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Survey on Methods of Moving Object Video Detection in Marine Environment

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Abstract. The basic methods of moving object video detection are introduced. Then the special background of marine environment is analyzed and discussed. Finally, the main problems and the development in the fields of moving object video detection in marine environment are presented.

Keywords: moving object, video detection, optical flow, background subtraction, frame differencing

1. Introduction

Video detection has been an important topic of computer fields, which can be used for vehicle detection, object recognition, personnel monitoring and others. The background of vehicle detection on land is relative simple and the algorithm is better developed than that for marine environment. For ship detection with special background of maritime environment, it used to be mainly using radar images or remote sensing images which are taken far away from the sea surface.. The techniques of moving object detection for marine environment are still in the exploratory stage because of the greater impact by natural weather conditions (such as wind, waves etc.) and the complex background of the marine environment. This paper proposes the moving object video detection techniques on land to be applied to ship detection of marine background, and provides theoretical basis and reference for future research.

This paper describes the basic methods of moving object video detection, and makes the appropriate analysis and discussion about the special background of marine environment with each method. Finally, it sums up the above analysis and discussion and points out the main problems, application prospects and development.

2. Main Detection Methods

Background of video images can be divided into two categories, dynamic ones and static ones. Static background is the relatively fixed state with camera and background. And dynamic background refer to the relatively fluctuating state, which is caused by camera moving and scene changing. Currently, the moving object detection techniques for video images include optical flow, background subtraction and frame differencing. We will describe and analyze these methods.

2.1. Optical flow

A fundamental problem in the processing of image sequences is the measurement of optical flow (or image velocity). The measurements of image velocity can be used for a wide variety of tasks ranging from passive scene interpretation to autonomous, active exploration. It has been suggested that only qualitative information can be extracted. Optical flow techniques can be viewed conceptually in terms of three stages of processing:

(1) pre-filtering or smoothing with low-pass/ band-pass filters in order to extract signal structure of interest and to enhance the signal-to-noise ratio,

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(2) the extraction of basic measurements, such as spatio-temporal derivatives (to measure normal components of velocity) or local correlation surfaces, and
(3) the integration of these measurements to produce a 2-D flow field, which often involves assumptions about the smoothness of the underlying flow field. [1]

Optical flow is the estimation of pixel-level, which is mainly based on the constancy assumption of brightness. If $I(x, y, t)$ is the image intensity of pixel (x, y) at time t, then

$$\frac{dI}{dt} = 0 \tag{1}$$

We can obtain optical flow constraint equation

$$I_x u + I_y v + I_t = 0 \tag{2}$$

in which

$$I_x = \frac{\partial I}{\partial x}, \quad I_y = \frac{\partial I}{\partial y}, \quad I_t = \frac{\partial I}{\partial t} \tag{3}$$

and optical flow components

$$u = \frac{dx}{dt}, \quad v = \frac{dy}{dt} \tag{4}$$

Optical flow constraint equation (2) includes two unknown quantities, and it need to add other constraints for solving (u, v). We assume that the changes of optical flow are smoothing, which are combined with smooth constraints. And we assume the squared values of gradient amplitude of optical flow velocity $\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y}\right)^2$ and $\left(\frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2$ are minimum. For seeking optical flow, we can use regularization method to make the functional formula minimum as follow:

$$\iint \left\{ \left(I_x u + I_y v + I_t\right) + \alpha^2 \left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 \right] \right\} dxdy$$

which α is the canonical coefficient. We use calculus of variations and recursive algorithm for getting the recursive solution (u, v)

$$u^{k+1} = \bar{u}^k - I_x \left[I_x \bar{u}^k + I_y \bar{v}^k + I_t \right] / \left(\alpha^2 + I_x^2 + I_y^2 \right) \tag{5}$$

$$v^{k+1} = \bar{v}^k - I_y \left[I_x \bar{u}^k + I_y \bar{v}^k + I_t \right] / \left(\alpha^2 + I_x^2 + I_y^2 \right) \tag{6}$$

which $\left(\bar{u}^k, \bar{v}^k\right)$ is neighborhood average value of velocity estimation $\left(u^k, v^k\right)$ of the k th iteration.

$$I_x = I(x, y, t) - I(x-1, y, t) \tag{7}$$

$$I_y = I(x, y, t) - I(x, y-1, t) \tag{8}$$

$$I_t = I(x, y, t) - I(x, y, t-1) \tag{9}$$

If the number of iterations k is large enough, we can get more stable optical flow vector $\left(u^{k+1}, v^{k+1}\right)$. So we only need to determinate two parameters: canonical coefficient and neighborhood size.[2]

Optical flow method can detect independent moving object without knowing any prior information of scene which is suitable for dynamic background. Sea is the dynamic background by the influence of wind, waves, sea clutter and others. It's a good choice to use optical method for object detection with sea background. However, optical flow method has complex algorithm and great amount of calculation, which may lead to poor real-time of object detection and not suit the requirement of high real-time situation.

