A Comparative Study of Background Segmentation Approaches in Detection of Person with Gun under Adverse Weather Conditions

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***Abstract*—The ability to detect gun held in hand or other body parts is an ordinary human skill. The same detection problem presents an exceptional challenge for machine vision system. Very few works has been done in the area of automatic detection of moving persons carrying gun in hand under adverse weather condition, although it has several implication in the area of video surveillance and security. The quality of outdoor video scenes suffered from poor visibility and loss it's contrast due to adverse weather atmospheric conditions by scattering of aerosols. In this article, we present a structured comparison carried on between the state-of-art object detection algorithm. Different quality assessment matrices has been used for the evaluation of the performances of state-of-the-art methods. Incidentally relevant public datasets handling such a problem is scanty, if not absent, so far as our knowledge goes. As a result, the present article provides a newly collected several real time crime scene based video data clips from different web sources. The dataset consists of seven sets of data clips, such as, clear day, night, blur, disguise, dusty, foggy, and rainy. The proposed dataset will facilitate the research community to assess the performance of algorithms.**

***Index Terms*—Object Detection, Atmosphere, Weather Condition, Background Model, Security and Surveillance.**

I. Introduction

In recent days surveillance is a monitoring tool for combat with crimes. The aim of Close Circuit Television (CCTV) is to fight against the crime and different social offences by monitoring the scene under the surveillance. CCTV footage of crime area and its analysis are used in forensic for discovering clue to detect suspect [1]. Security systems are already installed at the important areas such as airports, offices, places of worships, shopping mall, border areas, and parking areas etc. [2]. Along with this security issues, video monitoring systems (such as CCTV) is used to reduce other crimes and social offenses in public areas. CCTV footage are also accepted as evidence in courts for prosecution [1] [3]. Video monitoring consists of one remotely mounted camera and an operator for monitoring the videos transmitted by the cameras to a screen of the base station. The operator has the twin responsibility of (i) giving due attention to all the video feeds from the camera and at the same time (ii) detecting suspicious activities of any objects carrying gun, thereby collecting evidence followed by informing appropriate authorities thereof [4]. It is a challenging task for an operator to pay attention to all the videos. So, automation of suspicious object detection becomes imperative for achieving comprehensive security and surveillance system. Such an automated system is liable to raise the alarm or indication whenever any aberrant activity is encountered under CCTV surveillance, because of which the operator will prioritize his awareness on the video feed and will initiate appropriate action there on [4].

Detection of suspicious subject with gun is an imperative task for the investigators. For person carrying gun and/or engaged in shooting may be identified from the CCTV footage's as formidable legal evidence. Detection of specific position of the gun held by the moving object as available from the video scene from CCTV footage is extremely important, gun position, hand and finger orientation associated to the subject in particular. As a gun in the hands of a human is considered to be greater threat as compared to a gun alone. The moving object detection and monitoring depends closely on the high quality video/ images. Quality of the outdoor videos images are affected by different atmospheric conditions like, fog, rain, dust, low/ poor illumination etc. The adverse weather conditions observed scattering in camera sensors; as a result most of the video footages are not informatics. There is several literature represented in various ways to detect objects for number of security reasons. M. Nicolescu [5] presented a detection of both objects and events for vehicle traffic control in various outdoor weather conditions. N. Dong et. al. [6] proposed an algorithm which detects foreground objects from video sequences collected under foggy condition, and also enhance their visibility. X. Zou et. al. [7] presented a crowed environment based detection of retention and stolen objects in security purpose. A. Rajan et. al. [8] proposed a security and quality ensured novel video enhancement technique with secret sharing technique. V. S. Rasmi et. al. [9] also elaborated a detection system of events in low resolution videos. S. Chandana [10] proposed a video monitoring system which is capable in live motion detection and record the video feed where will the motions detect. Recently, K. Dahmane et. al. [11] had provided learning and testing environment for the development of pedestrian detection. They developed a pedestrian detection database which is consists of several weather conditions based data. Although, there are dataset for moving object detection, but still research community lacking dataset that depict issues related to the detection of object in weather degraded condition.

