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# Automatic Object Tracking with Particle Filter Coupled To Edge Detectors

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**Abstract:** ***Object tracking can be defined as the process of selecting an object of interest from a video scene and keeping track of its motion in order to extract useful information. Object tracking is an important field in the area of image processing. Detection of an object that is to be tracked is generally given as an input manually. In certain scenario it is required for automatic detection of moving objects (human, car) in a video sequence. Automatic tracking of objects can be the foundation for many interesting applications like in biomedical, security, identification of threats, unauthorized intruders in defense and navy. Detection of moving object is accomplished by capturing the image frames, background subtraction and edge detection. This paper proposes a new concept of automatic detection of moving object and initiating the particle filter algorithm for tracking such object selected.***

**Keywords:** Background subtraction, Edge detection Object detection, Particle filter, Thresholding.

## 1. Introduction

The automated tracking a moving object systems is currently of immense interest due to its implications in the field of security. Identification of objects or vehicles depends on the factors like size, shape, color, type, model and etc. As these factors changes from object to object identification becomes quiet complex and a challenging domain [1].

Moving object detection in real time is a challenging task in visual and traffic surveillance systems. It often acts as an initial step for further processing such as classification of the detected moving object. One of the simpler method for moving object detection is by using background subtraction method which often uses background modeling. Temporal difference method is very simple and it can detect objects in real time, but it does not provide robustness against illumination change. Tracking an object manually by specifying the object location in a video frame is not efficient and may not be able to perform in real-time automatic applications [2]. Edge detection is an important part of digital image processing, it is not only reduces the amount of data but also maintain useful structural information. This paper proposes a method that initiates the moving object automatically using edge detection and background subtraction.

The various edge detectors are used and their efficiency is tested by quality metrics; the best method is chosen for the algorithm.

## 2. Proposed Method

One of the features for detecting the moving object in a video sequence is edge. Various edge detectors are used to check its performance on the algorithm. Edge detection is applied to a specified number of frames at the beginning and output subjected background subtraction for locating the object in the frame which is given by,

$$I = Ib - If$$

The location of the object is the input to the particle filter based tracking algorithm. Tracking algorithm continues to track the object. There are three modules in this algorithm.

1. Edge detection.
2. Background subtraction for detecting the moving objects [5].
3. Particle Filter based tracking.[6][7].

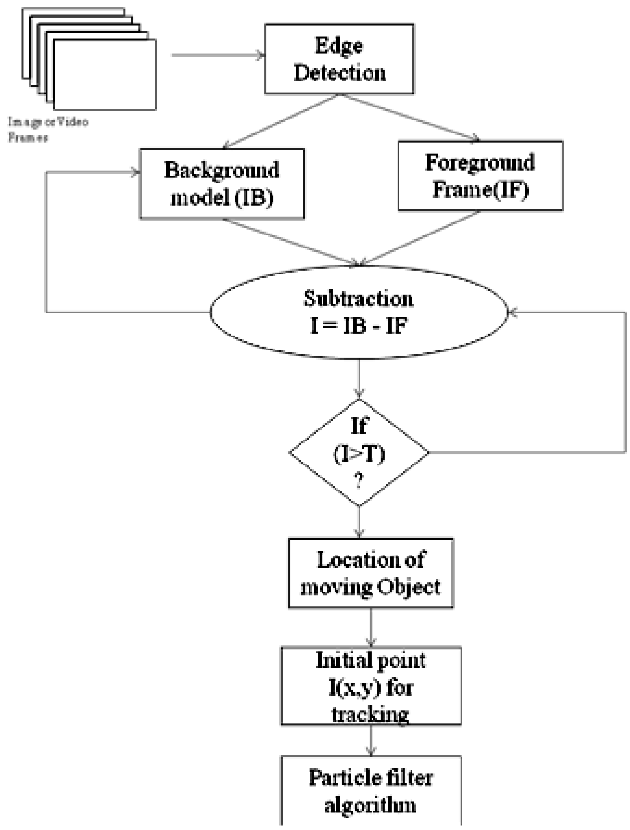


**Figure 1:** Block Diagram of Proposed Method

### 2.1 Edge detection

Edge Detectors are used to outline the boundaries of an object. The purpose of edge detection in general, is to significantly reduce the amount of data in an image, while preserving the structural properties to be used for further image processing [3].

