Tracking of a Missile in a Video using Accelerated Chan-Vese Model

Divya Nemidoss, Muthaiah Rajappa, Jaikanth Jayakumar

Abstract*: The target of tracking is to find the trajectory of an object of interest in motion and it is one among the significant applications in image and video processing. Some of the applications of tracking are video path planning, motion based recognition and automated surveillance. The two phases involved in tracking of object of interest in motion are object detection and tracking of detected object of interest. One of the technique used for tracking of object of interest (missile) in a missile video is Chan-Vese model based tracking. Chan-Vese model based tracking consists of the following steps: Segmentation of object of interest in first frame by using deformable model (Chan-Vese model) and tracking that segmented object in consecutive frames by giving the segmentation output of previous frame as the initial contour to the successive frame. The advantage of Chan-Vese model is that it works even with noisy input image but its drawback of slow convergence to optimum solution restricts its usage to tracking application since tracking demands quick tracing of object of interest in successive frames of a video. This paper focuses on accelerating the convergence of Chan-Vese model using first order optimization scheme called Hybrid method. Hybrid method is a fusion of Nesterov accelerated gradient descent method and Barzilai and Borwein gradient descent method. The fastened algorithm has been tested with static missile image (both clean and noisy image) and also in missile video. The metrics noted were processing time (in seconds) and number of iterations. The efficiency of the proposed optimization technique has been proved through these metrics.

***Index Terms*: Chan-Vese model, segmentation, tracking**

I. INTRODUCTION

The target of tracking is to find the trajectory of an object of interest in motion and it is one among the significant application in image and video processing. It is an interdisciplinary technology with a combination of image processing, pattern recognition, artificial intelligence etc. [1]. Tracking of an object of interest is complex due to the following reasons: [2]

- Data loss because of projection of a 3D scene onto 2D space
- Quality of the image may be poor due to noise and blur
- Complexity in object movement
- Complex object shape
- Illumination
- Occlusion
- Real time processing

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There are two steps in tracking of object of interest and they are:

- Detection of object of interest using object detection algorithm
- Tracking the detected object using object tracking algorithm

Object detection is the task of identifying the object and categorizing them into their respective classes. Simply, it is the process of identifying, categorizing, discrimination of object of interest. The methods used for object detection [2], [3] are depicted in Fig.1.

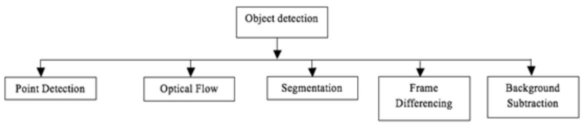

Fig. 1: Methods available for detection of object of interest

Point detection aims to find the same features between various images from different position or time. Depending upon the illumination and camera viewpoints, the interest points are plotted on the image. The object of interest is detected from those interest points. The algorithms such as Moravec's detector, KLT detector, moreover, combination of two or more detector algorithm can be used to detect object of interest using point features [4]. Point detection is not suitable for low quality images.

Optical flow detection works by initializing a contour. By performing the mathematical operations on the initial contour of the image, the closed boundaries can be obtained. From the obtained results, the contour which is having the maximum area is considered as the object of interest [5],[6]. The algorithms used for optical flow are Lucas-Kanade, Horn-Schunck, Dense optical flow. When compared to point detector, optical flow produces a satisfactory result but the drawbacks of optical flow are: (1) It requires large calculation and hence the performance time is higher [3] and (2) It is not suitable for noisy images and for those objects whose velocities are high [3].

The simplest method in object detection is frame differencing. The difference in pixel intensity between current frame and previous frame is calculated. If the difference in pixel intensity is greater than a threshold then, that particular pixel is set as pixel of object of interest. This process is continued for consecutive frames until the object of interest is detected [7]. If the object of interest fails to appear in a particular frame, then it will not be considered in the next consecutive frames. So this technique is not practically possible [3].

