Comparative Analysis of Single Target Tracking Algorithms in IR Imaging

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***Abstract*—Target tracking plays a vital role in the development of battlefield surveillance, airspace surveillance and Border Patrolling. The rapid uses of IR imaging in target tracking prevents from a wide range of attacks in border security, sea shore security. IR imaging is an effective method to cluster heat generating targets and it can penetrate fog, haze, dust, smoke, snow, rain and extreme darkness operate at day and night. Infrared imagery is one of the major and efficient defensive medium in surveillance and monitoring activity. In this paper, an introduction of target tracking algorithms in IR imaging is discussed and detection algorithms with tracking algorithm are implemented and analyzed. This will open the new area for the researcher in the research field of security.**

Keywords—Infrared Imagery, Target Tracking Algorithms.

I. Introduction

A. Infrared Imagery

Sir William Herschel, an astronomer, discovered infrared in year 1800. Infrared (IR) light is electromagnetic radiation, range of wavelengths (0.74 µm to 1000 µm) and includes thermal radiation emitted by objects near room temperature. Infrared light is emitted or absorbed by molecules when they change their rotational-vibrational movements. It is effective method to cluster heat generating target [1-3]. A thermal imaging device gives the ability to see targets in darkness or smoke. Thermal imaging is a technology that creates a photographic image or video sequence of light emitted by an object at terrestrial temperatures [13-14]. Infrared (IR) thermal imaging, also often briefly called thermography, is not the same as night vision. Night vision operates on the principle of light amplification, so in a totally dark environment light amplification would yield no image where as a thermal imager would based on Emitted Energy + Transmitted Energy + Reflected Energy[1-2][4]. There are numbers of merits of infrared imagery in target tracking such as

- Infrared sensors can detect camouflaged objects.
- Infrared Imaging is not affected by illumination conditions.
- Infrared sensors are passive and involve one-way propagation.
- Infrared imaging has some medical application, essentially in physiotherapy.
- Infrared imaging can successfully penetrate harsh environment such as fog, dust, smoke, snow and rain.
- Infrared imagery can even operate during night time and low light conditions.
- Infrared imagery is capable of catching moving targets in real time.

B. Target Tracking

Target tracking has been an intensive research area since the early 1960s, driven primarily by aerospace applications such as radar, sonar, guidance, navigation, and air traffic control. It has also found applications in biological systems, econometrics, robotics and sensor networks. Target is generally described as any area of interest such as persons, mammals, birds, air vehicles, land vehicles, water vehicles, and buildings. Tracking is the process of locating a moving object over time using a camera [1-2]. The objective of video tracking is to associate target objects in consecutive video frames. To perform video tracking an algorithm analyzes sequential video frames [5-6] and outputs the movement of targets between the frames so we say that Target Tracking can be defined as the problem of estimating the trajectory of an object or target in the image plane as it moves around a scene[1-2]. There are number of merits of Target Tracking such as

- Tracking is the key for monitoring motion parameters, such as location, velocity, orientation and acceleration, are obtained by targets.
- A target tracking is used for recognizing and understanding target behaviours, especially suffering from illumination, scale, pose variations and occlusions.

Target tracking can be classified in two forms:

1) *Single Target Tracking:* A single target and single sensor scenario consists of a target whose state evolves through time and is only partially observed by a sensor at discrete intervals of time. The objective is to estimate the state of a target given a sequence of observations made by the sensor up to the current time step [10].

2) *Multiple Target Tracking:* In a multiple target tracking scenario, the number of targets changes over time as new targets may appear in the surveillance region due to spontaneous target birth. Moreover, existing targets may not survive to the next time interval and disappear from the scene. The duration for which a target exists in the surveillance region is unknown. At the sensor, not all targets present in its field of view generate measurements [1-2][3].

C. Target Tracking Procedure

In this target tracking, first step is infrared video acquisition then split this video into frames. Second step is to do pre-process theses frames means eliminate noise added during video acquisition or transmission [15]. Background modeling or foreground detection in infrared video is used in third step [7-9]. In this paper background modeling is used such as single frame differencing (SRF), Running Average (RA), Temporal median filter (TMF). In the fourth step, tracking is performed with Kalman filter and labeling based connected component and Mean Shift Filter (MSF), Blob analysis (BA) with Gaussian mixture Model (GMM). There are also some other methods in which tracking is performed before detection, called track before detect (TBD). Here, in this paper tracking is performed after detection of target or directly with the tracking filter. In the last step, the performance of tracking algorithm along with selected detection algorithm will be evaluated through performance metrics like Sensitivity (s) measure, Positive Predictive Value (PPV), Target Tracking Accuracy Rate (TTAR) and Tracking Accuracy Rate (TAR) as shown in Fig 1.

