Obstacle Detection from Still Images using Improved Background Subtraction Method

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Abstract

Background/Objectives: We propose an approach that aims at improving the current method of obstacle detection so as to improve efficiency, detection rate and running time. Methods/Statistical Analysis: Background subtraction is a technique used in obstacle detection to find out the area of hindrances for traversal or navigation. In this technique two consecutive frame of video is taken for differencing and resultant giving the area in which obstacle is identified. Findings: The current technique has some limitations working under high intensity and change of illumination. We propose a hybrid approach which include merging of gamma correction with background subtraction. This method reduces the level of illumination and works well at different weather conditions. Our proposed method is useful in detection of area of changing objects and would be useful in video surveillance applications.

Keywords: Background Image, Background Subtraction, Gamma Correction, Illumination, Obstacle Detection

1. Introduction

With the swift advancement in computer science, detection technologies in computer vision are enhanced more extensively in different aspects. Object detection is widely used in computer vision for public security, visual surveillance, robot path traversal, blind navigation system, object recognition, pedestrian detection systems and many other fields. Obstacle detection is one of the fundamental areas of problem in mobile robot navigation. For navigation in the world, it is crucial to identify that portion of the world which are difficult or impossible for traversing. Popular sensors used in range-based obstacle detection systems include ultrasonic sensors, stereo vision, laser rangefinders, and radar as these sensors measure the distance of obstacles to the robot, they are suited for the tasks of obstacle detection and obstacle avoidance. The major disadvantages of using such sensors is there interference with the environment which lead to difficulty in interpretation of output signals, high consumption of power consumption, high price of acquisition, poor resolution and inability to detect small obstacles. This signify the need of using visual method for obstacle detection. However, object detection technology still has many shortcomings such as slow detection rate, low detection accuracy and poor environmental adaptability, false detection etc. Thus, object detection technology tends to have need in-depth study.

Obstacle detection is an attempt to reveal the objects that are present in the locomotive path to prompt collision free navigation. The primary purpose of this technique is to utilize visual perception of machine to make it understand the structure of environment around it and to predict the hindrance in path by itself without any human intervention. Till now, various approaches are being proposed but fail to give ideal results. So, it will not be immoral to state that there is scope of improvement in them. In this paper, we have presented a review on the various obstacle detection techniques that can be used in different area and application.

Background subtraction method, also known as frame differencing method is used for detection of obstacle from the video sequence. In this approach two consecutive frames with same background from video is taken and
then arithmetic difference is calculated. The resultant would give the area in which changes due to presence of obstacles have occurred.

The current method is having some limitations while working under changing weather conditions and illuminations effect. So, we intend to improve this method by overcoming the limitations. Gamma correction is merged with current BS method which tends to darken or brighten up an image, we can adjust average brightness of an image by normalized algorithm by adding constant value to pixel intensity value and carries exponential function on each pixel values. The relation between frame buffer value and actual intensity is non-linear. The relation is given as:

\[ \text{Luminance} = \text{constant} \times (\text{frame buffer value})^\gamma \]

In different computer vision applications, Background Subtraction (BS) has been a “quick and dirty” way of identifying moving objects in frame taken from a video shot by a static camera. In this viewpoint, detection of motion is often regarded as the first step of a multi-stage computer vision system such as video surveillance, person recognition, tracking, navigations etc.

For this purpose, it should be easy to compute and result must be calculated in short interval of time. Subsequently, most BS methods are labelled as “in motion” for every pixel at time \( t \) where color is considerably different with respect to background.

