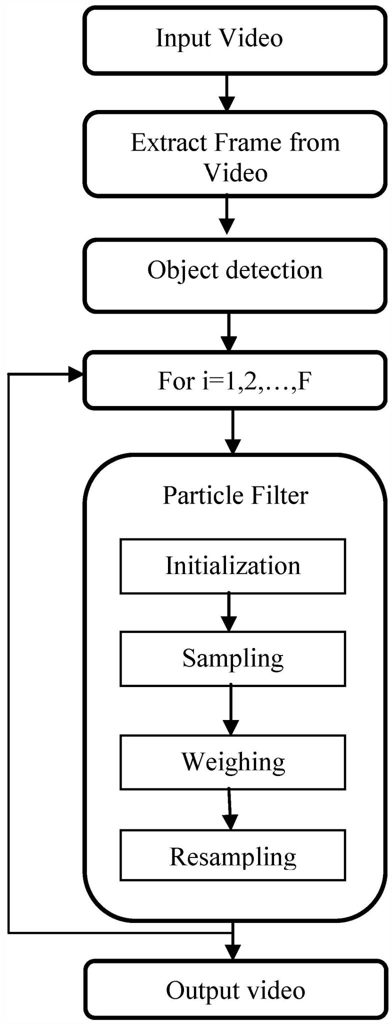


Fig 1. Flowchart for particle filter object tracking

Detection of object can be performed by using various methods, which include point detectors, background subtraction, segmentation techniques, supervised learning, etc. [6].

Segmentation techniques are widely used for the purpose of object detection. Segmentation of image refers to identification of homogeneous regions in the image. Pixel based segmentation techniques include thresholding, clustering and fuzzy clustering. Region based segmentation techniques include region growing, region merging, etc. while the edge based techniques can also be used for segmentation. Hybrid methods [7] combine these techniques for more realistic results.

Here seeded region growing and merging technique is used for object detection. The proposed method involves automatic seed selection based on edge information. According to the selected seed pixels, region growing based on color similarity and connectivity of pixels is performed. This process is followed by region merging based on similarity and size to reduce over-segmentation. The process can be done in CIELab as well as HSV color spaces.

One of the clusters from the large number of clusters formed by segmentation is selected as object region. The parameters of the selected cluster like minimum and maximum X and Y coordinates, coordinates of centroid and mean color component values for the cluster are used as input parameters for tracking process using particle filter algorithm.

## III. PARTICLE FILTER ALGORITHM

Tracking process is performed by using color based particle filter algorithm which is a probabilistic approach used for state estimation. Tracking process is generally affected by rotation and scale variance. Here color is chosen as tracking feature to make the process scale and rotation invariant [8].

The particle filter algorithm consists of following steps:

### *A. Initialization*

All the pixels in the detected object region are considered as initial particles. Particle filter algorithm uses state transition model. Thus initial state S can be defined as $S=[X \quad Z]^T$.

Here X represents the state vector and Z represents the observation vector. State of the particle indicates the position of the particle in terms of coordinates. The propagation of particles is achieved using the state space model.

### *B. State Update*

In this step, new state is set for each particle using proposal distribution. The particle state is updated by using following equations:

$$S_k = F_{update} * s_{k-1} \tag{1}$$

$$X_k = X_k + \sigma_{pos} * randn(2, N) \tag{2}$$

$$Z_k = Z_k + \sigma_{vec} * randn(2, N) \tag{3}$$

Where, $\sigma_{pos}$ and $\sigma_{vec}$ are the satandard deviations for noise distribution and value of $F_{update}$ [2] used is :

$$F_{update} = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

### *C. Weighing*

The important step in particle filter algorithm is weighing in which each particle is assigned a weight according to value of likelihood function for that particle. For color based particle filter the color similarity of the particle with the initially selected object region is used as measure to compute likelihood.

For using CIELab color space, the degree of similarity is computed as:

$$D = C - C_{ref} \tag{4}$$

$C_{ref}$ represents mean color component values of the selected object region used as reference while C represent color component values of the particle for which likelihood is determined.

In case of HSV color space, hue (H) component with either saturation (S) or value (V) component is used to compute degree of similarity [9]. If value of saturation is smaller than threshold value, then H and V components are used. For larger value of saturation, H and S components are used as given in (5).

$$D = \sqrt{(H - H_{ref})^2 + (K - K_{ref})^2} \tag{5}$$

Where, K represents either S or V component depending on the value of saturation. The value of saturation threshold is set to 120.