II. Types of Tracking Alogrithm

There are many types of algorithms which usually use in target tracking but in infrared, some other classification of tracking algorithm is used by researcher. Tracking can be done through target representation and localization or by the use of filtering and data association [3-4]. Target representation and localization is mostly a bottom –up process which has also to cope with change in the appearance of the target. There are some common target representations and localization algorithms such as blob tracking, kernel based tracking, contour tracking. Filtering and data association is mostly a top – down process dealing with the dynamics of the tracked object, learning of scene priors, and evaluation of different hypotheses[6-9]. Some filters for tracking are such as optimal Bayesian filter, linear filter (Kalman filter), non-linear filter (extended Kalman, unscented Kalman, Gaussian sum filter, particle filter) and techniques for data association are such as nearest neighbour standard filter, probabilistic data association filter, multiple hypothesis tracking [22-26], Random sets for multi-target tracking. According to A.Yilmaz et al [4] object tracking is classified into three parts such as point tracking, kernel tracking, silhouette tracking. Point tracking consists of MGE tracker, GOA tracker, Kalman filter, JPDAF, PMHT and kernel tracking consists of mean- shift, KLT, Eigntracking, SVM tracker and Silhouette Tracking consists of state space models, heuristic methods, Hough transform, and histogram [3-4].

III. Comparative Analysis of Different Detection Algorithm with Tracking Algorithm

In this section, target detection algorithms such as Single Reference Frame (SRF) and Running Average (RA), Temporal Median filter (TMF) along with Kalman filter (KF) [11-12], Mean shift filter, Blob analysis (BA) with Gaussian mixture model (GMM) are applied on Ohio State University (OSU) Infrared dataset.

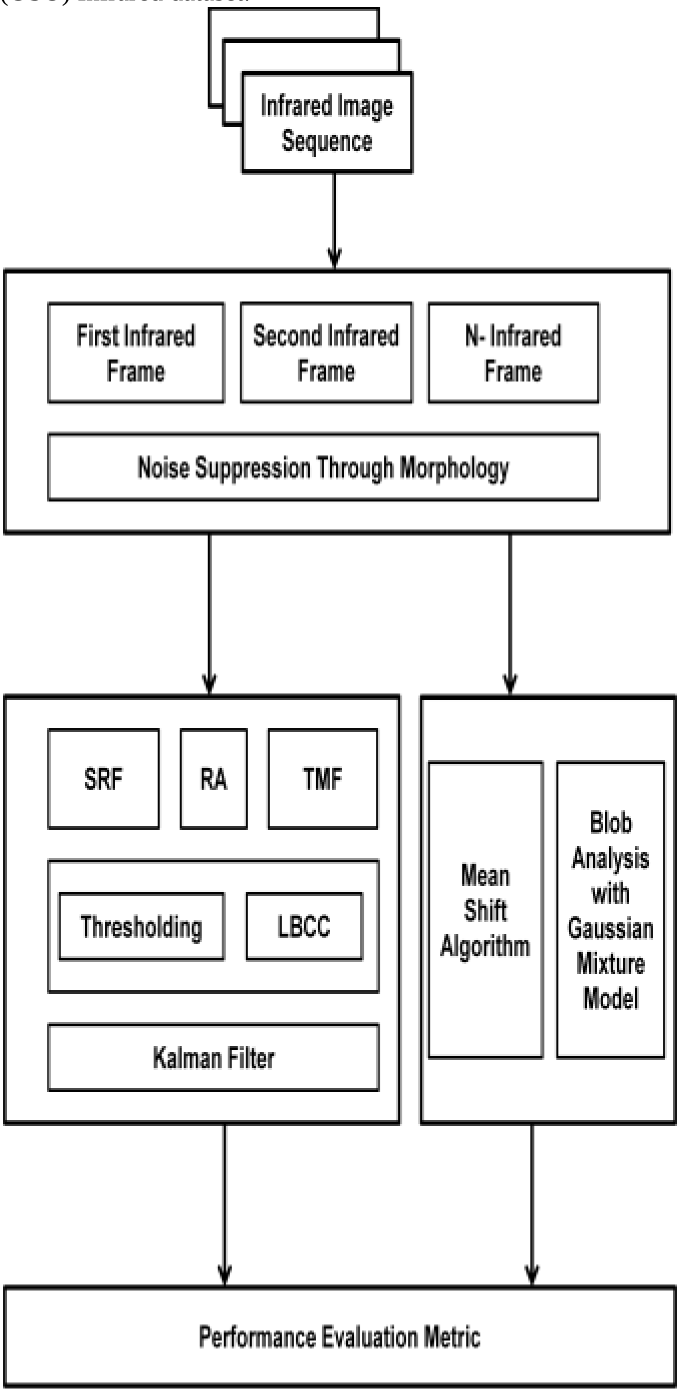


Fig 1. Proposed Diagram of Target Tracking Procedure

The detection and tracking performance are analyzed on the parameters such as True Positive, True Negative, false negative, false positive, sensitivity, Positive Predictive Value, Tracking accuracy rate (TAR) using f-measure, Target Tracking Accuracy rate (TTAR)[30].