Fig. 1 depicted the flow of the proposed system. We introduce a video dataset collected form different web sources which contains, moving persons carrying gun in adverse weather condition in the first step of the work. Afterward, we compare

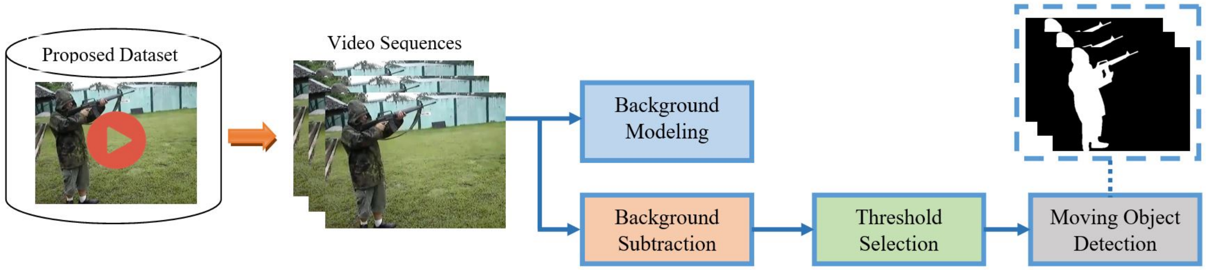

Fig. 1. Proposed System Flow

different state-of-the-art background subtraction based object detection methods using different quality assessment matrices. The primary contributions of this paper are summarized as follows:

1) We introduce a video dataset of moving person carrying gun, collected from different web sources as real time scenario (a) in various weather degraded conditions such as foggy, dusty, rainy etc., (b) in low visible condition such as night time, (c) also there are set of disguise and blurred video footages, and (d) clear visual day time videos.
2) Different background modelling based object detection methods are tested on the proposed dataset. Obtained results indicate that 'ViBe' performs better related to the other state-of-the-art methods.

The rest of this paper is constructed as follows: In the second section, the collection of dataset, atmospheric conditions, and statistics of the dataset are described. Section III describes the methodology. In Section IV, an extensive evaluation of the collected dataset is presented, followed by qualitative and quantitative analysis of state-of-the-art approaches. Finally, in Section V concludes this work and discusses about the future scope.

II. Dataset Description

A para amount of work has been done on object detection under adverse weather condition, in case of gun detection along with object under such condition is scanty, as far our knowledge goes. Incidentally relevant public dataset is also not available, as a result, we create a dataset under adverse weather condition, to collect videos from different web sources. The videos are collected in different atmospheric challenging condition such as, rain, fog, dust, clear day, clear night etc. and other challenges like, disguise, blurred image are also collected to enrich the complexity of this dataset. This dataset is also contain images of only objects (without gun) under such adverse weather condition condition. These are also collected to enrich the non-gun class.

The visibility of the targets are reduces in a scene by atmospheric aerosols. Especially this affect is debilitating at night time and directly affects the visibility through the aerosols. When the light from a source is reflected by the objects and back to the terminal camera sensors, the objects are typically visible. For electrooptical sensors, when an electromagnetic wave propagates through the atmosphere, the key factors that are responsible for extinction are absorption and scattering by atmospheric aerosols such as rain water droplets, fog particles, and so on. The degradation of the performance of all sensors are caused by both factors. Due to these adverse atmospheric weather conditions, the contrast is degraded of a scene which affects the visibility. This degradation also depends on the droplets size is as follows: the amount of scattering increases as the droplet size decreases.

A. *Related Datasets*

Since there is no database available by object along with gun for security purposes under adverse atmospheric condition based scenarios such as foggy, rainy, disguise based footages, the most relevant databases in the literature include visual and thermal frames. These video databases are having very important role to testing purpose on detection algorithms. But those datasets are not useful for the purpose of video surveillance security. A summary of existing object detection databases either night or day or thermal or visual provides in Table I. Among all these databases, 4 (four) have been created and collected with thermal/ Infrared (IR) sensors for detection and tracking of objects (i.e. PTB-TIR [13], LTIR [14], and TIV [15]), where TIV [15] database is primarily captured for visual analysis tasks which contains 63,782 thermal video frames of 1024x1024 resolution. The TIV [15] dataset contains pedestrian, runner car, bicycle, motorcycle, bat for detection and tracking which consists of four tasks: (i) tracking a single object through clutter, (ii) tracking multiple objects from a single view, (iii) tracking multiple objects from multiple views, and (iv) visual counting. The LTIR [14] dataset contains 11,269 video frames with resolution of 1920x480. The dataset is all about hotspot tracking i.e. tracking the warmer objects against a cold background like missile warning and track grey scale single object. These databases contain video sequences of day time only with the challenges of occlusion of objects, cluttered background, static and dynamic camera, group motion etc. The PTB-TIR [13] dataset is specifically designed for pedestrian tracking in infrared modalities. Numerous datasets, such as OSU-CT [12] and KAIST [13], contain both thermal/ IR and colour video sequences; one of them i.e. OSU-CT, it fuses two modalities, that is IR and visual, for robust detection which contains 17,089 video frames. The KAIST [13] database contains 95,328 video frames of resolution 320X256 presented in colour-thermal images for the purpose of only pedestrian detection.

