Moving Object Detection under sudden Change of Illumination: A Review

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Abstract: In Computer vision field moving object detection defines the detection of object from the given video of concerning area using its property of movement. Over the last few decades, moving object detection has achieved attention because of its large number of applications in the field of computer vision, video processing and surveillance. Moving object detection is essential for the further analysis of surveillance videos such as moving object recognition, behavior recognition of an object in surveillance video, shape detection of moving object and weapon detection along with the moving object. Reliability and accurateness are the indications of the performance of moving object detection method. The sudden change of illumination is a challenge to detect the accurate moving object. To solve the problem in a visual surveillance system, many researchershave developed a number of new approaches to detect the accurate moving object in a sudden change of illumination. In this paper, we review existing literatures trends to detect the moving object under sudden change of illumination. We also discussed the algorithm used by the researchers along with the discussion of key points and the limitations of each approach.

Keywords: Computer Vision, Moving Object Detection, Security & Surveillance, Illumination Change.

1. Introduction

Now days, Closed Circuit Television (CCTV) has gained popularity as surveillance tool for fighting crimes. CCTV is used to lessen the crime and social violation of the area under surveillance. Use of CCTV varies according the need of respective user. For example, CCTV is being used in street surveillance for monitoring various activities like finding a missing person, identifying anti-social behavior, drug misuse, etc. [JinMin Choi et al.].

Moving object detection has a wide range of application such as surveillance (in airports, marine, offices etc), automatic human recognition, identification of human possess etc. Therefore, moving object detection is an active research area in the field of computer vision [W. Hassan et al.]. The object detection algorithms, previously implemented in Closed Circuit Television (CCTV) video analysis, detect pedestrians', animals and vehicles. These algorithms can be extended further to detect a person holding weapons like firearms or sharp objects like knives in public or restricted places. As a weapon in the hands of a human is considered to be a greater threat as compared to a weapon alone. A weapon is used to harm another person or group of persons. These harmful things need to be detected for security purpose of general public in public areas such as airports and buildings etc. In different public areas such as offices, airports, public events etc. manual screening for weapon is common to controlled crimes. Purpose of manual screening is to detect the person, who carrying weapons. In this public areas flow of peoples are not controllable, so manual screening has its own limitation in order to provide efficient security. Therefore detection of weapons from a fair distance without manual interventions will aid the whole security system. So, it needs a good automated algorithm to detect weapons along with profile, and an accurate moving object detection method would be the initial step of this algorithm.

Over the past few decades, different approaches were proposed by different researchers for detection of moving an object in the surveillance video. Background subtraction, frame differencing, temporal difference, optical flows are such example of methods for object detection. These methodsdefined above are extended and modified to cope with the different challenges in moving object detection. Illumination changes, repetitive motion of background and sensor noise are some examples of those challenges.

In this work, we concentrate on the illumination change problem on moving object detection. Stationary objects are considered as moving the object as illumination of the scene changes over time and meanwhile it changes the color profile of that object. Illumination change causes shadows; shadows are also challenging factor to be handled during object detection.

Illumination change causes false detection; some background pixels may be detected as foreground pixels, which make it hard to obtain the clean moving objects. Background subtraction, frame differencing, temporal differencing techniques are mostly affected by the illumination change. Changing of illumination modifies the pixel intensity drastically and that is the reason it creates a problem during the moving object detection.

2. Illumination effect on moving object detection

Illumination variation is considered as a significant problem in object recognition. Illumination variation can be classified into two broad categories as outdoor illumination and indoor illumination. Daylight variation in different time causes the illumination variation in outdoor environment. Whereas, lighting conditions are responsible for the indoor illumination variation. Outdoor illumination is more sensitive than indoor lighting condition as human can somehow control the indoor illumination. Recognition systems can be learned with the known indoor illumination. In contrary, outdoor illumination variation creates more difficulties in recognition of object. Moving object detection in outdoor environment is a challenging task as illumination variation changes the background during detection. [Michael J. Tarr] investigate the effect of illumination variation on the recognition systems of objects with experiments. Variation in lighting condition creates both the shadows and shades. They experiment with both the shadows and shades and showed the effect of illumination in recognition. [Michael J. Tarr] also showed advantages of cast shadows in recognition. Shades are more challenging compared with shadows, concluded by them. The fact of effect of shadow and shades in recognition are confirmed by them. Shadows, as well as shades will change the intensity distribution of an image. In moving object changing pixel intensities represent the object of interest. When the pixel intensities of background objects start changing, they are considered as a moving object. The illumination model will able to define the change mathematically. According to illumination model, three factors such as ambient light, diffuse reflection and specular reflection effects the pixel intensity. The following equation describes this:

$$I_p = I_{amb} + I_L S_P \tag{1}$$

where, I_P is the intensity of the pixel P. I_{amb} is the ambient light and I_L is the reflection, both represents the pixel intensity. Both may be change as time varies. S_P is the shading coefficient of the pixel and is different for each pixel

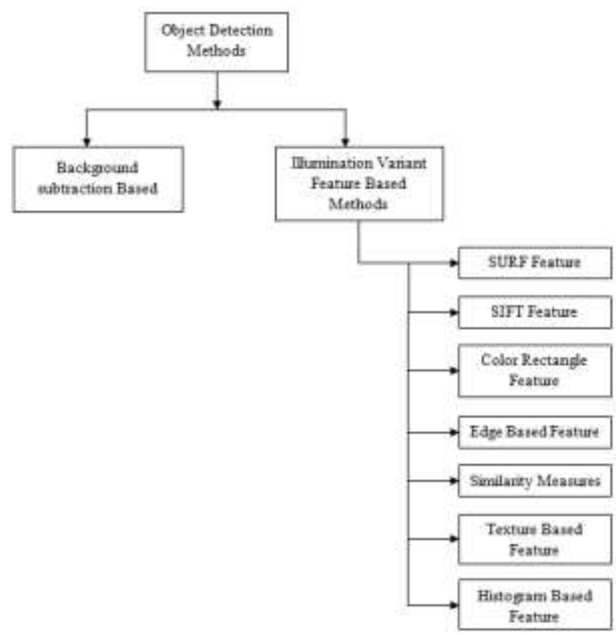
$$S_P = k_{diff} \cos\theta + k_{spec} \cos^{n\phi} \tag{2}$$

k_{diff} and k_{spec} are the reflection coefficients, ɵ is the incidence angle between the normal of the surface and the direction of light-source, Φ is the viewing angle relative to the specular reflection direction. So, if any object creates shading in the scene it will change the intensities distribution of that object. Change in lighting condition will affect the shading coefficient and it will change the pixel distribution. Variation in illumination can be sudden or slow & steady. Sudden illumination can be described as sudden weather change, whereas the daylight itself an example of slow illumination changes. Indoor illumination variation is usually sudden changes. However, now it is more evident that for moving object detection, illumination is a considerable challenge.

3. Recent Research Trend

Existing literatures on moving object detection also describe the illumination effect on the algorithm. There are algorithms, proposed in the literatures to handle the illumination problem. Some algorithms handle illumination during the detection of moving object, some algorithms do some post processing to remove the shadows. Algorithms are present in literature that can handle the indoor illumination and outdoor illumination. Some can't handle the sudden illumination but effective in slow variation. Some proposed algorithms are accounting the slow illumination change. In this literature we describe different illumination handle methods, how they work, advantages and disadvantages of these algorithms. We divide the methods into the following groups as per their working principle. The following figure will describe the different category of object detection algorithms shown in Fig 1:

Fig 1 - Taxonomy of the methods used for handling illumination in detection of object



3.1. Background modelling based:

Background modeling is a simple and popularly used algorithm for moving object detection for past several years. It is based on the assumption that background will be always constant, so objects that have change this consistency of pixel distribution will be detected as a moving object. Handle different challenges in moving object detection such as illumination and other this method evolved a lot. Backgrounds modeling based algorithms are able to handle complex situation. Background initialization, foreground detection and updation of background model are the key steps of algorithm based on background modeling. Model can be initialized by initial frame, considering there are no moving object appeared.