2.2. Background subtraction

The basic idea of background subtraction[3] is to detect moving regions by subtracting the current image f_k pixel-by-pixel from a reference background image B_{k-1} that is pre-stored or created by real-time. If the value of pixel difference D_k is greater than a threshold T, the pixel is belong to the foreground or else the background. Threshold operation is show directly the information of object about location, size and shape. The formulas as follow:

$$D_k(x,y) = |f_k(x,y) - B_{k-1}(x,y)| \quad (10)$$

$$R_k(x,y) = \begin{cases} 1 & Foreground \quad D_k > T \\ 0 & Background \quad D_k \le T \end{cases} \quad (11)$$

From (10) and (11) we can know the key to background subtraction: the choice of threshold and the creation of background. Threshold selection methods commonly include grey level histogram method, minimum error method, OTSU method, maximum entropy threshold method, etc. The methods of background construction mainly have statistical average method, single Gaussian distribution background model, Gaussian mixture distribution background model, background model based on Kalman filtering, background model based on kernel density estimation, etc.(show the example of background subtraction as fig. 1)

The algorithm of background subtraction is simple, which amount of calculation for constructing background is small. Therefore, it has good real-time which suits static background. In the case of fixed camera, it often has been used for vehicle detection and personnel monitoring. Using this method may lead to false or missing detection by the dynamic background of sea and the influence of noise from sea. However, considering that background subtraction is superior to optical flow for multi-video sequences in real-time detection, some researchers[4] consider that how to improve the detection rate of moving object detection in dynamic background by using background subtraction.

2.3. Frame differencing

The basic idea of frame differencing[5] as follow: if the object in a certain position of one image changes, then the grey values of correspondence location will change; the gray values which part of the object has not changed will not change or change a little. Therefore, frame differencing only need to compare the corresponding pixel grayscale values of two consecutive frames. The algorithm as follow:

$$D_F(i,j,t) = |I(i,j,t) - I(i,j,t-1)| \quad (12)$$

$$M(i,j,t) = \begin{cases} 1 & D_F(i,j,t) > T_h \\ 0 & D_F(i,j,t) \le T_h \end{cases} \quad (13)$$

which i and j are the position coordinates of pixel, t is time, T_h is threshold, $D_F(i,j,t)$ is frame differencing image by adjacent, $I(i,j,t)$ is current frame image and $M(i,j,t)$ is moving image by detection.

Frame differencing method, which based on temporal series, is using frame difference for moving object detection. It has good adaptability to the dynamic environment, simple algorithm, and good real-time. It also has a good inhibitory effect for environmental change and needn’t to consider the background update. However, it can only extract the profile of moving object. If the moving distance of object is small, the result of detection may be a large hole; if the object moves slow or static, the result may be missed. It’s helpful that the moving distance of object as large as possible for detection in sea environment. The video sequence by camera shooting can be 30 frames/ sec, industrial camera of good performance can be 500 to 1000 frames/ sec. The moving object which is far away but moving fast may have relatively small moving distance in image, while the moving object which is near and moving too long distance may lead to object missing (that is the object has passed the range of camera shooting during the time of frame selected). So it is important that how to choose the frame images by appropriate interval (the temporal difference method of one or more adjacent frames). This choice should consider not only the moving object of long distance but also the detection of fast moving object at close range.

3. Summary And Outlook

Sea background is the dynamic background. The blinks of sea waves, which caused by wind, swells and other natural environment, even strong sunlight may lead to specular reflection of sea. It will affect the moving object detection of marine environment because of the interference of this dynamic background. In recent years, the techniques of video moving object detection have made great progress in research and applications, especially in the field of land environment which is more mature. In order to make the work of ship detection for better applications, such as navigation safety, ship security, maritime search and rescue, and so forth, it is imperative to promote and develop video detection techniques in maritime fields. However, the video detection techniques are not perfect, which mainly reflected in:

(1) different moving detection methods in use all have some limitations, there is no moving object detection method in a satisfactory way;

(2) in order to improve the performance of object detection, it is completely inadequate by using a single detection method. In practical application and research process, we must make reasonable choice for different methods of practical work. If deemed necessary, we should make the integrated use of various methods for improving the rate of object detection;

(3) because of application occasion(such as dynamic or static background), real-time(such as the complexity of the algorithm and computation), robustness(such as stability and capacity of resisting disturbance of algorithm) and index of the rate of object detection which can not reach an agreement, it has not yet formed a unified standard data set and evaluation system for the problem of the rate of moving object detection.

Using video detection techniques in marine environment has a huge space for development, which can serve as an independent means for moving object detection or as a complement of other detection techniques.

In future work, we will make further experimental research for object detection techniques.

4. Reference

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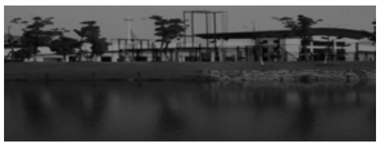
(a) current image



(b) background image

(c) subtracting image

(d)final detection result by using threshold

Fig. 1: Example of using Background subtraction.