The likelihood distance ($\pi$) for the updated particle is calculated using (6) [2].

$$\pi = \frac{1}{\sqrt{2 * pi * \sigma}} * e^{(-\frac{D^2}{2*\sigma^2})} \tag{6}$$

If the updated position of the particle lies outside the video frame boundaries, lowest possible value (-Inf) is assigned to it as the likelihood distance. After the likelihood computation, weights ($w_t^i$) are assigned to each particle. Larger weight or value is assigned to the particle having larger value of the likelihood function and vice versa.

*D. Resampling*

When the above algorithm is used for tracking, some low weight particles are also generated. These low weight particles affect the accuracy of the tracking algorithm. This is known as particle degeneracy [10]–[11]. To overcome this problem, resampling process is used for generating new set of particles while removing the low weight particles. The effective sample size ($N_{eff}$) is used as a measure to determine particle degeneracy.

$$N_{eff} = \frac{1}{\sum_{i=1}^{N_s} (w_t^i)^2} \tag{7}$$

If the effective sample size is less than the threshold sample size ($N_{th}$), degeneracy is said to have occurred and resampling stage is activated. During resampling step, only the particles with lowest weights i.e. the particle with weight less than the threshold weight, are eliminated and replaced with new set of particles while other particles are stored for further processing [12]. This reduces the computational cost and the processing time required for resampling.

## IV. RESULTS

The experimental results are obtained on many video sequences in avi and mp4 format to obtain reliable results. The algorithm has been implemented in Matlab R2011b. The algorithm uses CIELab and HSV color spaces for both object detection and tracking.

Object to be tracked is selected by the user and only a small region surrounding object is segmented to obtain the final object region. As segmentation is not performed over complete video frame, the computation time is reduced.

The position error can be used as a measure to determine the accuracy of tracking algorithm and is represented in Fig. 2. The position error is computed as a difference between the actual position and the estimated position of the object.

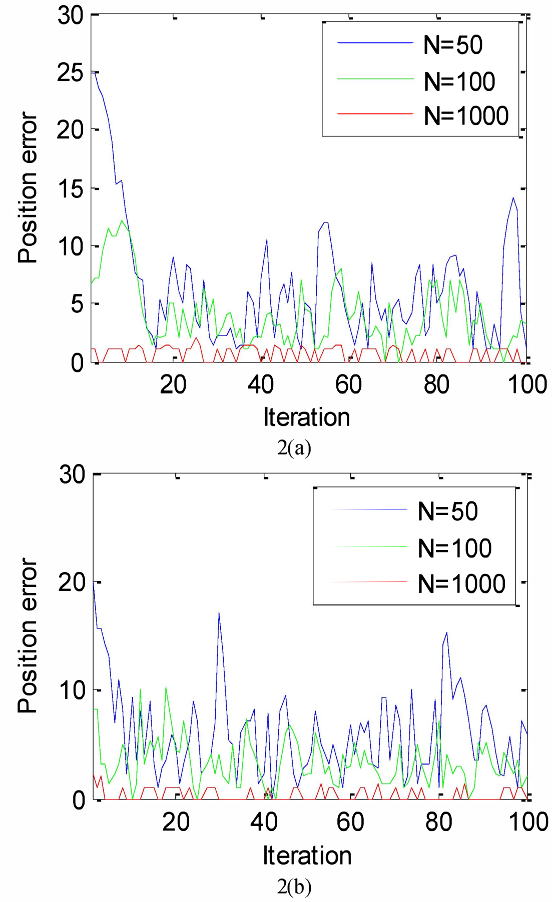


Fig 2. Position error obtained using (a) CIELab color space and (b) HSV color space

The error is averaged over total number of frames to obtain the average position error. The average position error obtained with different number of particles is given in Table 1.

From the values of average position error, as the number of particles used for tracking increases the value of average position error decreases which results in increased accuracy of the tracking algorithm. The tracking results are obtained by using above mentioned algorithm for outdoor as well as indoor video sequences.

Tracking outputs using CIELab color space are shown in Fig. 3 and Fig. 4 while the results using HSV color space are shown in Fig. 5 and Fig. 6. The tracking process is continued till the object moves out of video frame boundaries. If there is scale variation in the input videos i.e. the object to be tracked moves from far to near and size of object also varies as the video Sequence progresses then also satisfactory results are obtained in such cases.