These datasets are considered for object detection purposes only. Therefore, it is difficult to evaluate the robustness of methodologies for object detection under different adverse at-

TABLE I
LITERATURE SURVEY ON OBJECT DETECTION DATABASES

Database	Purpose	No. of Frames	Resolution	Object Category
KAIST [12], 2015	Object detection	95,328	320X256	Pedestrian
PTB-TIR [13], 2015	Object tracking	30,128	1280X720	Pedestrian
LTIR [14], 2015	Object tracking	11,269	1920X480	Human, Rhinoceros, Car, Horse, Quadrocopter, Dog
TIV [15], 2014	Several visual analysis tasks has addressed in thermal videos	63,782	1024X1024	Runner Car, Pedestrian, Motorcycle, Bicycle, Bat
OSU Color-Thermal [16], 2007	Fusion-based object detection	17,089	360X240	Pedestrian

mospheric weather conditions, and disguise, blur conditions for security surveillance. In this purview, our aim is to providing a new database containing person/ objects with gun under of several poor atmospheric conditions, disguise and blur conditions for security and surveillance. The dataset videos are collected from different web sources with person carrying gun or person involved in shooting.

B. Application of the Database

The proposed dataset has two fold applications; one is in the area of forensics and other one is in security and surveillance under adverse weather condition. Forensics includes the analysis of the crime scene before the crime, during the crime and also after the crime. These features are included to provide the dataset for forensic analysis. The category indicated as during crime are used for detection of gun, detection of suspect (moving person carrying gun in hand). This dataset incorporates real life challenges to create a useful dataset. For security and surveillance an automated system is liable to raise the alarm or indication whenever any abnormal activity is encountered, because of which the operator will prioritize his awareness on the video feed and will initiate appropriate action there on.

C. Database statistics

The surveillance and security based video sequences in atmospheric outdoor environment are affected by several element, for example - disguise, blur, adverse atmosphere, poor visibility, low light at night time [23][24]. Such circumstances amend the key feature of electromagnetic radio wave due of attenuation by atmospheric particles [22]. The proposed database offers diverse set of realistic outdoor person-weapon based videos over security purposes. The current database consists of 58 video sequences in total under disguise/blur/low light/poor visibility/different atmospheric conditions of total 82,134 frames. Whole statistics has shown in Table II, and Fig. 2 shows some sample frames at several adverse conditions. The key characteristic of the designed database are as follows:

1) The video frame consists of two types of moving objects all together, for e.g. person without gun, and person with gun.
2) The video sequences are categories through (a) three outdoor adverse atmospheric scenes are rainy, dusty, and foggy which produce less contrast in frames; (b) two outdoor adverse scenes are disguise and blurred conditions, and (c) two outdoor illuminated scenes are low light and clear day conditions.
3) To analyze the efficiency of object detection methodologies, we generated binary mask based ground truth annotation of targets in the video sequences.

D. Ground Truth (GT) Annotation

To test the flexibility of object detection methods under atmospheric weather condition, the annotation of targets (moving person with/ without gun) in video sequences is important. Here we have considered the binary mask based annotation pixel level to assess existing state-of-the-art background segmentation methods. To generate the ground truth annotation, we have selected 2500 frames from rainy condition, 1200 frames from dusty condition, 2300 frames from foggy condition, 5000 frames from blurred condition, 3200 frames from disguise condition, 3000 frames from night time, 1500 frames from day time video clips respectively as shown in Table II. We have used a user-friendly and advanced Tool for Semiautomatic Labelling (TSLAB) [17] for fast labelling of moving objects. As a consequence, one user can reliably label pixels of either moving or static class: allocated binary value of 0 to Static class, and allocated binary value of 1 to the Moving class. Some of the generated GT samples have shown in Fig. 3. Our research team verified time to time the whole procedure.

