Moving Target Detection Based on Block Projection and Matching

Jun-yong MA\textsuperscript{1,2,*}, Xia CAO\textsuperscript{3} and Bo Wang\textsuperscript{3}

\textsuperscript{1}Science and Technology on Electro-Optical Control Laboratory, Luoyang 471009, China
\textsuperscript{2}Luoyang Institute of Electro-optical Equipment, AVIC, Luoyang 471009, China
\textsuperscript{3}Luojia College Wuhan University, Wuhan 430064, China

*Corresponding author

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Abstract. Moving target detection in image sequence for dynamic scene is an important research topic in the field of computer vision. Block projection and matching are utilized for global motion estimation. Then, the background image is compensated applying the estimated motion parameters so as to stabilize the image sequence. Finally, background subtraction is employed in the stabilized image sequence to extract moving targets. Experiment tests denote that the proposed moving target detection algorithm based on block projection and matching can efficiently extract moving targets in dynamic scene.

Introduction

Moving target detection aims to separate moving object area from background in image sequence, the detection results of which will directly impose influence on the object tracking, classification and identification. Actually, because of change of climate, illumination variation, background disturbance, ambiguous target brim and regional feature, object occultation and so on, moving target detection turns to be critically difficult [1-3].

According to whether the scene is changing temporally or not, moving target detection algorithms are classified into two categories. They are detection in static scene and detection in dynamic scene. Background estimation and subtraction can be used in moving target detection when the imaging sensor is stationary [4]. However, because both the target and the background are moving when the imaging sensor is also moving, background estimation and subtraction will not be effective any more [5,6]. Actually, the background motion in image sequence is caused by the motion of the camera. But motion of the target is independent of motion of the camera. In this case, moving target detection is to address the problem of how to differentiate the global background motion cased by the camera motion and the local target motion independent of camera motion.

Generally, they are two categories of algorithms to tackle with this problem. One is classification methods. Because they need to train the classifiers in advance, they only apply in detection of target of specific class, e.g. passerby. The other is optical flow methods. They can precisely differentiate the global motion of the background and the local motion of the target. But they are computationally expensive for real-time implementation [7-10]. However, if the global motion can be compensated beforehand, the inter-frame difference method and background subtraction method will be effectual in the dynamic scene.

We propose a moving target detection method based on inter-frame motion estimation. Firstly, apply sub-block projection matching for global motion estimation and compensation. Then, inter-frame difference method is utilized to detect moving target. Experiment results verify the efficiency of this method.
Global Motion Estimation

The global motion refers to the whole motion of the image caused by motion of the camera. For example, when the camera is in these motions such as translation, rotation, zoom and tilt, the image sequence is accordingly changing and will deteriorate the effect of moving target detection and tracking. It is helpful to estimate the inter-frame motion caused by the motion of camera and compensate it. Global motion estimate aims to distinguish the motion rule of the camera according to the image sequence.

To improve the real-time performance for moving target detection, we proposed a rapid algorithm of global motion estimation. The matching precision for global motion estimation of block matching method is high and it is suitable especially for global motion estimation of image sequence. However, the common block matching method is based on some matching rule, such as absolute error rule, mean square rule and regulated correlation function rule and so on. All of them seek the most similar image block in the search region. Although the computation speed can be enhanced through optimization of the search strategy, they are still time-consuming. The gray projection method uses variation rule of the gray distribution to estimate the motion vector. Although it isn’t suitable for the occasions of rotation or scaling, it is simple and computation efficient.

To improve the real-time performance of the propose algorithm, block matching method is combined with the gray projection algorithm. Firstly acquire the translation vector of image block through gray projection. And then estimate the global motion by WRANSAC method.

Assume motion of the scene in the image is caused by the moving of the camera, the global motion of the camera can be represented by the six parameters affine model

\[
\begin{pmatrix}
    x' \\
    y'
\end{pmatrix}
= \begin{pmatrix}
    h_1 & h_2 & h_3 \\
    h_4 & h_5 & h_6
\end{pmatrix}
\begin{pmatrix}
    x \\
    y
\end{pmatrix}
\]

(1)

Where \(h_1, h_2, h_4, h_5\) represent rotation and zooming and \(h_3, h_6\) represent translation. If several feature correspondences are known, the global motion estimation is translated into solution of the \(H\) matrix by the feature correspondences.

Firstly, divide the image into \(M \times N\) blocks. Compute the translation vector of corresponding sub-block in adjacent frames by projection matching. Then, apply an assessment function to estimate the correction of the translation vector. Finally, the robust estimation method is employed to compute the global motion parameters, which are used to compensate \(F_{k-1}\).

In a word, if the global motion compensation is completed for dynamic image sequence, the moving target detection methods for static scene can also be suitable.