Suppose, BG_{model} is the background model consisting the pixels of first frame,

$$BG_{model} = \{P_k\} k <= L \quad (3)$$

Where L is the number of pixel present in first frame and P_k is the pixel values. The step is to compare the incoming frame from the model. Pixel of incoming frame will be considered as a moving pixel if it has any difference with the pixel of background model.

$$Object_{moving} \leftarrow F_k, \cdot F_k \neq P_k \quad (4)$$

Where, $P_k \in BG_{model}$ so, the $Object_{moving}$ is populated by the moving pixels. The basic principle of background modeling described above is simple. The simple background model is unable to handle challenges. Such as, if moving object is present in the first frame then the initialization of background model will be erroneous. Moving background object such as swing tress are also results in false negative detection. Sudden illumination change in the scene will also increase the false negatives. So, to handle these challenges proposed algorithms present in literature evolve the simple method into a complex one. We describe the evolution in each step of background subtraction algorithm.

3.1.1. Generation of background model

[Peixoto P. Nuno et al., Adin Ramirez Rivera et al.] used edge features and hue components for modeling the background, [Adin Ramirez Rivera et al.] used edge segment to initialize background model. Learned binary descriptors [Adin Ramirez Rivera et al.] are also used for background initialization. These initialization methods are based on the features that are invariant to illumination. Whereas [JiuYueHao et al.] fused the background and foreground model for effectively remove the effect of illumination variation. Some algorithms are based on the model update procedure to handle the variation. [Waqas Hassan et al.] used a SHI (segmentation History images) with the GMM (Gaussian Mixture Model) to remember the previous background image. This knowledge used during the updation of background. GMM is a known method for modeling background model for object detection. Methods based on the background modeling to handle illumination change are tabulated in table 1.

Table 1–Review on the object detection methods based on background subtraction to handle illumination change problem

Author	Overview	Positive aspects	Limitations	Database used
Lucia Maddalena et al.	Background subtraction based on neural network. The temporal median method is used for background initialization	Can handle the gradual change of light, cast shadows and waving tree	Cannot handle sudden and abrupt illumination	BMC evaluation video
Waqas Hassan et al.	Conventional GMM with SHI (segmentation history images). Edge-based tracking method	Illumination change and occlusion	SHI will work as a register so that it will increase the complexity of the algorithm.	i-LIDS PETS 2006
Peixoto P. Nuno et al.	Background modeling by temporal estimation in Hue component.	Immune to water oscillation, ripples, splashes and environment light variations.	-	-
JiuYueHao et al.	Fusion of Background model and Foreground model has been taken for encounter illumination challenge along with the swing trees, dynamic background.	Model handles both rapidly (such as trembling trees or camera jitter) and slowly (moving shadows over the time of day) changing background and still detects temporarily stopped objects (vehicles standing for traffic lights).	Eliminate small objects during illumination of shadow and other background objects. Not effective for shadow removal correctly.	500 frames reported in [Yaser Sheikh et al.].
Adin Ramirez Rivera et al.	Edge segment based Background modeling is proposed, as edges are invariant to illumination, so, to handle illumination it works well. Learning is used to handle change edge position and orientation.	Proposed method use the edge based background modeling to handle the illumination as previous literatures. But they overcome the position and shape change problem of edges efficiently.	Background modeling is itself a complex method as they consist of several critical steps. In addition to this complexity learning procedure increase the complexity. Learning is used for learn the segmented edge position and shape. One segmentation method also required.	PETS 2001 PETS 2009 (Outdoor)
Min-Hsiang Yang et al.	Parametric modeling is used to model background and foreground model. Parameters are obtained from learning. Binary descriptors are used for learning.	Galaxy Binary descriptor is used for the modeling the background and foreground mode. Galaxy descriptor is invariant to illumination and dynamic background. So, it effectively eliminate illumination effect.	Binary descriptor has an inherent disadvantage. They produce false negatives in case of homogeneous region.	PETS 2001 CDNET 2012 (outdoor)

3.2. Feature based methods

Image features are also used for moving object detection and tracking. Object is identified by its features, as different objects can be specified by different features. Simple example of feature is color, which exhibits different value for different objects. Image features have different application in computer vision area. Studies on image features adopt different kind of features and features are also combined for achieve better performance. Among these image features some features are invariant to lighting condition, they does not change their features values along with the change in lighting condition. These kinds of features are used in moving object detection in order to handle the illumination. Descriptions of such features are as follows:

3.2.1. SURF Feature

SURF (speeded up robust features)[ZHOU Dan et al.] was proposed by Herbert Bay and Tinne Tuytelaars in 2006. SURF is a descriptor of the key-points and in addition they are invariant to scaling, rotation and illumination. Initially the proposed SURF key points are based on the Fast Hessian detector to approximate the Hessian matrix to get key points of a specific object. Gaussian second order derivative is used for this approximation. Later, box filters are used to replace the Gaussian second order derivative to reduce the computational complexity. The approximation determinant is as follows:

$$\det\left(H_{approx}\right) = D_{xx}D_{yy} - \left(0.9D_{xy}\right)^2 \quad (5)$$

Where, D_{xx} , D_{xy} and D_{yy} respectively present the convolution of box filter in x-direction, xy-direction and y direction with image *I* in point *X=(x,y)*. Using this three dimensional linear interpolation algorithm obtains sub pixel key points, which are invariant to rotation, & illumination.

3.2.2. SIFT Feature

SIFT feature are also known as scale, occlusion and illumination invariant features. Kai Du et al. and Xinying Liu et al. used this SIFT feature for proposed object detection algorithm that will be invariant to change in illumination. Extraction of SIFT feature based upon four steps: 1) scale space peak selection; 2) feature points localization; 3) orientation assignment; 4) feature point descriptor. In the first stage, scale space peaks are selected by constructing the Gaussian pyramid and searching for local peaks in a series of difference of Gaussian (DoG) images. In the second step, candidate feature points are selected based on the peaks. Candidate feature points are checked for stability, if found to be unstable, they are eliminated. The next step is orientation assignment which make the SIFT feature invariant to scaling, occlusion and illumination variation. In this step dominant orientation specifically scale and locations for each feature point is identified based on its local image patch. So, after this step a canonical view for the feature point that are invariant to similarity transforms are provide by the SIFT algorithm. Based on the gradient variation of its local neighborhood local descriptor for each feature point is generated in the final step. Magnitudes and orientation information of that image gradient in the patch around the feature point is used to build the feature point descriptor. Sampling of the magnitude and direction of the said image gradient is also an important part of the step. Smoothed orientation histograms also used to capture significant features of the patch.

3.2.3. Color rectangle Features:

The rectangle features were introduced by Viola and Jones for real-time object detection. They use integral image format rather than RGB or Gray format. So, if we consider a rectangle in the image than the sum of the pixel of that rectangle can be computed in four table look up operations on the integral image. This procedure can be implemented in the color images by generating multi-channel integral image. Suppose, *R* is the RGB color images, we can pick *n* rectangular regions $R_1,\ldots\ldots R_n$ within the object to be detected. Each rectangle R_i is represented by the mean *(r,g,b)*color of the pixels within region R_i

$$\left(r_i, g_i, b_i\right) = \sum_{(x,y)\in R_i} \left(r(x,y), g(x,y), b(x,y)\right) \big/ A_i \quad (6)$$

Where, A_i is the number of total pixel within the rectangle R_i. The mean color vector of each region R_i can be computed during initialization. This feature provides robustness against noise and illumination variation [Changjiang Yang et al.]. Using color rectangle features we can model the background and foreground and their difference can be obtained by simple Euclidean distance.

3.2.4. Edge based Features

Literatures showed that edge of an image are less affected by the illumination variation. They able to handle change in lighting condition, as the edge pixel always maintained their gradient. Edge feature are used [Xiaofeng Lu et al. and Changjiang Yang et al.] along with other features such as color, texture to handle illumination. But the edge features are likely to affect by scaling or orientation. So, the edge features are used with the other features. Edge features are easy to compute. Using any edge detection method can provide edge image. From the edge image edge features such as gradient direction, gradient magnitude, and edge based histogram can be obtained.

3.2.5. Similarity Measures

Similarity measures are mostly used for the shadow removal. Shadows are more likely to detect as foreground as they persists larger difference than the difference between foregrounds. Chulhee Lee et al. used window based methods to find the similarity measures. Bhattacharya Distance and

SSIM are used in their work. Bhattacharya Distance can be defined as follows:

$$b = \frac{1}{8}(M_2 - M_1)^T \left[\frac{\sum_1 + \sum_2}{2}\right]^{-1} (M_2 - M_1) + \frac{1}{2}\ln\frac{\left|(\sum_1 + \sum_2)/2\right|}{\left|\sum_1\right|^{1/2}\left|\sum_2\right|^{1/2}} \quad (7)$$

The first term represents the mean difference and the second term represents the covariance difference. Other similarity measures are also used for removal of shadow. Correlation coefficient is such measures. Chulhee Lee et al. used SSIM for similarity.