TABLE II
PROPOSED DATASET STATISTICS

Environment	No. of Videos	No. of Frames	Resolution	Day/ Night	No. of Ground Truths
Rain	6	10439	320x240, 1280x720	Night, Day	2500
Fog	5	8312	450x360, 1280x720	Night, Day	2300
Dust	6	5535	1280x720	Night, Day	1200
Disguise	11	16238	480x360, 1280x720	Night, Day	3200
Blur	10	18355	480x360, 1280x720	Night, Day	5000
Low Light/ Night	9	13560	1280x720	Night	3000
Clear Day	11	9695	480x270, 640x352, 1280x720	Day	1500

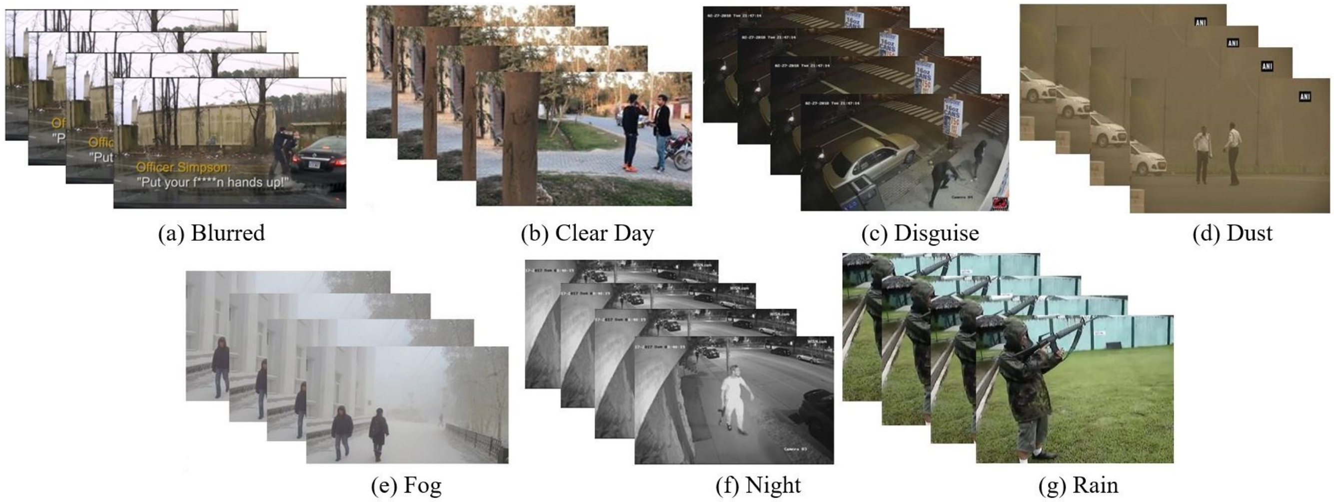

Fig. 2. Some sample frame sequences of the created database (a) visual frames under blurred condition; (b) visual frames under at day time; (c) visual frames under disguise condition; (d) visual frames under dusty condition; (e) visual frames under foggy condition; (f) visual frames at night time; and (g) visual frames under rainy condition.

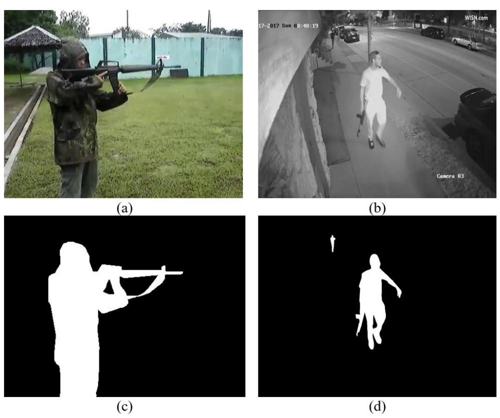

Fig. 3. Few sample Ground Truth of Proposed Dataset; (a) One Visual frame of the dataset; (b) One Infrared frame of the dataset; (c) and (d) represent their corresponding Ground Truths.