Background subtraction separates out the foreground pixels from the background pixels [8]. According to the requirement, either the first frame or the average of n frames can be considered as the background .Algorithms used for background subtraction are Gaussian mixture based Background Model [6], Eigen background model, Wall flower based background model, Dynamic texture based background model [4].This method requires less memory. But the main drawback is background should be stationary. Segmentation is partitioning of an image to constituent sub regions such that pixels within a region are connected and they share a common feature such as color or texture. The image is partitioned such that sub regions within an image are not similar to each other and they do not overlap with each other. Preprocessing step such as noise removal is needed in order to avoid false segmentation. Segmentation algorithms can be classified as follows:

A. Threshold based segmentation

Segmentation based on threshold is done on the intensity level of pixels. If intensity level of a pixel is greater than or equal to the defined threshold, then, that particular pixel is referred to an object pixel. The pixels whose intensity level is less than the defined threshold are called background pixels. Thresholding based segmentation is simple and easy to implement. Threshold based segmentation is not conducive for noisy images and for separating out objects with weak borders [9].

B. Edge based segmentation

Algorithms on segmentation depending on discontinuity (i.e.) sudden changes in intensity values assume that boundaries of different regions are sufficiently different from each other and these algorithms partition an image into different regions based on abrupt changes in intensity. There are three types of features that can be detected by sharp local changes in intensity. They are: (i) Point (2) Line and (3) Edge. The most common way to look for discontinuities is to scan a small kernel over the image. The kernel determines which kind of discontinuity to look for (i.e.) point or line or edge. Lot of edge detection techniques is present. Best edge detection algorithms are Robert operator, Sobel operator, Prewitt operator, Krish, Marr-Hilderth, LoG and Canny edge detection. Edge based segmentation is not suitable for noisy image and if there is a weak boundary between object of interests in an image [10].

C. Region based segmentation

Segmentation algorithms based on similarity in intensity values tend to separate an image into distinct, non overlapping regions according to predefined criterion defined in terms of gray scale intensity. A region is a group of connected pixels with similar property. Segmentation algorithms based on similarity in intensity consists of finding distinct non overlapping regions in an image by using Region growing and Region split and merge techniques [11]. Compared to algorithms on segmentation based on edge information, algorithms on segmentation using region information are more robust to noise and segment out objects with fragile boundaries.

D. Segmentation based on clustering

Searching distinct groups is clustering in feature space (i.e.) grouping of pixels in an image based on their features, into distinct groups, such that pixels within a region are identical with respect to some feature. The feature may be color or texture or gray level intensity. Thus, the clustering task divides the pixels in an image into number of partitions and these partitions are represented as volumes in n dimensional feature space.

E. Segmentation based on machine learning approach

This segmentation technique consists of using machine learning algorithms to do segmentation. The drawbacks of this approach are: (1) High computation cost (2) They are not able to model structural information such as global shape or appearance information (3) Segmentation output depends strongly on the quality of the training dataset.

F. Object tracking

Position and other relevant information of an object of interest in motion can be determined by using object tracking algorithms. Object tracking is the method of determining the position and other relevant information of moving object in a video. Tracking of can be done using any of the following methods as shown in fig.2.

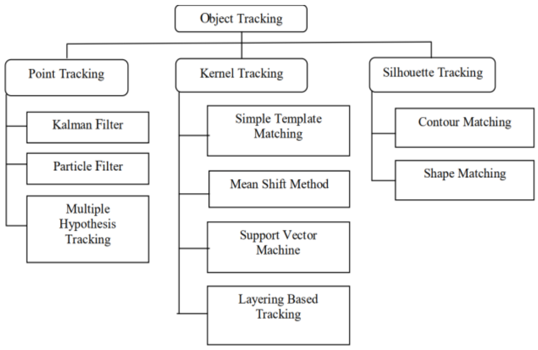

Fig 2 Object Tracking Methods [12]

Point based tracking consists of representing the object of interest by feature points. By associating the point across the frame, tracking can be done. The algorithms available for tracking of object of interest based on point features is depicted in Fig.2.The drawback of point based tracking is that it relies heavily on key-point detection and hence fails to achieve results in case of tough illumination conditions and movement blur, where it is difficult to find reliable key-points. In kernel tracking, the motion of object which is to be computed is in the first frame. Using those computed values, the consecutive frames can be tracked using any of the methods as discussed in fig 2. The drawback of kernel based tracking is that it does not suitable for objects with irregular shapes and for object and background with same features (eg: color, shape). Silhouette tracking is used for tracking of objects of complex irregular shapes since these complex irregular structures cannot be modeled by using standard geometric shapes. Silhouette based tracking can be done using shape matching or contour tracking method.