Seven different edge operators are used and their performance is tested [8].

i. Robert edge detector.
ii. Prewitt edge detector.
iii. Sobel edge detector.
iv. Canny edge detector.
v. Marr and Hildreth edge detector.
vi. Frei-Chen edge detector.
vii. Laplacian edge detector.

#### 2.1.1 Quality metrics for edge operators:

Quality assessment of images aims at quantification of image quality by means of quality metrics. For applications and products that target human consumers, it is desirable to have metrics that will predict the perceived visual quality as measured with human subjects. Visual quality assessment metrics can be further divided into full-reference, reduced-reference, and no-reference quality metrics [9] [10].

**Full-reference** *metrics compare the to-be-assessed image to an original reference image.*

1. Mean Squared Error (MSE)
2. Peak Signal to Noise Ratio (PSNR)
3. Mean Absolute Error (MAE)
4. ESSIM: Edge-based Structural Similarity

**Reduced-reference** *metrics make use of set of reference features that could have been extracted from original image.* Reduced Reference Metrics [12]

*i. Pratt's Figure of Merit(FOM)*
*ii. Global Index*

**No-reference** *metrics attempt to predict the image without any reference image.*

5. Statistical Measures [11]
***i.*** *Relative Frequencies*
***ii.*** *T-Statistics*
***iii.*** *Confidence Interval (CI)*

*Refer* APPENDIX I for *detailed explanation.*

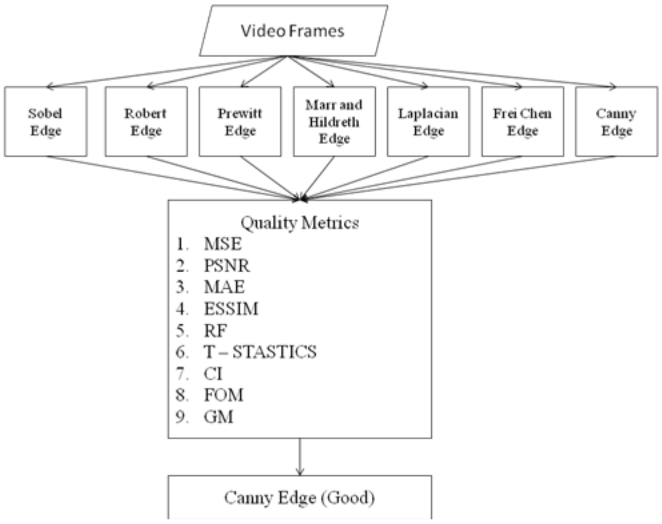


**Figure 2:** QM for choosing the best edge detector.

### 2.2 Background Subtraction

Background subtraction is the process of separating out foreground objects from the background in a sequence of video frames. Analysis and detection of human motion in a video sequence is the foremost task in computer vision based problems. It is a worthy issue in human motion analysis system since the subsequent algorithm such as tracking follows motion detection. The technique of background subtraction involves subtracting an image that contains the object, with the previous background image. The area of the image plane where there is a significant difference within these images indicates the pixel location of the moving objects. These objects are represented by groups and a thresholding value is used to get the location of the object. Background subtraction is used in many emerging video applications, such as video surveillance, traffic monitoring [5][6], and gesture recognition for human-machine interfaces and etc.

$$I = Ib - If.$$

Where, Ib is background image and If foreground is image.