3.2.6. Color, Texture, Histogram based Features:

Histogram, color and texture are the basic feature of an image. These features are also helpful in handling illumination variation. Such as color features there are different color spaces. Hue color component believed to invariant against illumination. Xiaofeng Lu et al. are used generalized color histogram along with edge feature for tackling lighting variation. Xiaofeng Lu et al.used color features along with the texture; as if background & foreground share same color then they may differ in texture [Guo-wu YUAN et al.]. Texture is a unique feature for images. Co-occurrence matrix, run length matrix, Local Binary patterns are most commonly used method for defining texture.

Histogram not directly used as features, but histograms are evolved to generate features that can tackle illumination. Bing-Fei Wu et al showed an efficient application of histogram in detection of moving object. They also showed efficiency of the histogram in handling illumination.

So, features that are invariant to variation of illumination are used for moving object detection in illumination variation. The following table listed the literature based on the detection of moving object in illumination variation.

Table 2 –Review on the methods based on the illumination invariant features for object detection

Author	Overview	Positive aspects	Limitations	Database used
ZHOU Dan et al.	Feature from conventional SURF and dominant orientation information of SURF key points. Template cache is used for template update.	Scale, rotation invariant. Can handle the illumination change	Cannot handle the fast and abrupt change of illumination. Template matching algorithm increases the complexity	-
Chulhee Lee et al.	Bhattacharyya distance, SSIM (structural similarity index measure), correlation and normalized mean difference. Neural network for classification	Illumination change	Simple. Not effective in abrupt and sudden illumination change.	-
Xiaofeng Lu et al.	Color histogram and Harris corner features are fused in particle filter framework. Temporal differencing used for detecting the object.	Illumination and occlusion invariant	Harris corner features are extracted from object rough location. Rough location	Toronto University
Changjiang Yang et al.	Harr-like rectangle features and the edge orientation histogram of integral images are used with particle filtering.	Illumination change. Simple and computationally inexpensive	Incapable of accounting the significant illumination change	-
Kai Du et al.	Meanshift with adaptive block algorithm used for tracking. SIFT method is used for illumination problem	Illumination change	Cannot handle the Abrupt change of illumination	OneBookOcclusion.avi
Xinying Liu et al.	Particle filtering with SIFT and Gabor features.	Remarkable efficiency in illumination change and pose	Cannot applicable for multiple objects	-
Guo-wu YUAN et al.	Camshaft algorithm used with texture and color features	Invariant to illumination change and comparatively simple.	Cannot handle local illumination	PETS2000 PETS2001
Bing-Fei Wu et al.	Histogram Features are used for handling illumination		Failed in detection of other objects as use different traffic	-

4. Conclusion and Discussion

Moving object detection or tracking invariant of illumination change is very vital research field as it affects the moving object detection and tracking application. The purpose of the paper is to outline the established approach to imposed illumination invariant feature in the object detection or tracking method. This paper also depicts the other disadvantages of existing methods.

Different approaches are present in detecting a moving object. From the survey, it was identified that edge based features of objects are invariant to illumination change and used extensively in existing methods. Object detection and object tracking based on the edge or contour of objects are not susceptible to illumination change. Whereas approaches based on color information are mostly affected by the illumination change. Shadow removal after detection of moving object is another type of approach to handling illumination. Shadow removal has done as a post-processing step. Though these approaches make existing object detection methods invariant to illumination change but require more computational time and also need additional algorithms to achieve efficiency. Neural network, optical flow, and other color space conversion based object detection algorithm do not require additional algorithm, but they emerged as a computationally complex algorithm. Illumination change can be described in two ways, one is an abrupt change of illumination, and another one is slow to change of illumination. Methods resistant to both the illumination is also found as a challenging task in this review.

The review of recent trends in the removal of the adverse effect of illumination change gives an overview of the strength and as well as their weaknesses. In future, new techniques can be developed using the strength of existing methods for better performance.

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