The limitations of tracking based on point based tracking and tracking based on kernel can be overcome by using Contour based approach for tracking. Contour based tracking consists of the following steps: (1) Segmentation of object of interest in first frame by using deformable model and (2) Tracking that segmented object in consecutive frames

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by giving the segmentation output of previous frame as the initial contour to the successive frame. The region based deformable model used for segmentation of region of interest is Chan-Vese (CV) model [13]. Its advantage is it is robust to noise which also makes it to work well for image with low quality. It is also able to separate out object of interest with faint boundaries. Even though there are several advantages in CV model, its drawback of slow convergence to optimum solution restricts its usage in tracking applications.

The classical method to get an optimum solution for the energy functional is to find a solution to Euler's equation of the given energy functional based on optimization technique. In CV model, Gradient Descent (GD) optimization technique was used to find the optimum solution for Euler's equation of the energy functional. The use of GD optimization scheme resulted in slow convergence towards optimum solution. Since the convergence is slow, more no. of iterations is needed to obtain an optimum solution. As the no.of iterations increase, the processing time also increases.

This paper proposes a solution to solve the problem of slow convergence towards optimum solution by accelerating the convergence speed through first order optimization scheme called Hybrid method. Hybrid method is a fusion of Nesterov accelerated gradient descent method (NAGD) and Barzilai and Borwein gradient descent (BBGD) method. In hybrid method, step size formulation in BBGD method is put in the place of fixed step size of NAGD [14].

II.PROPOSED METHODOLOGY

The underlying principle of CV model is to deform the contour under constraints and fit the contour into object of interest. The separating curve, which is unknown, is defined by the zero level set of Lipschitz function $\varphi\,(x, y, t)$.The energy functional defines the constraints on deformation. CV model is Piece wise Constant (PC) approximation of a fundamental region-based deformable model named as Mumford Shah model. Segmentation methods based on the variational approach defines energy functional and optimum solution is found by minimization of energy functional. Minimum of the energy functional is found by solving the Euler's equation to steady state by using an optimization technique. Hence the segmentation problem is posed as an energy minimization problem. The energy functional of CV model is given by (1).

$$\boldsymbol{E\,(u_1,u_2,U) = \alpha.length\,(U) + .\gamma(Area\,(U)) + \beta_1 \int_{\Omega_1} |I-u_1|^2\,dx\,dy + \beta_2 \int_{\Omega_2} |I-u_2|^2\,dx\,dy} \quad (1)$$

Where Ω_1 = connected pixels with similar property within the closed curve U and Ω_2 = connected pixels with similar property outside the curve U. u_1 = mean intensity of the pixels within the curve and u_2 mean intensity of the pixels that lie outside the curve U. α, γ, β_1 and β_2 are constants.

$$\frac{\partial E}{\partial \varphi} = -\delta_0(\varphi)\left\{\alpha.div\left(\frac{\nabla\varphi}{|\nabla\varphi|}\right) - \gamma - \beta_1(I-u_1)^2 + \beta_2(I-u_2)^2\right\} \quad (2)$$

The Euler's equation for (2) is given by $\frac{\partial E}{\partial \varphi} = 0$.

$$-\delta_0(\varphi)\left\{\alpha.div\left(\frac{\nabla\varphi}{|\nabla\varphi|}\right) - \gamma - \beta_1(I-u_1)^2 + \beta_2(I-u_2)^2\right\} = 0 \quad (3)$$

The solution to (3) is found through GD scheme (i.e.) to find solution to (4) to steady state.

$$\frac{\partial \varphi}{\partial t} = -\frac{\partial E}{\partial \varphi} \quad (4)$$

$$\therefore \frac{\partial \varphi}{\partial t} = \delta_0(\varphi)\left\{\alpha.div\left(\frac{\nabla\varphi}{|\nabla\varphi|}\right) - \gamma - \beta_1(I-u_1)^2 + \beta_2(I-u_2)^2\right\} \quad (5)$$

The approximation solution to (5) as given by GD scheme is given by (6)

$$\varphi^{(i+1)} = \varphi^i - \tau\frac{\partial E}{\partial \varphi^i} \quad (6)$$

Where step size is denoted as τ. Given φ at $t = 0$, φ at any point in time can be found by using $\frac{\partial \varphi}{\partial t}$. Optimum is attained when initial contour (u_0) fits exactly onto the curve that separates object of interest from background (U).