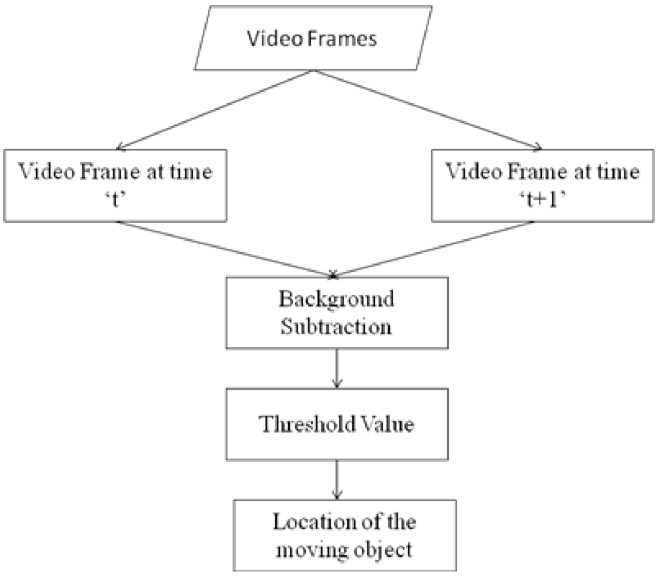


**Figure 3:** Background Subtraction

### 2.3 Particle Filter based Tracking

Particle filtering has emerged recently in the domain of computer vision. The advantage of particle filter over other types of filters (Kalman, Extended Kalman, etc.) is that it allows for a state space representation of any distribution. It also allows for non-linear, non-Gaussian models and processes. A particle filter tracking method based on adaptive optimization is presented by using color clue of object. Particle Filter is concerned with the problem of tracking single or multiple objects. It is a conjecture tracking system that is expected to explain certain observations, that approximates the filtered further back in positions distribution by a set of weighted particles. It weights the particles based on the likelihood score and propagates them according to the motion model used. Particle filter algorithm uses Bhattacharya distance to calculate the score and uses residual Re-sampling. Re-Sampling is used to select and re-generate the particles around the target location to keep the tracking process intact [7]. Particle Filter algorithm requires initial location i.e co-ordinates for initiating tracking. Generally the location is fed manually by the user. This method automatically provides the location.

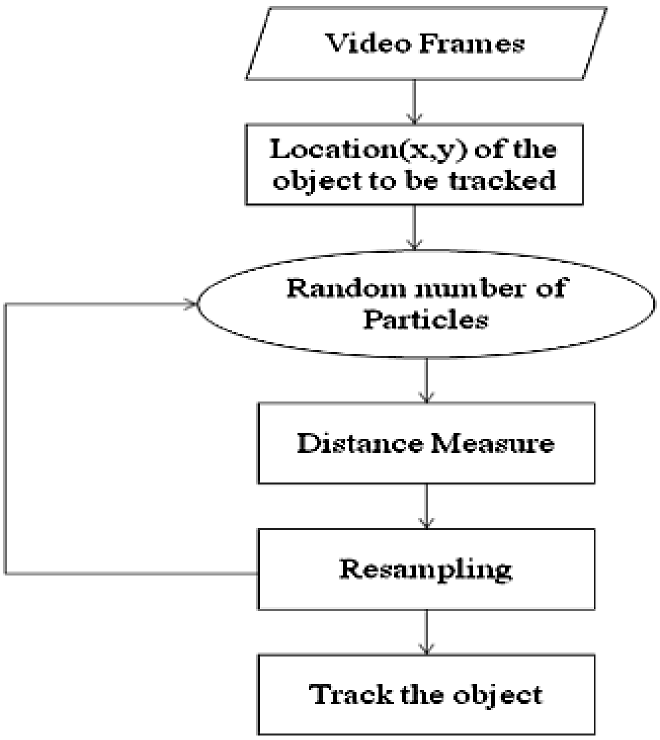


**Figure 4:** Particle Filter Tracking

## 3. Algorithm

Detection of a single moving object with automatic initiation of tracking.

