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Design of Moving Object Tracking Model using Feedback Particle Filter

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Abstract: This paper deals with the problem of visual target tracking the proposed Feedback Particle Filter (FPF) algorithm is used to track the object in motion under a non-linear, non-Gaussian state. At present, numerous technologies are used for target tracking in motion. To track the target efficiently with fewer occlusion problems color-based feedback particle filter is used. Since color feature outperforms against noise and occlusion problems and increases robustness in target tracking. Comparison is also given between feedback particle filter and other filter algorithms to study performance analysis in target tracking. FPF is useful in Neuroscience, Neuromorphic implementation, Attitude estimation of aircraft, and also in visual target tracking applications.

Index Terms **– Feedback Particle Filter Algorithm, non-linear, non-Gaussian, target tracking, occlusion, Neuroscience.**

I. INTRODUCTION

Tracking objects is one of the most important tasks in computer vision and various research fields. It is a multitude of real-life applications including traffic monitoring, robotics, medical imaging, autonomous vehicle tracking, and many more.[11] Object tracking is a process where an algorithm tracks the movement of the object. In other words, it is the task of estimating or predicting the position and other relevant information of the moving object in a video sequence where the algorithm classifies and detects the object by a bounding box or spreading particles the objects to the input information[11]. By assigning unique identification to the object to be tracked the tracking is performed as the object moves through frames while storing the relevant information in the tracking process.

Tracking of the object will only work if the object is visible in each frame of the video sequence and if the object is hidden by any interface it will not able to detect it this problem is termed occlusion, where object tracking is the process to track the trajectory of the object despite occlusions[11]. To perform tracking in a video sequence we had to select features of the object to be detected since it is associated with the object representation. In the edge-based detection method change in image, intensity generated by object boundaries are detected by the edge feature hence it is used as the main agent in object tracking but it fails in a cluttered environment while in color based tracking method color is used as a feature for histogram-based appearance representation color space ranging from grayscale, RGB, YCbCr and HSB color spaces[12].

The proposed algorithm used the RGB color-based histogram technique for the detection of an object since it gives robustness against partial occlusion and noise while background matching and illumination change are its disadvantages [5]. The most commonly used algorithm for object tracking are Mean shift algorithm which is fast with less computational complexity but inaccurate for a fast-moving object, Kalman filter algorithm is optimal recursive and fast but only applicable in the linear system hence accuracy decreased, [10] The Particle Filter algorithm is the most widely used algorithm for tracking purpose since particularly it is useful in non-linear, non-Gaussian tracking estimation.[7]

There have been a number of the methodology proposed for tracking using a particle filter algorithm. Monte Carlo important sampling is the basis of the Particle Filter Algorithm it uses Bayesian estimation which is Bayes' law of probability. The Bayes' law of probability states that posterior probability is determined by multiplying the prior with the likelihood. Probability is the similarity between ground truth and estimation, while prior is the distribution of variables previously analyzed [7] Particle filter include following steps of processing- 1) Prediction that is the generation of particles 2) Updating weight of particles 3) Resample includes regeneration of particles with higher weight and diminishing the low weight particles.[14] However, the problem of weight degeneracy and particle diversity reduces its performance.

The Feedback Particle Filter is a non-linear filtering algorithm that provides a numerical approximation to the filtering problem. The FPF has a comparatively low variance compared to conventional particle filter and also give a reduction in mean square error at a lower number of particles.[13] The Comparative study of different algorithm based tracking is given below

1.1 Literature review

A qualitative comparison of tracking methodology is done for the performance analysis of various tracking techniques. Since adaptive filters are the most commonly used techniques for tracking.

Table I- Comparison of various tracking techniques.