Target Detection

Target detection is carried by Gaussian model background subtraction method [11-14]. Suppose the background is already constructed. Compare the current pixel with the background model distribution of the corresponding pixel. The pixels whose gray value is not apply with the statistical distribution are recognized as moving targets. The diagram is as follows:
Subtract the background $B_{k-1}$ from the $k$th frame and acquire the difference image $D_k$,

$$D_k(x, y) = |I_k(x, y) - B_{k-1}(x, y)|$$  \hspace{1cm} (2)

Then the binarization is done for the difference image. A pixel is deemed as the target when its gray value is larger than a given threshold $T$, otherwise it is belongs to the background area.

$$R_k(x, y) = \begin{cases} 
0 & D_k \leq T \\
1 & D_k \geq T 
\end{cases}$$  \hspace{1cm} (3)

Actually, the background is changing temporarily, and it is need to be updated in time. In common, the following method is used to update the background image. However, its drawback is that the target is imposed on the background in a certain extent.

$$B_k = (1-\alpha)B_{k-1} + \alpha I_k$$  \hspace{1cm} (4)

To enhance the efficiency of the background updating method, the background area but the target area can only be updated. As the following equations shown, brightness mean and variance of every pixel in the image sequence is computed in a longer time,

$$\mu_0(x, y) = \frac{1}{T} \sum_{t=1}^{T} I_t(x, y)$$  \hspace{1cm} (5)

$$\sigma_0(x, y) = \frac{1}{T} \sum_{t=1}^{T} [I_t(x, y) - \mu_0(x, y)]$$  \hspace{1cm} (6)

Image $B_0$ with $\mu_0$ and $\sigma_0^2$ as its Gaussian distribution parameters is regarded as original background estimation image. In the following, the background estimation is updated once a new image is acquired,

$$\alpha = K \frac{1}{\sqrt{2\pi \times \sigma_{k-1}}} \exp\left(\frac{-(\mu_{k-1} - I_k)^2}{2}\right)$$  \hspace{1cm} (7)

$$\mu_k = (1-\alpha)\mu_{k-1} + \alpha I_t$$  \hspace{1cm} (8)

$$\sigma_k^2 = (1-\alpha)\sigma_{k-1}^2 + \alpha(I_t - \mu_k)^2$$  \hspace{1cm} (9)

Once the statistical model of the background is acquired, target detection is executed as follows,

$$R_k(x, y) = \begin{cases} 
0 & |I_k(x, y) - \mu_k(x, y)| < \omega_0 \sigma_k(x, y) + \omega_0 \\
1 & \text{other} 
\end{cases}$$  \hspace{1cm} (10)

Where $\omega_0$ and $\omega_1$ are two constants.
Object Localization

Object area represented by the detected binary image may have deviation because of eliminate the noise disturbance. To correctly localize the object, firstly apply morphological operation to eliminate the noise disturbance, and then extract the object centroids and size by connected component analysis. Erosion operator and dilation operator are used for morphological operation, and moment method is used to determine object centroids as follows

\[ x_c = \frac{m_{10}}{m_{00}}, \quad y_c = \frac{m_{01}}{m_{00}} \]  

\[ m_{00} = \sum_x \sum_y I(x, y), \quad m_{10} = \sum_x \sum_y xI(x, y), \quad m_{01} = \sum_x \sum_y yI(x, y) \]  

The second-order centered moment is used to determine the object size

\[ \mu_{pq} = \sum_x \sum_y (x-x_c)^p (y-y_c)^q I(x, y) \]  

If the moving target is represented by ellipse, the main axis orientation angle and the long axis are determined as follows

\[ \phi = \frac{1}{2} \arctan \frac{2\mu_{10}}{\mu_{20} - \mu_{02}} \]  

\[ \alpha = \sqrt{\frac{2(\mu_{20} + \mu_{02} \pm \sqrt{(\mu_{20} - \mu_{02})^2 + 4\mu_{11}^2})}{\mu_{00}}} \]  

Experiment Result and Analysis

VIVID datasets are used to test the proposed algorithm, and the results are shown in fig.9 -10. As we can see, the detection method can correctly detect the moving targets in the dynamic scene.
Conclusion
The global motion estimation method based on projection matching can only be used for translation occasion. However, its computation speed is high. So it is applied into the matching procession. It enhances the computation efficiency while assuring the matching accuracy. In fact, the new method addresses the contradiction between estimation accuracy and the computation speed. Because we choose the improved RANSAC algorithm, in which abandon automatically sub-blocks including target. Thus the estimation accuracy is also enhanced. Experiment tests denote that the proposed moving target detection algorithm based on block projection and matching can efficiently extract moving targets in dynamic scene.

References