The separation of foreground from background is mandatory in field of computer vision systems such as surveillance tracing. The biggest challenges in background subtraction are illumination changes and other changes occurring in background such as shadows and flickering objects screen. The Background differencing method uses two consecutive frames to extract mobile regions. This technique is more prone to pseudo detection of object when changes areas are encountered by noise or illumination changes occurred due to changes in weather conditions. To lower the impact of limitations different methods are studied in literature. But motion detection through background subtraction is a difficult process as in case of some videos which have poor signal-to-noise ratio due to low quality camera or noisy environment, generates numerous false positives which can also be induced by sudden changes in illumination, using an animated background such as water waves, shaking trees or camera jitter. On contrary to this, false negatives may also occur while a mobile object Which are composed of colours similar to the background is encountered. In such scenarios, a simple inter frame difference method would be a weak solution. In order to cope with such challenges, various background models have been proposed which are more robust to instability of background and noise as compared to basic background subtraction approaches.

The basic idea behind our study is to:
1. Analyse the limitations of the existing method and evaluate how these limitations are to overcome by our approach.
2. Compare the results with simple background method and study the processing requirement and accuracy rate of it.
3. Evaluate the potential of our technique as compared to existing background subtraction method.
4. Determine which type of objects are best detected and analysed from a given image.

Background subtraction method is widely used in field of computer vision, different surveys and Comparative studies have been done over the previous years. While some papers provide descriptive evaluation of object detection methods others give quantitative evaluation based on pre-annotated sequences of video. As in the case of author\(^2\) who conducted comparative study for various pixel-based background subtraction algorithms. In their papers, they define background subtraction methods as a single set of parameters and there by executing it on various video sequences.

Author\(^1\) proposed a novel technique to compare different background subtraction method based on analysis of disturbances. In a first stage, the rate of False Positive is fixed in a video sequence after the adjustment of value of some ad-hoc thresholds. Then, background of video sequence is degraded using a vector of disturbance in omni directions of the RGB space. Such degradation simulates the foreground moving objects. The capability of background subtraction algorithm for detection of low-contrast goals against background is measured as a function of contrast. The main advantage of the method is \( i \) ability to use all kinds of videos for the assessment of quality, also for those without ground truth but this method is not void of drawbacks. While the distribution of pixel in a foreground unimodal, the disturbance analysis method with multimodal background include simulated foreground moving objects which are combination of the multimodal distribution as well as the disturbance. Also, this method doesn't either allow the evaluation of region-based methods or the benefits of post-processing tools.
Author proposed a model using BMC (Background Models Challenge) dataset which contain both synthetic and real sequences presenting a pragmatically state of art about background subtraction, related to BGC library. After initializing, they perform background modelling by using equation (1) recursively

$$B_t=(1-\alpha)B_{t-1}+\alpha Z_t$$  \hspace{1cm} (1)

Where $B_t$ denotes the background model at time $t$. This method has an advantage of adaptive maintenance while the changes are occurring in the scene. They have interpreted five methods from the benchmark given by BMC and introduced the ranking function that combines F,SSIM and D-Score measures for determining better results. Remarks are modulated by processor and memory requirements also memory time consumptions is very high. They also propose a future model to integrate performance evaluation into the ranking function.

Author used two different techniques based on background subtraction method to optimize dynamic scene and their results displayed that background reduction along with foreground enhancement increased the accuracy as compared to those methods that directly merge pixels at lower resolution. With addition of more gray scale information, foreground enhancement strategy results in better performance with high recognition accuracy. They proposed a model based on visual prosthesis which applies electrical stimulation on different parts of path. The created percept is however limited due to low resolution of images caused due to limited number of stimulating electrodes. They demonstrated adaptive post-processing that effectively improved segmentation performance. The results of experiments indicated that BR and BRFE strategies are advantageous to perception of movement.

Author proposed Adaptive Neuro Fuzzy Inference System (ANFIS) controller for navigating mobile robots in highly cluttered environment. In their research they had tried to design a control system which is capable of deciding its own path in all environmental condition in order to reach target efficiently. ANFIS is the combination of fuzzy logic and neural network. In fuzzy system knowledge is represented in comprehensible logical rules while on other hand neural networks are capable of using knowledge and experience and by combining them two neuro-fuzzy controllers are developed. The main aim of ANFIS is to take learning capability of neural network and combine it with fuzzy inference system. FIS then will be able to train the procedures as in neural networks and thereafter learning mechanism will behave exactly as that of neural network which is comprised of different layers input, output and hidden layers inside. The technique in which input membership functions combine with each other is known as rule. The rule is comprised of two parts antecedent and consequent and they are handled independently and further their fusion gives output which is defuzzyfied to get result.