**Input**: Video/Image sequence containing a single moving object.

**Output**: Location of moving object and tracking

**Steps**:

1. Read the video.
2. Convert the color video into grayscale.
3. Apply canny edge detector to each of the frames obtained after analysis of each of the edge detector using Quality Metrics.
4. Subject each of the edge detected image to background subtraction.
5. Apply the threshold value.
6. Find the Centroid of the object.
7. Input the location of the moving object obtained after step 6 to Particle filter algorithm.
8. Initiate the Particle filter algorithm for tracking.

## 4. Analysis

Quality metrics is used to find the efficient edge detector. Our approach uses seven edge detectors and quality measures to find a better detector. Results and tabulation are shown below.

**Table 1:** Full-Reference QM for the images shown in Fig. 5

| Quality Metric | Sobel | Robert | Prewit | Marr Hildre | Laplacian | Frei Chen | Canny |
|---|---|---|---|---|---|---|---|
| FOM | 0.40 | 0.40 | 0.408 | 0.510 | 0.59 | 0.521 | 0.555 |
| G M | 1.16 | 1.16 | 1.162 | 1.265 | 1.07 | 1.286 | 1.526 |

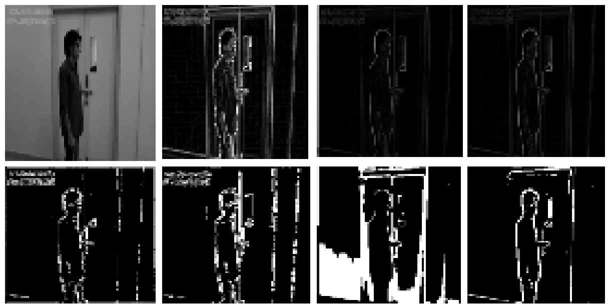

**Figure 5**

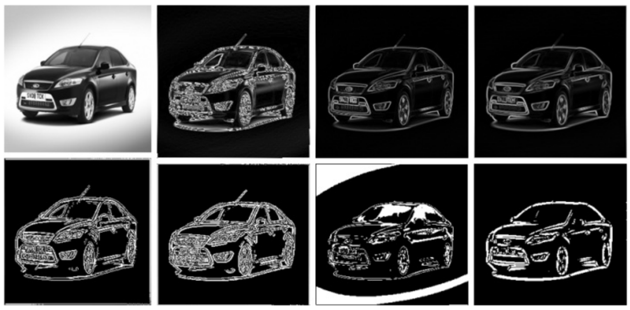

**Figure 6**

Results of seven Edge operators a) Input Image b) Sobel Edge c) Robert Edge d) Prewitt Edge e) Marr and Hildreth Edge f) Laplacian Edge g) Frei Chen Edge h) Canny Edge.

The tables below shows the various quality metrics used to find out the best possible edge detection method that can be used further in the algorithm.

**Table 2:** Relative Frequency of Edge Maps for Fig.5.

| | MSE | PSNR | MAE | ESSIM |
|---|---|---|---|---|
| Sobel | 130.908 | 62.080 | 165.270 | 0.660 |
| Robert | 132.184 | 62.061 | 166.546 | 0717 |
| Prewitt | 133.353 | 61.895 | 167.715 | 0.763 |
| Marr and Hildreth | 131.437 | 62.039 | 165.799 | 0.553 |
| Laplacian | 130.566 | 62.106 | 164.928 | 0.767 |
| Frei chen | 139.674 | 74.096 | 174.171 | 0.883 |