- *True Positive (TP):* It is defined as when some of these frames have the target and the method says they are positive[31].

$$\mathrm{TP} = \frac{\sum_{\mathrm{i}} \mathrm{TP(i)}}{\sum_{\mathrm{i}} \mathrm{GT(i)}}$$

- *False Negatives (FN):* It is defined as when some of these frames have the target but the method claims they are no real target [31].

$$\mathrm{FN} = \frac{\sum_{\mathrm{i}} \mathrm{FN(i)}}{\sum_{\mathrm{i}} \mathrm{GT(i)}}$$

- *True Negative (TN)*: It is defined as when some of these frames don't have the target and the method also says they are no real target [31].

$$\mathrm{TN} = \frac{\sum_{\mathrm{i}} \mathrm{TN(i)}}{\sum_{\mathrm{i}} \mathrm{GT(i)}}$$

- *False Positives (FP):* It is defined as when some of these frames don’t have target but the method claims that target are present [31].

$$\mathrm{FP} = \frac{\sum_{\mathrm{i}} \mathrm{FP(i)}}{\sum_{\mathrm{i}} \mathrm{GT(i)}}$$

- *Sensitivity (S):* It is defined as the fraction of targets that were correctly detected by the system. High Sensitivity value shows high detection rate but it does not give information of false positives (FP) [31].

$$\mathrm{S} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} * 100$$

- *Positive Predictive Value (PPV):* It is defined as the fraction of detections that actually are true targets. High Positive predictive value (PPV) shows a low false alarm rate [31].

$$\mathrm{PPV} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FP}} * 100$$

- *False Alarm Rate (FAR):* It is defined as subtraction ratio of total value and positive predictive value [31].

$$\mathrm{FA}R = (1 - \mathrm{PPV})$$

- *Tracking Accuracy Rate (TAR):* It is defined as to check the accuracy of tracking method with f-measure. It is harmonic mean of sensitivity and positive predictive value [31].

$$\mathrm{TAR} = 1/n \sum_{i=1}^{n} [x(i)]^{-1}$$

Where x (i) is sensitivity and positive predictive value.

- *Target Tracking Accuracy rate (TTAR):* which represents the method’s accuracy considering all object configuration errors made by the tracker, false positive, misses, mismatches over all frames [31].

$$\mathrm{TTAR} = 1 - \frac{\sum_{\mathrm{i}} (\mathrm{FN(i)} + \mathrm{FP(i)} + \mathrm{FAR(i)})}{\sum_{\mathrm{i}} \mathrm{GT(i)}}$$

In this paper, three different infrared dataset are used to analyze the detection and tracking accuracy from IEEE OTCBVS WS Series Bench, Roland Miezianko, Terravic Research Infrared Database [29]. The first data set is one object is walking from left to right side of the FOV holding an AK-47 rifle. Object fills ~10% of the field of view. The second data set is an object enters the FOV from the left. The object is partially & full occluded and continues walking right, and third dataset is an object walking in line somewhat perpendicular to the camera sensor, holding an AK-47 rifle. Object walks away then turns around and comes back toward the camera. Object's size decreases and then increases in this video sequence. Object initially fills ~40% of the field of view in which sensor details are Raytheon L-3, Thermal-Eye 2000AS, Format of images = 8-bit grayscale JPEG, image size = 320 x 240 pixels. All the experimented results on these infrared images are shown in Fig. 3 with Data1 (Frame no: 60, 90,120), Data2 (Frame no: 40, 190,240), Data3 (Frame no: 30, 100, 400, 800,900, 1100). In these all frames, green and red rectangles are moving around the target that represents the current estimation and prediction for next stage [28]. For analyzing and predicting the tracking accuracy rate, TAR, TTAR, PPV, FAR are measured. Result analysis of target detection and tracking are shown in Table I [30]

Single reference frame (SRF) with kalman filter (KF) is less efficient in case of thermal imagery to detect and track the target due to sensitive to noise and variation in illumination and high susceptibility for slight change in atmospheric condition, it is suitable for normal visible images but it cannot track varying intensity object of infrared image sequences.