E. Review Findings and Motivational Remarks

Very few datasets are considered adverse weather conditions with less number of video sequences those are suffered by low resolution imagery, limited weather sessions etc. Therefore, it is challenging to analyze the robustness of existing state-of-the-arts. In contrast, our motive is to providing a new database which will be beneficial to the applications of forensics to analyse the crime scenes that are used for detection of gun, detection of suspect; and applications of security-surveillance under several adverse weather conditions that be an automated system to raise the alarm whenever any abnormal activity is encountered.

III. Methodology

Background modeling is required to extract the foreground from the images. Only the moving objects are detectable as foreground but, sometimes because of highly dynamic backgrounds in wind like tree, water and various illumination changes considered as a background. We have gone through 4 background modeling techniques and tested our dataset on them to get the finest detection result.

In PBAS [18] (The Pixel-Based Adaptive Segmenter) several parameters are adaptively changing at the time of process for each pixel. They have worked with 4 steps to generate the background. First segmentation decision where it will decide the pixel is belongs to foreground or background, then in second step they updated the background modeling and also the neighboring pixel. In third step update decision threshold works for high dynamic backgrounds automatically, when the high dynamic background the threshold value will increase and for low the threshold value will be low. In fourth step update the learning rate.

ViBe (Visual Background Extractor)[19], ViBe is a popular method for motion detection. They classify a pixel value according to the corresponding model. Then its compares with closest values with the samples within the radius centered on pixel value and the pixel value classified as a background if the model samples larger than or equal to threshold value. Then the second step is to background modeling initialization from a single frame. In the updating the background model over time with each new frame which able to handle lightning changes and new objects appears in the scene. In ISBM (Illumination sensitive background modelling) [20] approach is to analyse the illumination changes and detect the moving objects which includes dynamically updating background model module, a sudden of illumination evaluation model, and finally, an object detection module.

The GMM (Gaussian Mixture Models)[21] the whole system deals with the lighting changes, repeated movements in the scene, track of the cluttered regions, moving objects which are slow and new or removed objects from the scene.

IV. Experimental Results and Discussion

In this scope of the paper, four background subtraction based object detection methods are applied on the dataset. This work

TABLE III
METRICS THAT ARE USED FOR QUANTIFY THE PERFORMANCE

Name	Acronym	Computed as	Better if	Range
Recall	Rec	TP/(TP+FN)	↑	0-1
Precision	Prec	TP/(TP+FP)	↑	0-1
F-measure	F1	(2XPrecXRec)/(Prec+Rec)	↑	0-1
Accuracy	Acc	(TP+TN)/(TP+FP+FN+TN)	↑	1-100

has two fold application, one is to design a video dataset and other is to evaluate performance of existing object detection on this dataset. The video dataset consist of videos taken from online and featuring objects in different environmental challenging conditions. Videos are collected from online for increasing the complexity of the dataset. The dataset have a vast amount of variety, inconsistency that increase challenges in designing an accurate algorithm. Therefore, we evaluate performances of existing object detection algorithm to provide insight of complexity of the dataset. This section is organizes as follows: in first subsection we will mentioned how we measuring the performance of different algorithm and in the next subsection we discussing about the obtained results.

A. Performance Measures

Appropriate choice of segmentation method for ascertaining the accurate shape of an object is a crucial task. Since none of the existing background subtraction based segmentation techniques are applicable to all types of images, and different techniques are not evenly acceptable for any specific application, the performance evaluation of different background subtraction based segmentation algorithms is essential. However, a finite number of performance measures are not sufficient to report the ability of background subtraction based segmentation techniques. Hence, in this present scope of work intensity-based likeness quantification of background subtraction based segmentation is carry out over the binary mask comparable to the machine segmented ROI (i.e. moving person with/ without gun).

Metrics frequently adopted for evaluating background subtraction methods in videos are summarized in Table III.

The usual way of the performance measure of background subtraction approaches for detection of moving person with gun in videos is to pixel-wise analyze the calculated foreground masks with its' corresponding ground truth masks and compute the suitable metrics. All of these metrics are determine with regard to the total number of True Positive (TP), True Negative (TN), False Positive (FP), and False Negative (FN) pixels in the whole video sequences. We used different accuracy markers for noted the results of different method. Recall (Rec), Precision (Prec), F-Measure (F1) and Accuracy (Acc) measures are used here for comparison of the four state-of-the-art methods.