| | | | | |
|---|---|---|---|---|
| Canny | 128.443 | 62.270 | 162.805 | 0.716 |

**Table 3:** Statistical Measures for Fig. 5.

| Relative Frequency | Canny | Frei Chen | Laplacian | Marr and Hildreth | Prewitt | Robert | Sobel |
|---|---|---|---|---|---|---|---|
| Canny | 1 | 0.359 | 2.063 | 2.252 | 0.244 | 0.272 | 0.263 |
| Frei Chen | 0.046 | 1 | 0.095 | 0.104 | 0.011 | 0.012 | 0.012 |
| Laplacian | 0.48 | 0.17 | 1 | 1.09 | 0.11 | 0.1 | 0.1 |
| Marr Hildreth | 0.444 | 0.159 | 0.9 | 1 | 0.10 | 0.1 | 0.1 |
| Prewi | 4.08 | 1.46 | 8.4 | 9.20 | 1 | 1.1 | 1.0 |
| Robert | 3.66 | 1.31 | 7.5 | 8.25 | 0.89 | 1 | 0.9 |
| Sobel | 3.79 | 1.36 | 7.8 | 8.52 | 8.25 | 1.0 | 1 |

**Table 4:** Reference QM for Edge Detection for Fig. 5

| Quality Metrics | Canny/ Frei Chen | Canny/ Laplacian | Canny/ Marr And Hildreth | Canny/ prewitt | Canny/ Robert | Canny/ Sobel |
|---|---|---|---|---|---|---|
| CI | (-3.607-4.607) | (-0.847-1.878) | (-1.773-3.128) | (-0.779-1.906) | (-0.814-2.189) | (-0.778-1.974) |
| T-Statistics | 53.613 | 24.237 | 25.721 | 84.304 | 75.332 | 78.052 |

- Table 1 shows the results of generally used quality metric for edge detection and it is observed that canny edge detector is better compared to other edge detector operators.
- Table 2 shows the results of relative frequency measure. This measure is helpful when ground truth image is not available and high accuracy measure is required.
- Table 3 shows the other alternative quality parameters when the ground truth or reference image is not available, using statistical parameter it is possible to find the better quality parameter for the given image.
- Table 4 shows the results of the quality parameters when the ground truth image is available for obtaining the accuracy and better quality.

## 3. Experimental Results

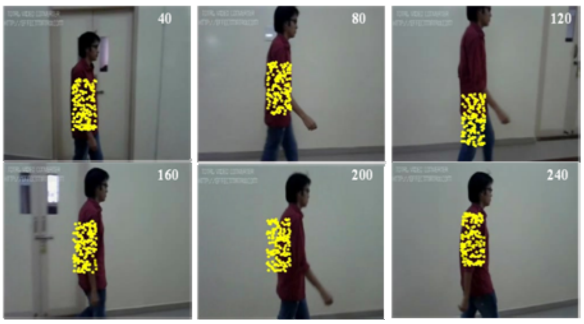


Figure 7


Figure 8


Figure 9


Figure 10


Figure 11

Fig 7 – Fig 9: Particle filter tracking for Sobel Edge Operator
Fig 10 – Fig 11: Particle filter tracking for Canny Edge Operator.

*Implementation details*
The proposed approach is implemented on Windows 7 in Microsoft Visual Studio platform using VC++ language for programming.

## 4. Conclusion

In this paper an algorithm for detection of moving object, location of the object and particle filter based tracking is proposed. Experimental results indicate that the proposed method provides better results for canny edge method obtained from the results of quality metrics. A technique for background subtraction with adaptive background model update depending on pixel differences between the background model and the previous frame is described, and a threshold is used for foreground and background detection. Particle filter is used for tracking the detected moving object.

## 5. Acknowledgements

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### Appendix

### Quality Metrics:

These are mainly used to suppress either high frequency components in the image i.e. smoothing the image or low frequency components i.e. enhancing or detecting edges in an image.