Running average (RA) with kalman filter (KF) [11] is working properly in partial occlusion but not working in full occlusion like a tree lying in middle of the frame [27]. Running average with Kalman is more suitable to track those objects in an environment where there may be changes in size of the objects but it is not fitted for non-uniform object in infrared imagery. It is also suited for normal visible image or colour image sequences.

In this Mean Shift algorithm method [16], black rectangle is moving around the target that represents the estimation of target location in these all frames. Mean Shift tracking is more suitable to visible imagery besides of infrared imagery [16-21]. The initial value of mean shift iteration is unreasonable, so it is unable to track the rapid movement target. The target pixel information can’t be updated adaptively and kernel window width cannot change adaptively, making it easy to generate the accumulated error. It is easy to lose target under complex background in thermal. Mean Shift tracking is also not working properly in partial occlusion and full occlusion in data sequence 2 due to high false negative. The Mean Shift algorithm almost lost target after 100th frame in data sequence 2, so it has poor tracking accuracy.

Blob analysis (BA) with Gaussian mixture model (GMM) [31] is not tracked in target size variation of thermal imagery. Two things are not detected and tracked by GMM. Firstly, it is less sensitive of variation in target size and second thing; it is not working when target stops for a while [28]. The Gaussian mixture model as it is presented here has the disadvantage that all eigenvectors of the local covariance matrix need to be extracted. However, its computational problem has greatly limits its application. It also has difficulty in segmenting objects that stop for a while during moving.

In this paper, we have implemented the different algorithm on benchmark data set of [30] Ohio state university infrared image sequence and done some performance test like f- measure for sensitivity and target accuracy rate (TAR) and target tracking accuracy rate are calculated that are shown in different graphs.

Original OSU Infrared Image Sequence Data 1

Original OSU Infrared Image Sequence Data 2

SRF with Kalman Filter Data 1

SRF with Kalman Filter Data 2

Running Average with Kalman Filter Data 1

Running Average with Kalman Filter Data 2

Temporal Median Filter with Kalman Filter Data 1

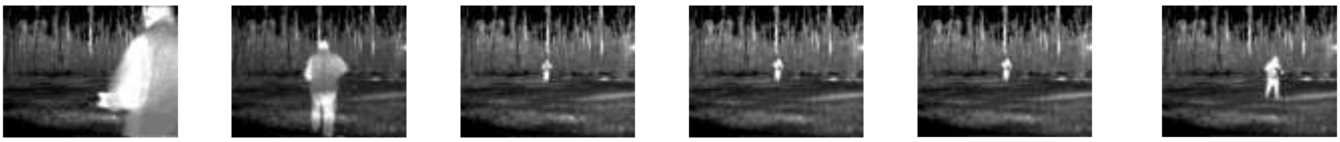
Temporal Median Filter with Kalman Filter Data 2

Mean Shift Filter Data 1

Mean Shift Filter Data 2

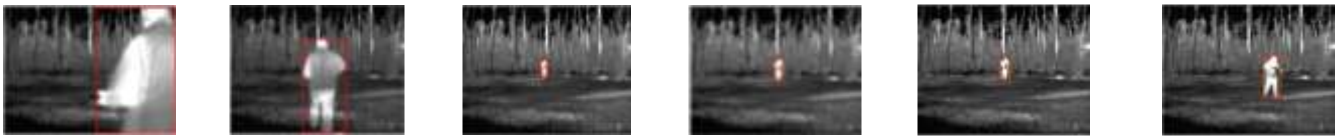
Blob Analysis with Gaussian Mixture Model Data 1