TABLE I
AVERAGE POSITION ERROR

| Number of particles | Average position error using CIELab color space | Average position error using HSV color space |
|---|---|---|
| N=50 | 8.5681 | 6.0634 |
| N=100 | 3.3702 | 3.3254 |
| N=1000 | 0.7298 | 0.3748 |

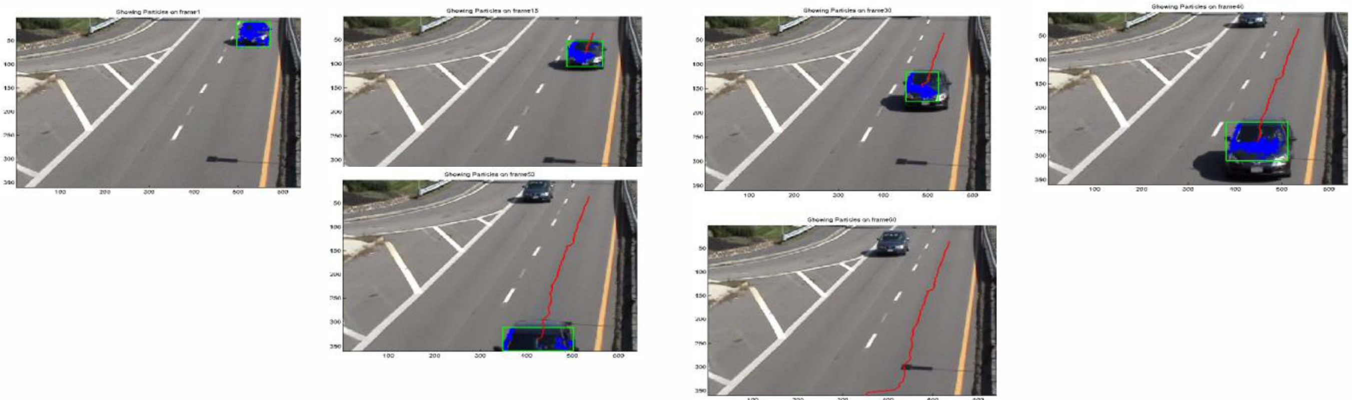

Fig 3. Tracking results obtained for outdoor video sequence using CIELab color space

Fig 4. Tracking results obtained for indoor video sequence using CIELab color space

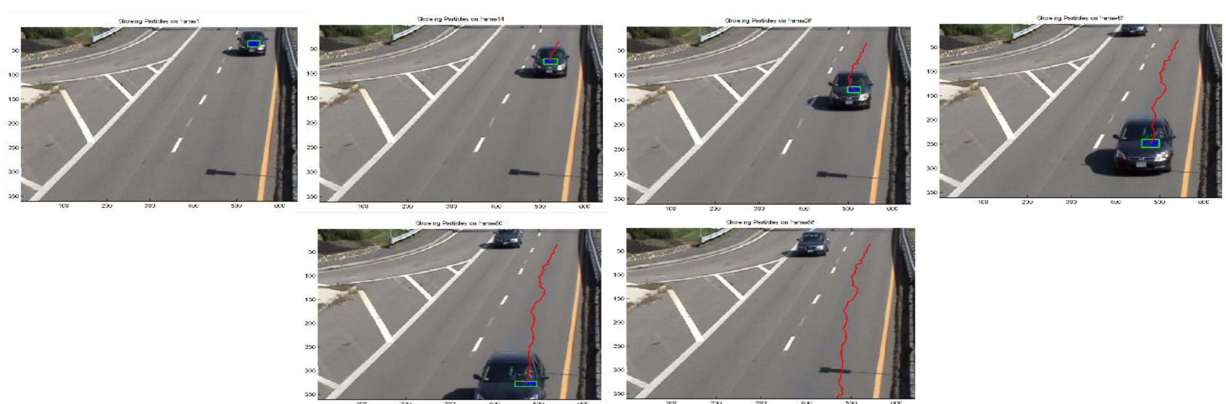

Fig 5. Tracking results obtained for outdoor video sequence using HSV color space


Fig 6. Tracking results obtained for indoor video sequence using HSV color space

## V. CONCLUSION

A color based particle filter used for object tracking in video sequences using CIELab and HSV color spaces is proposed in this paper. The object is detected using color image segmentation based on automatic seed pixel selection, region growing and region merging using CIELab as well as HSV color spaces. Particle filter tracks the object using initialization, sampling, weighing, and resampling. The accuracy of the tracking algorithm increases as the number of particles used is increased. The particle filter has many advantages like accuracy and robustness. Standard deviation value of σ is generally kept 1 but it should be high if number of particles is very small and should be low if there are large number of particles. The color based particle filter can provide satisfactory results providing scale and rotation invariance. It is observed that more accurate results are obtained using HSV color space as compared to CIELab color space. The particle filter based on single color cannot provide satisfactory results in case of background cluttering i.e. when the object and background have similar color. There is scope to develop particle filter based on color distribution to obtain more precise results.

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