S. No	Reference	Algorithm Used	Measured Parameters	Advantages	Limitations
1.	[1]	Cubature Kalman Filter Algorithm	The average Mean Square error over 1000 simulation runs is 2.28	Less computational complexity than Particle Filter	Less accuracy than particle filter.
2.	[2]	Particle Filter with additional random perturbation.	Measurement of normal noise is 1% and low noise is 0.14%	Quickly and accurately track a high dimensional maneuvering target	
3.	[3]	Intelligent Adaptive Unscented particle filter	RMSE v/s time analysis with estimated Trajectories graph.	Particle degradation and Particle impoverishment problem is mitigated	
4.	[4]	Color-based particle filter with RGB color scheme	Bhattacharya coefficient v/s frame index plot and Bhattacharya Coefficient are calculated	Tracking of speed and reliability on air and water videos.	
5.	[5]	Color-based particle filter with YIQ color scheme	Position estimation and size estimation by background subtraction	Multitarget or single target with multiple camera environment may be easily incorporate into the proposed	The inaccurate result when light intensity changes.
6.	[6]	Particle Filter with selected RGB histogram	Tracking based on a single color.	The selected color is tracked successfully	Similar color background problem
7.	[7]	Auxiliary Particle Filter	RMSE for object localization and size of the bounding box is predicted .	Enhances the observation based-estimation model.	
8.	[8]	Probabilistic data association-Feedback Particle Filter	Single and two target tracking models with RMSE calculation.	It is useful for designing integrating and testing the algorithm in a large system.	Computational complexity problem

1.2 Problem Formulation

Concluding from table 1 we find that adaptive filter application is most frequently used in the field of video tracking. So we used the most recent adaptive filter for tracking an object in motion. To increase the efficiency of the tracking process feedback particle filter is used. Hence the problem Design of the moving object tracking model using a feedback particle filter has been formulated.

1.3 Tentative steps required in designing the proposed model

- Retrieve input video clip data.
- Design of feedback particle filter.
- Performance and Experimental analysis.
- Comparison with existing technique.

The paper is organized as follows Section II gives feedback particle filter framework, Section III gives the proposed algorithm, Section IV gives experimental results, Section V gives a comparison of FPF with other algorithms and Section VI finally concludes the paper.

II. Feedback Particle Filter on the tracking algorithm

The Feedback particle filter is a new approach to approximate numerical solutions for non-linear filtering problems.[9] The gain function and the innovation error are the key factors of the feedback particle filter the feedback is taken from the particle filter output and given as input to the feedback element. And Feedback particle filter has a comparatively low variance as compared to the general particle filter also it reduces MSE at less number of particles.[13] The general particle filter with feedback structure is given below

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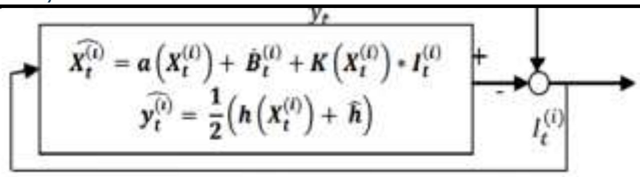

Fig.1 Feedback Particle Filter [9].

In Fig.1 the term of the sample represents by n. $X_t^{(i)}$ is the state of an i^{th} particle at time t, $K_t^{(i)}$ is the gain of an i^{th} particle at time t, $I_t^{(i)}$ is the innovation error for each of i^{th} particle. $B_t^{(i)}$ is the measurement noise it is an observation update. It is possible for the gain to be constant for an iteration at some time t or it may be different for each particle at time t.[9] In this paper, the gain is implemented using the constant value.

2.1 Target Identification

In this section, the target specification that is its color, position, and size is identified. The color value is input in the form of an RGB histogram.[5] The color feature is used since it gives robustness against occlusion and noise

2.2 Particle Filter Initialization

After getting the target information the particle filter initialize which uses discrete Monte Carlo Simulation for the calculation of state estimation using Bayes' law of estimation.[9] The state and observation process is given as

$X_n = A * X_n + \sigma_U * U_n$ Measurement equation (1)

$z_n = C * X_n + \sigma_v * v_n$ Observation equation (2)

2.3 Particle generation and weight update

To initialize particle filter generation of particle swarm $[x_0^i]_{i=1}^{N}$ according to prior probability as [9]

$$x_n^{(i)} \sim P(x_n|z_{n-1}) \quad (3)$$

Then density approximation is given as

$$P(x_n|z_{n-1}) = \sum_{i=2}^{N} W_{n|n-1}^{(i)} \delta\left(x_n - x_1^{(i)}\right) \quad (4)$$