Blob Analysis with Gaussian Mixture Model Data 2

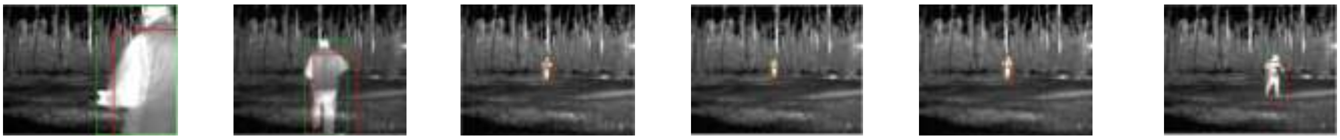


Original OSU Infrared Image Sequence Data 3

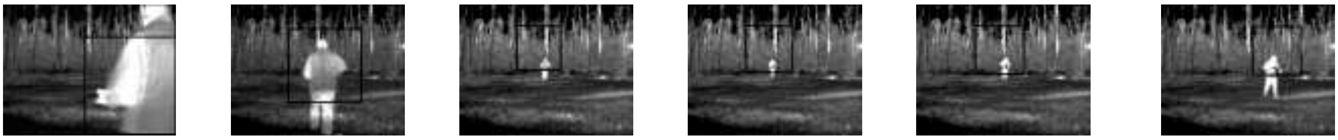
SRF with Kalman Filter Data 3



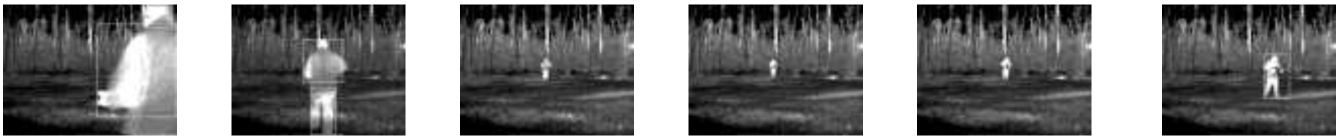
RA with Kalman Filter Data 3



TMF with Kalman Filter Data 3



Mean Shift Filter Data 3



Blob Analysis with GMM Data 3

Fig 2. Results of OTCBVS Infrared Image Sequence on SRF, RA, TMF with Kalman Filter, MSF and BA with GMM

Table I: Result Analysis of Target Tracking Algorithms

S.No	**Infrared Data Sequences**	**Total Frame**	**Ground Truth**	**Single Reference Frame with Kalman Filter**							
				TP	**FP**	**FN**	**S**	**PPV**	**FAR**	**TAR**	**TTAR**
1	Single men with Gun	190	162	147	3	8	0.948	0.980	0.02	0.945	0.932
2	Single men with Partial and full Occlusion	440	415	374	5	2	0.994	0.986	0.013	0.969	0.983
3	Single men move from front to last	1210	1193	1149	6	1	0.999	0.994	0.005	0.95	0.94
TOTAL		**1840**	**1770**	**1670**	**14**	**11**	**0.980**	**0.986**	**0.012**	**0.954**	**0.951**

S.No	**Infrared Data Sequences**	**Total Frame**	**Ground Truth**	**(Moving)Running Average with Kalman Filter**							
				TP	**FP**	**FN**	**S**	**PPV**	**FAR**	**TAR**	**TTAR**
1	Single men with Gun	190	162	148	2	6	0.961	0.986	0.013	0.975	0.950
2	Single men with Partial and full Occlusion	440	415	380	3	2	0.994	0.992	0.007	0.994	0.988
3	Single men move from front to last	1210	1193	1165	4	1	0.999	0.996	0.003	0.983	0.995
TOTAL		**1840**	**1770**	**1693**	**9**	**9**	**0.984**	**0.991**	**0.007**	**0.984**	**0.977**

S.No	**Infrared Data Sequences**	**Total Frame**	**Ground Truth**	**Temporal Median Filter with Kalman Filter**							
				TP	**FP**	**FN**	**S**	**PPV**	**FAR**	**TAR**	**TTAR**
1	Single men with Gun	190	162	149	0	0	1	1	0	1	1
2	Single men with Partial and full Occlusion	440	415	335	1	1	0.979	0.997	0.003	0.987	0.9807
3	Single men move from front to last	1210	1193	1175	1	4	0.988	0.999	0.001	0.993	0.9874
TOTAL		**1840**	**1770**	**1659**	**2**	**5**	**0.989**	**0.998**	**0.001**	**0.993**	**0.989**

S.No	Sequence	Total Frame	Ground Truth	Mean Shift algorithm							
				TP	FP	FN	S	PPV	FAR	TAR	TTAR
1	Single men with Gun	190	162	152	11	3	0.98	0.932	0.068	0.955	0.913
2	Single men with Partial and full Occlusion	440	415	218	5	214	0.50	0.977	0.023	0.661	0.472
3	Single men move from front to last	1210	1193	1191	18	4	0.996	0.985	0.015	0.990	0.981
TOTAL		**1840**	**1770**	**1561**	**34**	**221**	**0.825**	**0.964**	**0.0353**	**0.868**	**0.788**

S.No	Infrared Data Sequences	Total Frame	Ground Truth	Blob Analysis with Gaussian Mixture Model							
				TP	FP	FN	S	PPV	FAR	TAR	TTAR
1	Single men with Gun	190	162	160	0	0	1	1	0	1	1
2	Single men with Partial and full Occlusion	440	415	414	0	0	1	1	0	1	1
3	Single men move from front to last	1210	1193	648	3	750	0.463	0.995	0.005	0.631	0.368
Total		**1840**	**1770**	**1222**	**3**	**750**	**0.821**	**0.998**	**0.001**	**0.877**	**0.789**

S.No	Infrared Data Sequences	Total Frames	Sensitivity (S)				
			SRF with KF	RA with KF	TMF with KF	MSF	BA with GMM
1	Single men with Gun	190	0.948	0.961	1	0.98	1
2	Single men with Partial and full Occlusion	440	0.994	0.994	0.979	0.50	1
3	Single men move from front to last	1210	0.999	0.999	0.988	0.996	0.463
Total		**1840**	**0.980**	**0.984**	**0.989**	**0.825**	**0.821**