Author proposed BSFD algorithm which is based on dynamic background which can be achieved by frame difference method. To overcome the limitations of difference method various frames are chosen in order to detect slow moving objects. After apprising background image that is referenced image the BS method works for getting mov-

| Sr.no | paper                                                                 | Background subtraction approach | methodology            | Background model            |
|-------|-----------------------------------------------------------------------|--------------------------------|------------------------|----------------------------|
| 1     | QR decomposition –Based Algorithm for Background subtraction          | Block based                    | QR decomposition       | Initialization with moving objects |
| 2     | pixel-wise local information based background subtraction approach    | Pixel based                    | Gabor filters GMM      | NA                         |
| 3     | Detecting Moving Object From Dynamic Background with Shadow Removal   | pixel based                    | LPGMM                  | dynamic                    |
| 4     | block-based background subtraction                                   | Block based                    | MDPA and GMM           | dynamic                    |
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The background image used for processing the next frame image is produced by super positioning current frame image and thus the current background image with certain chance. The experimental results show that algorithm is able to detect moving objects a lot of effectively and precisely.

Author proposed ViBe background subtraction algorithm. This algorithm has an excellent anti-interference capability, real-time performance and high robustness. ViBe background subtraction method produces the ghost areas easily while detecting moving objects.

Author proposed an improved ViBe background subtraction technique to deal with the ghost area problem with the elimination of ghost area computational efficiency is improved. Their technique is to use histogram of ghost areas which has some similar distribution characteristics, but when compared to moving objects they are changing constantly to identify the ghost area in an image. Thus, reducing the influence of ghost areas from an image. They further compared the results of improved ViBe and the original ViBe.

Author proposed Novel background image estimation approach which is based on belief propagation algorithm that show improvement based on publicly benchmark dataset (CAVIAR13) as well as private test-videos used in project. Their method is centred on Markov Random Field, Belief Propagation and DBSCAN algorithms. The use of cyclic graph MRF model for non-overlapping image patches with the narrow set of background hypothesis generated by DBSCAN algorithm provide faster convergence of Belief Propagation with efficient accuracy.

Author proposed hybrid approach, based on skin colour information and Adaboost-based detection. The key points of their framework were background elimination and down-sized using the adaptive skin colour classification and segmentation, as well as size estimation of sub-window. Thereby searching the face candidates instead of whole image. To test the accuracy of the proposed algorithm, the system was implemented on the standard image datasets such as Caltech (California Institute of Technology) standard image dataset. The proposed hybrid detection system was compared with the Viola-Jones face detection system.

2. Background Subtraction Algorithms

The background subtraction technique, the assumes a video sequence I is made of a background B containing static stable objects and foreground F which is comprised of moving objects to the assumption that each moving object is comprised of a color (or a color distribution) different from the one observed in background B, various BS methods can be summarized by the following formula:

\[ R_k(x,y) = f_k(x,y) - B(x,y) \]

\[ D_k(x,y) = \begin{cases} 1 & \text{background, } R_k(x,y) > T \\ 0 & \text{target, } R_k(x,y) < T \end{cases} \]

Where \( f_k \) is current frame with stored background image B and \( D_k \) denotes the difference of the foreground and background which give the target. The primary concept is to store first frame image as background image and then the subtraction of current frame with background determine target depending whether the value is greater than threshold or not. If the difference is larger than the threshold, then it corresponds to pixel to pixel on the moving target, or as a background pixel. The choice of threshold is very important for accurate detection of
obstacle if the value of threshold is too small it will produce false change points, and if it is too large then it will reduce the scope of changes in movement.

The basic difference between various Background subtraction methods is how B is modelled and which distance metric d is being used.