As said above, the use of GD method to solve Euler's equation of energy functional of CV model causes slower convergence of level set to steady state. Since the convergence to steady state is slow, more no. of iterations is needed to obtain an optimum solution. As the no.of iterations increase, the processing time also increases.

This limitation of slow convergence towards optimum solution is accelerated by using hybrid method. Hybrid method is a fusion of NAGD and BBGD method. NAGD employs fixed step size. In hybrid method, step size formulation in BBGD method is put in the place of fixed step size of NAGD [14]. The formula for hybrid method is given by (7) and its work flow is depicted in Fig.3.

Equation for Level set updation using hybrid method:

$$\varphi^{i+1} = y^i - \tau\nabla f(y^i) \quad (7a)$$

$$y^i = \varphi^i + \left(\frac{i-1}{i+2}\right)[\varphi^i - \varphi^{i-1}] \quad (7b)$$

$$\tau = \left(\frac{\varphi^i - \varphi^{i-1}}{g^i - g^{i-1}}\right);\; g^i = \frac{\partial E}{\partial \varphi^i};\; g^{i-1} = \frac{\partial E}{\partial \varphi^{i-1}} \quad (7c)$$

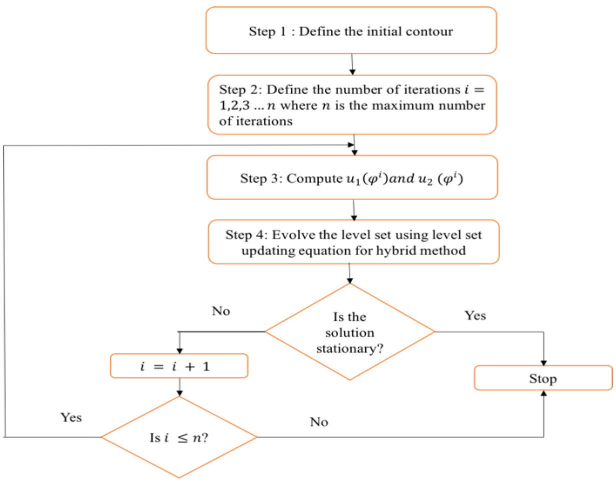

Fig. 3: Flow Chart of CV model with hybrid optimization scheme

III. RESULTS AND DISCUSSION

CV model with GD optimization technique and CV model with proposed hybrid optimization technique are tested with missile image and missile video and metrics such as number of iteration and processing time are noted. Tracking simulations were done in a computer system with i5 core @ 2.20 GHz, 8 GB RAM. The tool used was MATLAB 2016b version.

CV model with GD has been tested with a noise free missile image and this result is shown in Fig.4. The maximum iterations used by the user is 50,000 but the optimum solution was obtained by running for 14,036 iterations. The processing time was 355 seconds. The details of processing time in seconds for CV model with GD optimization scheme and CV model with hybrid optimization scheme is furnished in Table 1.

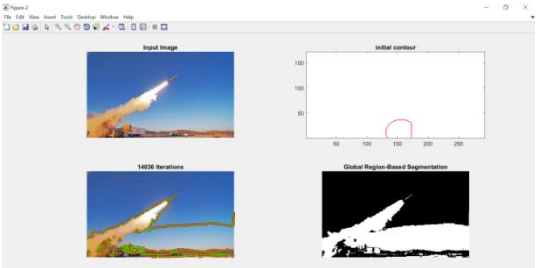

Fig.4 Segmented output attained by using CV model with GD scheme for clean image

CV model with hybrid optimization technique has been tested with a noise free missile image and this result is shown in Fig.5. The maximum iterations used by the user is 50, 000 but the optimum solution was obtained by running for 5 iterations. The processing time was 2 seconds. The details of processing time in seconds for the models used are furnished in Table 1.