S.No	Infrared Data Sequences	Total Frames	Positive predictive value (PPV)				
			SRF with KF	RA with KF	TMF with KF	MSF	BA with GMM
1	Single men with Gun	190	0.980	0.986	1	0.932	1
2	Single men with Partial and full Occlusion	440	0.986	0.992	0.997	0.977	1
3	Single men move from front to last	1210	0.994	0.996	0.999	0.985	0.995
Total		**1840**	**0.986**	**0.991**	**0.998**	**0.964**	**0.998**

S.No	Sequence	Total Frames	Tracking Accuracy Rate (TAR)				
			SRF with KF	RA with KF	TMF with KF	MSF	BA with GMM
1	Single men with Gun	190	0.945	0.975	1	0.955	1
2	Single men with Partial and full Occlusion	440	0.969	0.994	0.987	0.661	1
3	Single men move from front to last	1210	0.95	0.983	0.993	0.990	0.631
Total		**1840**	**0.954**	**0.984**	**0.993**	**0.868**	**0.877**

S.No	Infrared Data Sequences	Total Frames	Target Tracking Accuracy Rate (TTAR)				
			SRF with KF	RA with KF	TMF with KF	MSF	BA with GMM
1	Single men with Gun	190	0.932	0.950	1	0.913	1
2	Single men with Partial and full Occlusion	440	0.983	0.988	0.980	0.472	1
3	Single men move from front to last	1210	0.94	0.995	0.987	0.981	0.368
Total		**1840**	**0.95**	**0.977**	**0.989**	**0.788**	**0.789**

Temporal median filter (TMF) with kalman filter (KF) performs better in the case of single target tracking in thermal imagery. In single target detection and tracking, this method gives best results in thermal data sequence 1 and 2. Temporal Median Filter (TMF) with Kalman Filter (KF) is working properly in partial occlusion and full occlusion. There is a pose variation and change in size of the target in sequence 3 but overall it detects and tracks the single target efficiently in comparison of single reference frame (SRF) with kalman filter and running average (RA) with kalman filter. It is more sensitive (near to unity) to detect and track the target in thermal imagery as shown in table. TMF with KF is more sensitive towards target detection and tracking and its positive predictive value is also high in comparison of other methods as shown in table I [31]. So high positive predictive value means low false alarm rate (FAR) as shown in table I. Its tracking accuracy rate (TAR) towards target and target tracking accuracy rate (TTAR) [30] are also good in infrared imagery due to less all false positive and false negative. All the results are shown in figure 2 and 3.