The weight update equation is calculated as [9]

$$w_n^{(i)} \alpha \, p\left(z_n|x_n^{(i)}\right)\omega_{n-1}^{(i)} \quad (5)$$

The estimation of the next frame in the video is estimated as $X_{n,\text{ which}}$ is given as [9]

$$X_n = \sum_{i=1}^{N} w_n^{(i)} * X_n^{(i)} \quad (6)$$

2.4 Gain and Error calculation

The feedback particle equation is given as

$$X_n^{(i)} = AX_n^{(i)} + \sigma_v v + k_n^{(i)} I_n^{(i)}$$

Where the $k_n^{(i)}$ is the gain function given as[9]

$$k_n^{(i)} = \frac{c}{(\sigma_v)^2} \sum_{i=1}^{N} \left(x_n^{(i)} - \mu_n^{(N)}\right)^2 \quad (7)$$

And $I_n^{(i)}$ is the innovation error and given as[9]

$$I_n^{(i)} = z_n - \frac{1}{2}\left(h\left(x_n^{(i)}\right) + \hat{h}_n\right) \quad (8)$$

2.5 Performance Measurement Parameter

The efficiency of the proposed model is measured in terms of mean square error which is given as

$$MSE = \frac{1}{N} \Sigma_{n=1}^{N} (x_n - \dot{x}_n)^2 \quad (9)$$

Where N is the number of samples x_n is the actual state and $\dot{x}_n$ is the estimated state of the matrix.

III. PROPOSED ALGORITHM

Here the feedback particle filter-based tracking algorithm is used to track the object in motion the feedback is used as the output of the particle filter as input, At first, the input video sequence is taken then we define the RGB color sequence code for the object to be tracked then color-based particle filter is initialized n which particle generation and weight is updated according to likelihood. In likelihood, the particle is regenerated having a higher likelihood and the particle is diminished having a lower likelihood. Then the addition of feedback technique is done which consists of multiplication of gain function K and innovation error I over the n number of samples then until the end of the number of frames tracking is performed in the input video sequence. At last, the mean square error is calculated over 1000 iterations for efficiency calculations.

The Feedback Particle Filter (FPF) Algorithm.

1. For $n \geq 1$ do
2. Initialize
3. For i=1…………N do
4. Sample $X_0^{(a)}$ from P (X,0)
5. End for
6. Assign value at n=0

1. Iterate from n to Δn
2. Calculate $h_n^N = ½ \sum_{i=1}^{N} h(X_n^{(i)})$
3. For i=1………N
4. Generate a sample
5. Calculate weight and normalize
6. Calculate gain function $K_n^{(i)}$ using (7)
7. Calculate innovation error $I_n^{(i)}$ using (8)
8. Update Particle equation using (6)
9. End for
10. n = n+Δn.

IV. EXPERIMENTAL RESULTS

The experiment is performed on two input videos. In case study one the video is recorded from Adhartal, Jabalpur, India. A white color E-Rickshaw was tracked moving straight on-road and in case study two the video was taken from Matlab file exchange library in which red color upper-wearing girl moving around the table was tracked successfully. In both the cases the performance analysis is done by applying iteration and calculating the mean square error over n number of simulation runs.

.4.1 Case study I

The input video is the real-time recorded video in which a white color E-Rickshaw was tracked by selecting RGB sequence color input value as shown in fig.2 the blue color dot represents the distribution particles. The video parameters are given as frame rate is 25frame/sec, the video format is RGB 480×270, and the bit rate is 128kbps. Fig.3 shows the trajectory plot of the input video sequence between X-Position v/s Y-Position. Fig.4 gives the graph between mean square error and 1000 iterations applied.