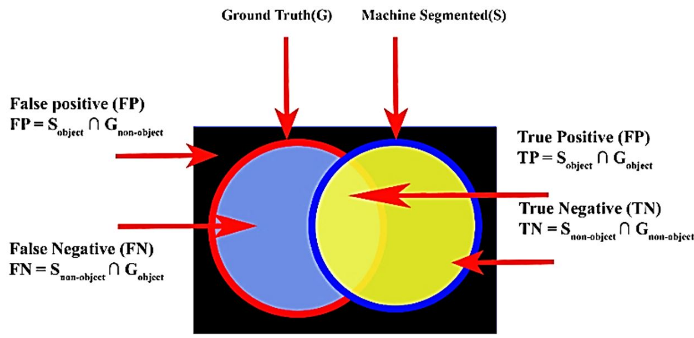

Fig. 4. Basis of performance measures.

Fig. 4 elaborately explaining about the basis of the performance measures. The blue circle referred to the ground truth and yellow circle referred to the output of the used segmentation algorithms (machine segmented). The measures TP, FP, TN and FN are calculated by comparing each pixel of machine segmented output and ground truth.

TP mention to the pixels that are accurately classified as foreground pixels. **TN** mention to the pixels that are accurately classified as background pixels. **FP** mention to the background pixels that are incorrectly classified as foreground pixels. **FN** mention to the foreground pixels that are incorrectly classified as background pixels.

TABLE IV
PERFORMANCE MEASURE OF DIFFERENT OBJECT DETECTION METHODS ON PROPOSED DATASET

State-of-the-Arts	Environment Conditions→	Blur	Disguise	Fog	Night	Others (day time)	Rain	Dust
	Prcc	0.6435	0.7529	0.7883	0.7747	0.5499	0.6634	0.6055
	Rcc	0.6723	0.7212	0.7613	0.7634	0.5723	0.6278	0.5912
	F1	0.6575	0.7367	**0.7745**	**0.7690**	0.5608	0.6451	0.5982
PBAS	Acc	94.8351	**98.0397**	95.4747	**98.1206**	93.7261	92.1784	79.9449
	Prcc	0.5134	0.6867	0.6369	0.7016	0.5535	0.6880	0.4915
	Rcc	0.5678	0.5954	0.6978	0.6766	0.5123	0.6512	0.5167
	F1	0.5392	0.6377	0.6659	**0.6888**	0.5321	**0.6690**	0.5037
VIBE	Acc	95.0182	**98.3828**	95.491	**98.1470**	88	92.2497	73.1167
	Prcc	0.5487	0.6256	0.5744	0.7417	0.4315	0.5619	0.5154
	Rcc	0.5198	0.4819	0.6138	0.5768	0.4210	0.6262	0.5089
	F1	0.5338	0.5444	**0.5934**	**0.6489**	0.4261	0.5923	0.5121
ISBM	Acc	94.3446	**98.6090**	95.1981	**98.1613**	67.2584	76.8758	92.3067
	Prcc	0.5945	0.4534	0.4312	0.5889	0.4467	0.5729	0.4134
	Rcc	0.4822	0.4756	0.4122	0.5944	0.4234	0.5568	0.4590
	F1	0.5324	0.4642	0.4214	**0.5916**	0.4347	**0.5647**	0.4350
GMM	Acc	**94.2261**	71.1947	74.3136	**98.7581**	88.0152	75.0336	56.5752

Based on this four factors, accuracy of segmentation method can be measured efficiently. In this work we used, precision, recall, F measures and lastly accuracy to compare performance of the existing methods on the proposed dataset.

B. Results and Discussions

Performance of the above mentioned background subtraction based object detection method on the proposed dataset is tabulated in Table IV. The best results are bold faced in this table for better understanding. We have analysed performances of the mentioned background subtraction method over adverse weather conditions. In case of *PBAS* method, the *foggy* and *night* condition is providing the better F1 score and accuracy, where *day time* and *dusty* condition shows lowest results. *Accuracy* of Disguise is also maintaining a good ratio with foggy and night condition. F1 score and Accuracy in *night* time outperforms other condition in case of ViBe. F1 score and Accuracy of *rain* and *disguise* respectively are also maintaining formidable ratio in case of highest accuracy. *Dust* condition shows lowest result. In case of ISBM approach F1 score and also accuracy is higher for night condition and for foggy condition it shows second highest accuracy and F1 score. In day time condition this method shows lowest accuracy. Night time condition is also showing highest accuracy and F1 score in case of GMM method. Blur condition is showing second highest accuracy in this case. Dusty and day time condition is showing lowest accuracy in case of GMM. Therefore, from the table it can be concluded that background subtraction based methods cannot performed well in each situation.