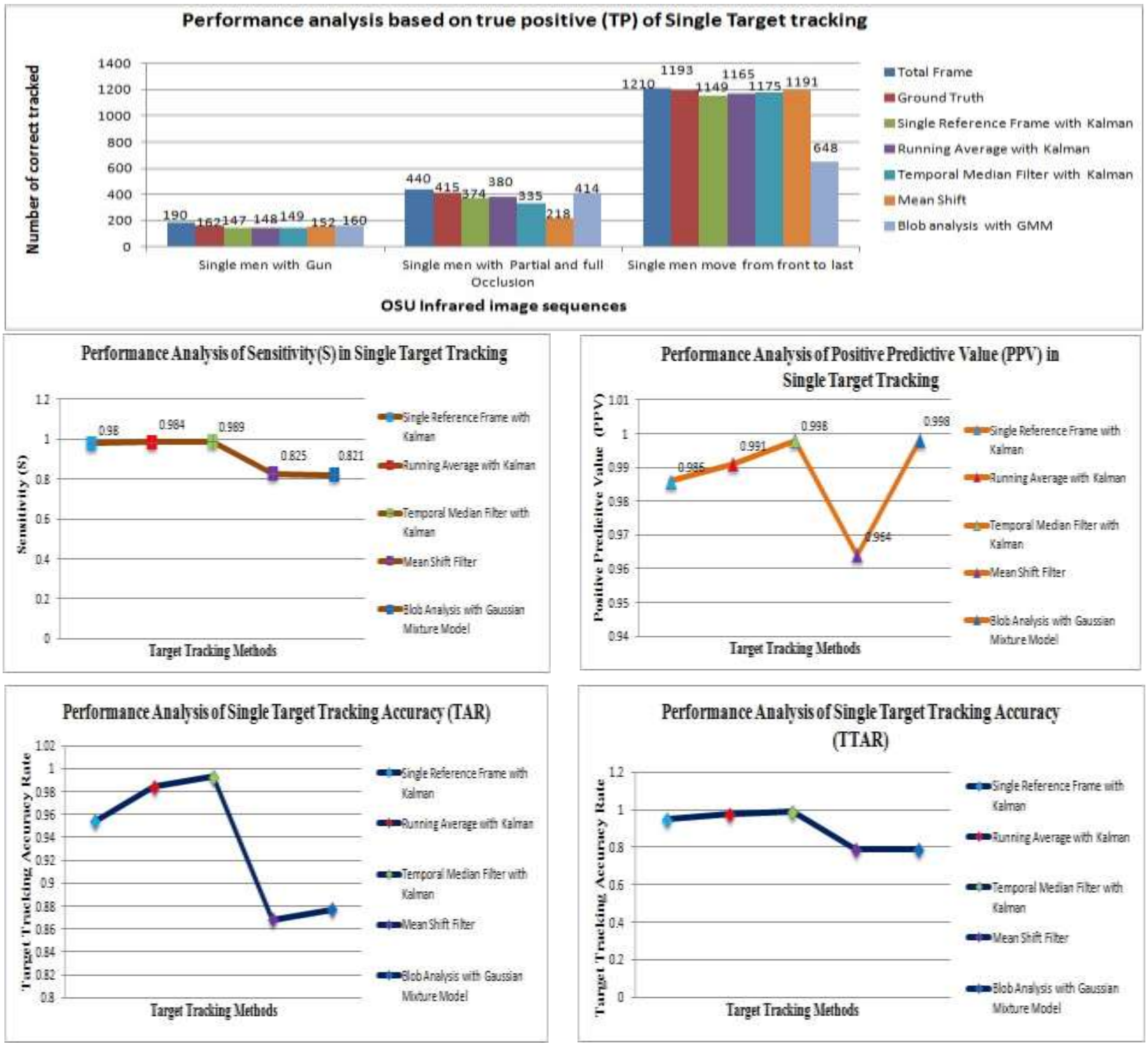


Fig 3. Comparative analysis of performance parameters in Single Target Tracking

IV. Conclusion

In this paper, we presented a brief review of different approaches of target tracking in infrared imaging. Temporal median filter (TMF) with kalman filter (KF) gives good result in tracking the target either single target in thermal imagery in comparison of these four tracking methods (SRF with KF, RA with KF, MS, BA with GMM) but there is limitation of temporal median filter with kalman filter in that temporal median filter with kalman filter has less false positive and false negative in comparison of these four methods but an effective and efficient tracking method it need more precise. Temporal median filter (TMF) with kalman filter (KF) is best method to detect and track the targets in infrared imagery. This comparative analysis could be helpful to enhance the security in many areas such as biological systems, econometrics, robotics and sensor network, intelligent transportation system, remote sensing, perimeter security system, intelligent transportation system and surveillance where it may contribute to save, sustain and protect human life.

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REFERENCES

[1] U. Gupta, M.Dutta, and M. Vadhavaniya, “Analysis of target tracking algorithm in thermal imagery,” International Journal of Computer Applications, vol. 71, pp. 12443-9140, June 2013.

[2] U. Gupta, M.Dutta, and M. Vadhavaniya, “ Target tracking algorithm in infrared imagery,” National Conference on Electrical systems & energy technologies (ESET-2013), vol. 1, pp.169-174, June 2013

[3] Comaniciu, Ramesh, Meer, “Kernel-based object tracking," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol.25, no.5, pp.564-577, May 2003

[4] Yilmaz, Alper, Omar Javed, and Mubarak Shah. "Object tracking: A survey."*Acm Computing Surveys (CSUR)*, 2006.

[5] J.-t. Wang, D.-b. Chen, H.-y. Chen, and J.-y. Yang, "On pedestrian detection and tracking in infrared videos," Pattern Recognition Letters, vol. 33, pp. 775-785, 2012.

[6] P. Dollar, C. Wojek, B. Schiele, and P. Perona, "Pedestrian detection: An evaluation of the state of the art," IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 34, pp. 743-761, 2012.

[7] S. Y. Elhabian, K. M. El-Sayed, and S. H. Ahmed, "Moving object detection in spatial domain using background removal techniques-state-of-art," Recent patents on computer science, vol. 1, pp. 32-54, 2008.

[8] M. Van Droogenbroeck and O. Paquot, "Background subtraction: experiments and improvements for vibe," IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops (CVPRW), pp. 32-37, 2012.

[9] H. Sun, C. Wang, B. Wang, and N. El-Sheimy, "Pyramid binary pattern features for real-time pedestrian detection from infrared videos," Neurocomputing, vol. 74, pp. 797-804, 2011.