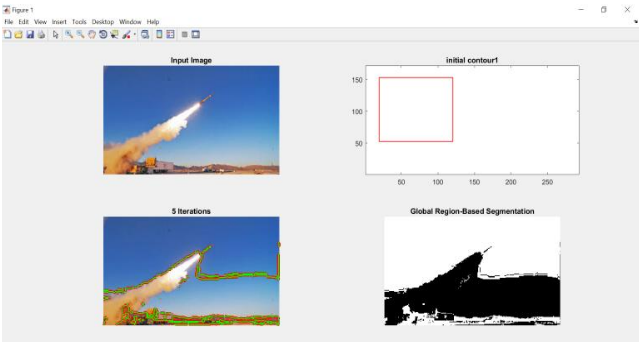

Fig. 5: Segmented output attained by using CV model with hybrid optimization scheme

From Fig.5, it is clear that CV model with hybrid optimization technique on noiseless image took only 5 iterations to segment out the object of interest and the processing time was 2 seconds which is drastically small when compared to CV model with GD optimization scheme which took 14,036 iterations and processing time was 355 seconds. Thus the hybrid optimization technique reduced the no.of iterations by 99.96% and processing time by 99.44%.

CV model with GD optimization method has also been tested with a noisy missile image (Gaussian noise with a variance 0.1) and this result is shown in Fig.6. The maximum iterations used by the user is 50,000 but the optimum solution was obtained by running for 7476 iterations. The processing time was 195 seconds. The details of processing time in seconds with these models are furnished in Table 1.

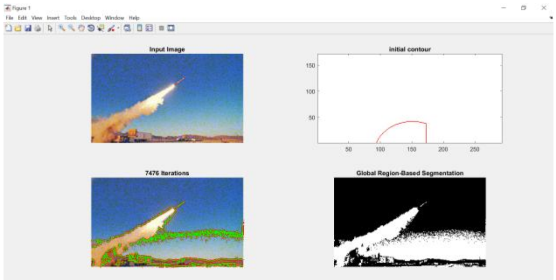

Fig.6: Segmented output attained by using CV model with GD scheme for noisy image

CV model with hybrid optimization technique has also been tested with a noisy missile image (Gaussian noise with a variance 0.1) and this result is shown in Fig.7. The maximum iterations by the user is 50,000 but the optimum solution was obtained by running for 5 iterations. The processing time was 2 seconds. The details of processing time in seconds are furnished in Table 1.

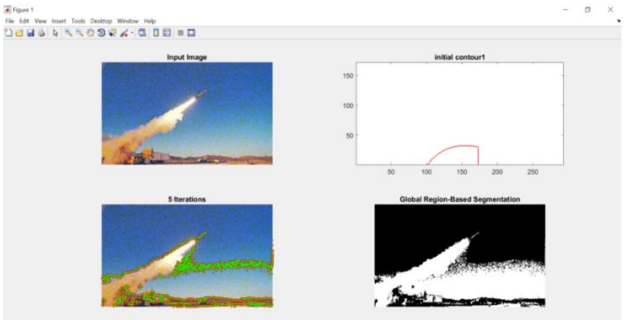

Fig .7: Segmented output attained by CV model with hybrid optimization scheme for noisy image

From Fig.7, it is clear that our chosen model is compared with hybrid optimization technique on noiseless image took only 5 iterations to segment out the object of interest and the processing time was 2 seconds which is drastically small when compared to CV model with GD optimization scheme which took 7476 iterations and processing time was 195 seconds. Thus the proposed optimization technique reduced the no. of iterations by 99.93% and processing time by 98.97%.