Fig.2 Tracked frame number 75 of E-Rickshaw

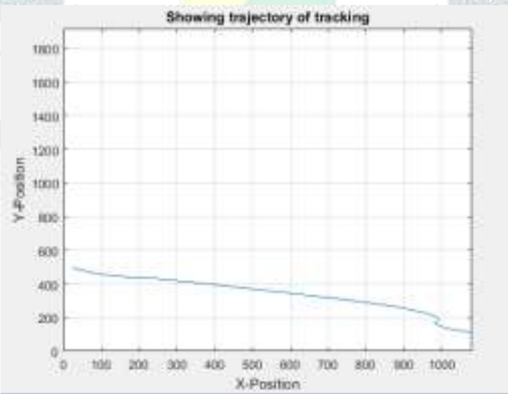

Fig.3 Trajectory Plot of the moving E-Rickshaw

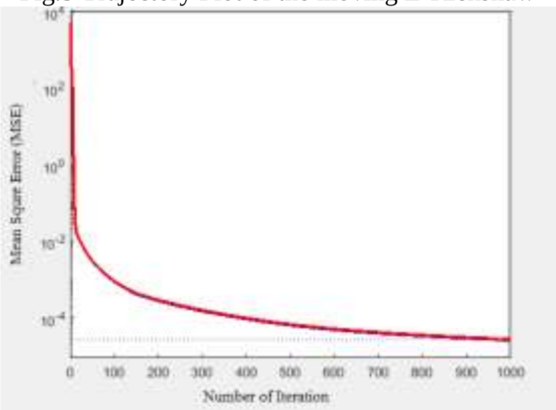

Fig.4 MSE v/s Iterations plot for moving E-Rickshaw.

4.2 Case study II

The input video is the recorded video taken from the Matlab file exchange library in which a red color pedestrian was tracked by selecting the RGB sequence color input value as shown in fig.5 the blue color dot represents the distribution particles. The video parameters are given as frame rate is 15frame/sec, the video format is RGB 640×480, and the bit rate is 48kbps. Fig.6 shows the trajectory plot of the input video sequence between X-Position v/s Y-Position.Fig.7 gives the plot between mean square error and 1000iterations applied.

Fig.5 Tracked frame number 99 of moving pedestrian.

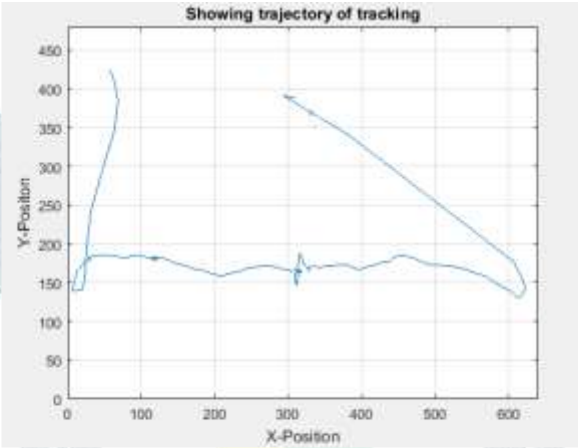

Fig.6 Trajectory plot of the moving pedestrian

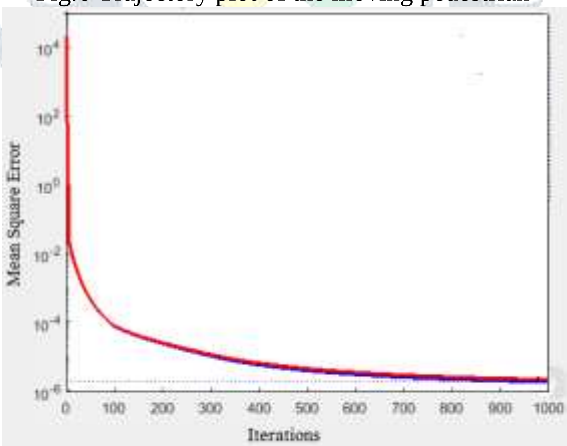

Fig.7 MSE v/s 1000 iterations plot of the moving pedestrian

V. Comparison with existing technique

Table II Comparison of FPF with other filter algorithm for 1000 iterations.

S. No	Methodology	MSE
1.	Cubature Kalman Filter [1]	2.28
2.	Particle Filter [1]	2.32
3.	Extended Kalman Filter [1]	4.39
4.	FPF Algorithm for case study I	0.0058
5.	FPF Algorithm for case study II	0.0018

VI. CONCLUSION

In this paper, we conclude that the Feedback Particle Filter Algorithm gives a quite efficient result than another conventional filter. As we know particle filter is the most widely used adaptive filter in the non-linear, non-Gaussian state for tracking purposes. The feedback particle filter is similar to a particle filter which uses a feedback structure with a particle filter to enhance its performance and reduce the error also it increases the robustness of the system. The comparison table.1 provides the comparison of tracking techniques using different algorithms and a comparison table.2 provide the performance analysis by comparing MSE with the existing conventional Particle Filter, Cubature Kalman Filter and Extended Kalman Filter algorithm, . Hence the proposed algorithm can be used to track the object in video tracking.

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