[10] Z. Chaohui, D. Xiaohui, X. Shuoyu, S. Zheng, and L. Min, "An improved moving object detection algorithm based on frame difference and edge detection," Fourth International Conference on Image and Graphics, pp. 519-523, 2007.

[11] Y. Zheng and L. Fan, "Moving object detection based on running average background and temporal difference," International Conference on Intelligent Systems and Knowledge Engineering (ISKE), pp. 270-272, 2010.

[12] M.-H. Hung, J.-S. Pan, and C.-H. Hsieh, "Speed up temporal median filter for background subtraction," First International Conference on Pervasive Computing Signal Processing and Applications (PCSPA), pp. 297-300, 2010.

[13] B. M. Bellis. (2012). Origins of Thermal Imaging or Infrared (IR)Imaging.Available:http://inventors.about.com/od/militaryhistoryinventions/p/thermal_image.htm

[14] V. Venkataraman, G. Fan, and X. Fan, "Target tracking with online feature selection in flir imagery," IEEE Conference on Computer Vision and Pattern Recognition, pp. 1-8, 2007.

[15] S. Jiang, "Automatic target detection and tracking in FLIR image sequences using morphological connected operator," International Conference on Intelligent Information Hiding and Multimedia Signal Processing, pp. 414-417, 2008.

[16] Y. Wei, H. Shuangyan, L. Junshan, and S. Deqin, "Robust Tracking in FLIR Imagery by Mean Shift Combined with Particle Filter Algorithm," IEEE International Symposium on Knowledge Acquisition and Modeling Workshop, pp. 761-764, 2008.

[17] C. Li, N. Jiang, J. Si, and G. P. Abousleman, "Robust target detection and tracking in outdoor infrared video," IEEE International Conference on Acoustics, Speech and Signal Processing, pp. 1489-1492, 2008.

[18] K. Zhang, D. Zhong, J. Yan, and J. Wang, "Research on the image matching and tracking algorithm for the end of infrared target tracking," International Conference on Audio, Language and Image Processing, pp. 557-562, 2008.

[19] Y. Yin and H. Man, "Adaptive mean shift for target-tracking in FLIR imagery," in Wireless and Optical Communications Conference, pp. 1-3, 2009.

[20] L. Yang, W. Lu, and J. Yang, "A new tracking method for small infrared targets," 16th IEEE International Conference on Image Processing (ICIP), pp. 3609-3612, 2009.

[21] M. Djalalov, H. Nisar, Y. Salih, and A. Malik, "An algorithm for vehicle detection and tracking," International Conference on Intelligent and Advanced Systems (ICIAS), pp. 1-5, 2010.

[22] S. P. Wang, "Adaptive Feature Selection for Infrared Object Tracking," 6th International Conference on Wireless Communications Networking and Mobile Computing (WiCOM), pp. 1-4, 2010.

[23] H. Ling, L. Bai, E. Blasch, and X. Mei, "Robust infrared vehicle tracking across target pose change using l1 regularization," International Conference on Info Fusion, 2010.

[24] N. Hongshan, H. Zhijian, D. Jietao, C. Jing, L. Haijun, and L. Qiang, "A Wiener Filter Based Infrared Small Target Detecting and Tracking Method," International Conference on Intelligent System Design and Engineering Application ISDEA), pp. 184-187, 2010.

[25] G. Su, H. Ma, and Y. Hou, "A Robust Approach for Anti-jamming Target Tracking in Forward Looking Infrared Imagery," Sixth International Conference on Image and Graphics (ICIG), pp. 636-641, 2011.

[26] Z. Wang, Q. Hou, and L. Hao, "Improved infrared target-tracking algorithm based on mean shift," Applied Optics, vol. 51, pp. 5051-5059, 2012.

[27] V. Venkataraman, G. Fan, J. Havlicek, X. Fan, Y. Zhai, and M. Yeary, "Adaptive Kalman Filtering for Histogram-based Appearance Learning in Infrared Imagery," 2012.

[28] G. Mirzaei, M. W. Majid, J. Ross, M. M. Jamali, P. V. Gorsevski, J. P. Frizado, et al., "Avian detection & tracking algorithm using infrared imaging," IEEE International Conference on Electro/Information Technology (EIT), pp. 1-4, 2012.

[29] L. Genin, F. Champagnat, and G. Le Besnerais, "Single frame IR point target detection based on a Gaussian mixture model classification," pp. 854111-854111, 2012.

[30] R. Miezianko. (2013, 20 Jan). IEEE OTCBVS WS Series Bench: Terravic Motion Infrared Database. Available: http://www.cse.ohio-state.edu/otcbvs-bench/

[31] (2013, 20 April). Performance Evaluation Parameters. Available: http://100dialysis.wordpress.com/tag/research/