Table 1: Metrics for CV model with GD optimization scheme and CV model with hybrid optimization scheme

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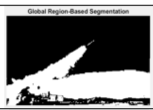
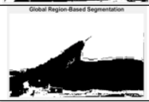
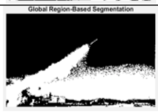
Input Image				
Optimization technique	**Type of input**	**Segmented Output**	**Iteration count**	**Processing time in seconds**
GD	Clean missile image		14,036	355
Hybrid method	Clean missile image		5	2
GD	Noisy missile image		7476	195
Hybrid method	Noisy missile image		5	2

CV model with hybrid optimization scheme was experimented with a missile video. The duration of the video is 10 seconds. This video is separated out into frames and the no. of frames was 272. CV model with hybrid optimization technique is applied in frame 1 to segment out the object of interest. This segmented out object of interest in frame 1 is given as initial contour to frame 2 (i.e.) the segmentation output obtained at n^{th} frame is given as initial contour to $n+1^{th}$ frame and tracking is done by tracking the contour of Object of interest. This is shown in Fig.8. The time taken to track a missile using our chosen model with proposed optimization technique in a missile video of 10 seconds was 766 seconds and this is shown in Fig.9.

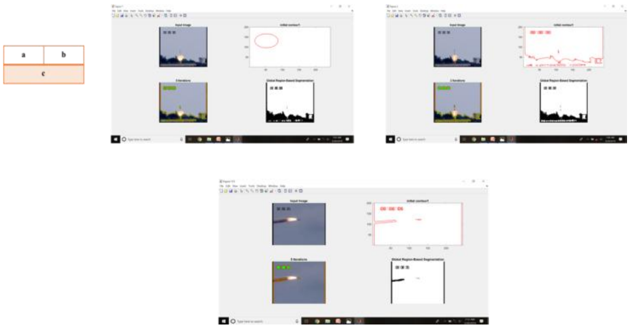


Fig.8: (a) Segmentation output obtained in frame 1. (b) Segmentation output obtained in frame 2 by giving frame 1 segmented output as initial contour to frame 2. (c) Segmentation output obtained in frame 125.

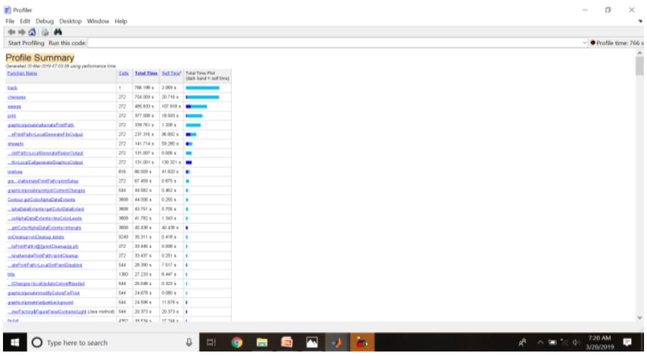


Fig. 9: Time taken to track a missile using CV model with hybrid optimization technique in a missile video of 10 seconds.

From the above results, it is clear that our chosen model with proposed optimization technique track the object of interest with reduced iterations and executing time without visual quality trade-off.

IV. CONCLUSION

Tracking is one among the significant applications in image and video processing. Various object detection techniques along with the merits and demerits are discussed. CV model has been adopted to detect the object of interest. This model can work well even with degraded (noisy) input image. This has been shown in Fig.6. CV model can also segment out objects with weak boundaries since it doesn't rely on edge information for finding out object of interest. Region information of region of interest is utilized to attract the initial contour in the direction of object of interest. In spite of several advantages of CV model, its drawback of slow convergence to optimum solution restricts its usage to tracking application since tracking demands quick tracing of object of interest in a series of frames of a video. This motivated towards accelerating the convergence towards optimum solution by using first order optimization scheme called Hybrid method. Hybrid method is a fusion of NAGD and BBGD method and it consists of replacing the fixed step size formulation in NAGD by step size formulation in BBGD scheme. Both these schemes are first order optimization techniques. The fastened algorithm has been tested with missile image (Clean and noisy image) and also in missile video. The metrics noted were processing time (in seconds) and number of iterations. The efficiency of the proposed optimization technique has been proved through these metrics. The proposed optimization technique reduced the no.of iterations by 99.96% and processing time by 99.44% for clean missile image. Similarly, the proposed optimization technique reduced no.of iterations by 99.93% and processing time by 98.97% for noisy image. Tracking of 10 seconds missile video was completed in 766 seconds by using proposed optimization scheme. From the above results, it can be concluded that CV model with hybrid optimization scheme is best suited for tracking applications since the no.of iteration required for tracking the object of interest and processing time (in seconds) for tracking the object of interest is very less when compared to CV model with GD optimization scheme.

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