### 5.1 Mean Squared Error (MSE)

It measures the change in quality between the original image and the edge output [9].

$$MSE = \frac{1}{MN}\sum_{m-1}^{M}\sum_{n-1}^{N}(X(m,n) - X'(m,n))^2$$

Where X (m, n) - input image, X'(m, n) - output image- Height, N- Width

### 5.2 Peak Signal to Noise Ratio (PSNR)

**PSNR** is the evaluation standard of the reconstructed image quality, and is important feature. PSNR calculation of two images, one original and an altered image, describes how far two images are equal. The small value of PSNR indicates that the image is of poor quality. Higher PSNR means more noise removed [9].

$$PSNR = 10\log\frac{255^2}{MSE}$$

Where, MSE is value that is computed from first quality metric.

### 5.3 Mean Absolute Error (MAE)

The MAE measures the average magnitude of the errors in a set of forecasts, without considering their direction. It measures accuracy for continuous variables.

$$MAE = \sum_{i,j=1}^{M,N}(X(m,n) - X'(m,n))$$

Where X (m, n) – input image, X'(m, n) – output image, M - Height, N- Width.

### 5.4 ESSIM: Edge-based Structural Similarity

The primary reason of performance improvement in ESSIM is that it pays more attention to the edges and details in images, which represents the higher layer image structure information. Greater the ESSIM value more clarity in visibility.

$$e(x,y) = \frac{\sigma'_{xy} + C_3}{\sigma'_x\sigma'_y + C_3}$$

Where $\sigma_x$ and $\sigma_y$ are the standard deviation of vector $D_x$ and $D_y$ respectively, $\sigma`_{xy}$ is the covariance of vector $D_x$ and $D_y$, and $C_3$ is a small constant to avoid the denominator being zero. And the edge-based structural similarity (ESSIM) is described as follows:

$$ESSIM(x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[e(x,y)]^{\gamma}$$

### 5.5 Statistical Measures

Edge detection methods investigated are further assessed by quality measures that give reliable statistical evidence to distinguish among the edge maps obtained.

### 5.5.1Relative Frequencies

$R_f$ = no. of edge pixels / total no of pixels.

**5.5.2T-Statistics:**

T-Statistics = (mean1-mean2) / √ ((var1/no. of pixels) + (var2/no. of pixels))

**5.5.3Confidence Interval (CI):**

Confidence Interval = (Mean-t_stat * (s / √N), Mean + t_stat * (s / √N))

## 6. Reduced Reference Metrics

It is a quantitative performance measure where the comparison is made between the edges in captured image and the ground truth image.

### 6.1 Pratt's Figure of Merit(FOM)

This measure uses the distance between all pairs of points corresponding to quantify, with precision, the difference between the contours. The figure of merit of Pratt, which assesses the similarity between two contours, is defined in below formula and Ranges between (0, 1) and is defined as follows:

$$IMP = \frac{1}{\max(NI, NB)} \sum_{i=1}^{NB} \frac{1}{1 + \alpha * d_i^2}$$

where NI and NB = Edge points in the image and ground truth image. di = Distance between edge pixel and the nearest edge pixel of the ground truth, Empirical calibration constant α= 1/9

### 6.2 Global Index

A new global index, which is defined by Euclidean distance is $d_{E2}^4$ in $R_4$ to the point, P = (1; 1; 0; 0), where its coordinates are optimum values achieved by indices Pco, IMP, $P_{nd}$ ε $P_{fa}$ respectively. The point *P* represents the optimum point to be reached by an ideal edge detector. The distance to this point can be calculated by the equation below:

$$D_{E2}^4 = \sqrt{(Pco - 1)^2 + (IMP - 1)^2 + P_{nd}^2 + P_{fa}^2}$$

The percentage of pixels that were correctly detected ($P_{co}$):

$$P_{co} = \frac{TP}{\max(NI, NB)}$$

Where TP = True Positive, False Positive

The percentage of pixels that were not detected ($P_{nd}$):

$$P_{nd} = \frac{FN}{\max(NI, NB)} \quad P_{fa} = \frac{FP}{\max(NI, NB)}$$