V. Conclusion

This paper presents a new Ground truth annotated video dataset of moving person carrying gun in hand under different adverse weather condition, collected form different web sources. Different environmental conditions possess challenges in detection of the objects from the real time videos. The dataset aims to facilitate the research community to assess algorithms in detection of moving person carrying firearms in hand under adverse weather conditions. Though the dataset fulfill every aspect required to be a benchmark dataset, one limitation of the dataset is low quality videos as the videos are collected from the web. Furthermore, in the present scope of work, we examine the ability of the few well-known background subtraction based object detection techniques based on quality assessment metrics. Existing object detection algorithm are not capable to perform well in all environmental conditions. More specifically, the existing algorithm not able to cope up with Blur videos, Videos captured in rain, dust and Fog. In future, we will try to overcome the shortcomings of existing algorithms and also extend our work to develop an algorithm to detect gun alone from that segmented results.

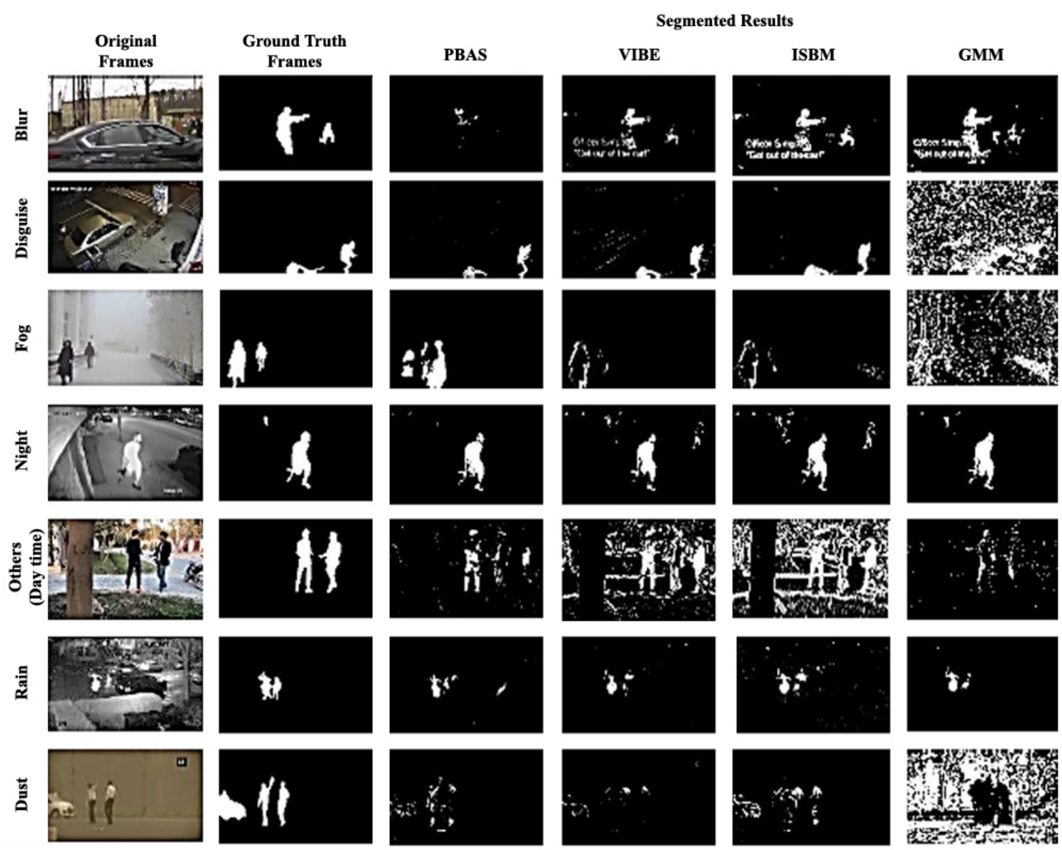

Fig. 5. Background Subtraction Based Segmentation Results of Different State-of-the-art Techniques under Adverse Weather Condition in our proposed dataset.

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