2.1 Basic Motion Detection

One of the simplest approach is to model background through a single gray scale image without moving objects. This image is taken at rest or should be estimated through temporal median filter. In order to handle the problem of illumination changes with background modifications, it can be iteratively updated as

$$B_{s,t+1} = (1-\alpha) B_{s,t} + \alpha I_{s,t}$$

Where $\alpha$ is a constant ranging between 0 and 1. With this simple model, pixels of foreground moving objects could be detected by the threshold of any distance functions. We can also use previous frame as background image $B$, this inter frame change detection is robust to illumination changes but suffers from aperture problem as only single portion of moving object is detected.

2.2 One Gaussian (1-G)

Modelling with a single image requires a strictly fixed background without noise and artifacts. Since this requirement is quite difficult to achieve in every real-life scenario, various model with each background pixel with a Probability Density Function (PDF) is learned over a sequence of training frames. The background subtraction problems have become an issue in thresholding-PDF in which low probability pixel to correspond foreground moving object. In order of the justification for noise, proposed a model for every background pixel with a Gaussian distribution. The covariance matrix have more value in the area of noise and less in stable area. The value of temporal gradient is directly related to

$$\left| M_s - I_{s,t} \right| < T d \mu$$

where $T$ is user-defined threshold and $d \mu$ is median of the interframe absolute difference of an image. Similar to the 1-G method, a pixel in noisy area requisite to be a larger variation labelled in motion area than a pixel compared in stable area. Each background pixel is linked to three maximum values instead of a mean vector and covariance matrix.

2.4 Frame difference Method

This method is also known as adjacent frame difference method; two images are taken from a small interval of time based on difference of time changes are detected in images. After interpretation of frames binary subtraction is applied in order to detect the moving object. This binarization of image will give movement of the collected pixel annotating the object.

| Table 2. review of BS technique based parameters |
|-----------------------------------------------|
| **Technique** | **Static parameter** | **Test parameter** |
| Basic Motion Detection | Time | distance $d_2$, $\alpha = 10^{-3}$ |
| One Gaussian | Number of components, initial variance | distance $d_M$, $\alpha = 10^{-3}$ covariance matrix is diagonal |
| Minimum, Maximum and Maximum Inter-Frame Difference (MinMax) | Pixel | user-defined threshold |
| Frame Difference Method | None | Foreground threshold $T_s$ |
| Kalman Filter | None | Adaptation rates $\alpha_1, \alpha_2$ Foreground threshold $T_s$ |

2.5 Kalman Filter

It is a recursive method for the estimation of dynamical system in presence of noise. It simultaneously maintains state of matter as well as estimate error covariance matrix which correspond that kalman filter is Gaussian PDF with mean and covariance $P$. In the context of localization the output of kalman filter is likely to give position of object instead of single position estimate.
3. Proposed Work

We propose background subtraction technique for novel detection of objects. In this technique we attempt to overcome the limitations of background subtraction method. Due to changes in weather and intensity of light the problem of illumination is causing hindrance in proper detection of objects so we propose a method which combines gamma compression with that of background subtraction method to reduce the effect of illumination in an image. Application of image normalization equalisation can reduce the impact of illumination. Gamma compression done either by computation of square root or by taking log of colour channel helps in reduction of local shadow and variations on illuminations. So, using this technique with background subtraction method will reduce the problem of illumination faced in most of the background subtraction method.

4. Discussion

As studied so far background subtraction is most used method in field of moving obstacle detection. Various approach of this method is discussed above. The techniques studied above have their own pros and cons. A comparison table is presented showing comparative analysis based on some parameters. The proposed technique will rectify the limitation of background subtraction method for detection of objects more effectively and accurately.

5. Conclusion

In this paper, we surveyed various background subtraction algorithms in literature. We have done analysis of their working based on their Pre-processing, foreground detection, background modelling, and data validation. We have proposed a new approach in background subtraction method. In distinction from the traditional Background subtraction approaches, our method can work well under the influence of illumination and intensity changes.

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