

Estimating Velocity of Moving Objects Using an Improved Optical Flow Method

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Abstract: In order to eliminate the disturbance of the changing illumination during the process of estimating the velocity of moving objects, an improved optical flow method is proposed and applied in the research on FAE in this paper. First of all, images are preprocessed by Gaussian kernel adaptive smooth filter; Secondly, according to the illumination invariability of rgb color model, we convert RGB color model to rgb color model; Finally, the improved optical flow method based on rgb color model is applied in the estimation of the velocity of the diffusing cloud in FAE explosion. It has been proved by the experiments that we can get a satisfied result by using this method.

Keywords: optical flow, FAE, Gaussian kernel adaptive smooth filter, color model

1 Introduction

The detection, Identification and tracking of the moving objects are a pop problem studied in the modern digital image process field. It has been widely applied to the civil and military aspects. The optical flow method is a kind of common methods, by which we can compute the velocity data of moving objects. However, because of the disturbance of the strong illumination inferred, the influence of the changing illumination is often detected as the information of the movement. Therefore, this paper proposes an improved optical flow method, combines the traditional optical flow theory and illumination invariability theory. It restrains the impact of changing illumination on the optical flow estimation effectively, expands the application of the optical flow method.

FAE throws scattered fuel to the air, which makes fuel and oxygen combine to form the cloud particle suspended medium, and then it forms a large exploded area. The velocity of the diffusion of the cloud plays an important role in the research on choosing the variety of fuel. The researchers who engage in explosion science usually adopt the artificial method to read the data from the photos to carry on the data analysis, but the efficiency is low and the error is great. According to the improved method proposed in this paper, we promote the research on the velocity of the cloud diffusion in FAE explosion, and get a satisfied result.

2 Conventional Optical Flow Method

The optical flow method was put forwarded in 1981 by Horn and Schunck at first. It is a computing technology based on the theories of grayscale gradient invariability and illuminance invariability^[1].

In grayscale images, $I(x, y, t)$ is supposed as the gray value of point (x, y) , u, v is the optical flow in x and y direction, defined as:

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

and we can also get the optical flow equation of constraint as:

$$\frac{\partial I}{\partial x} \frac{dx}{dt} + \frac{\partial I}{\partial y} \frac{dy}{dt} + \frac{\partial I}{\partial t} = 0 \quad (1)$$

or

$$I_x u + I_y v + I_t = 0 \quad (2)$$

Horn-Schunck optical flow method is usually expressed to the iteration expressions as:

$$u^{(n+1)} = \bar{u}^{(n)} - I_x \frac{I_x \bar{u}^{(n)} + I_y \bar{v}^{(n)} + I_t}{\alpha + I_x^2 + I_y^2} \quad (3)$$

$$v^{(n+1)} = \bar{v}^{(n)} - I_y \frac{I_x \bar{u}^{(n)} + I_y \bar{v}^{(n)} + I_t}{\alpha + I_x^2 + I_y^2} \quad (4)$$

Here, α is the parameter, which controls the smooth degree. n is the number of times of the iterations. \bar{u}, \bar{v} are the average values of u, v which are in the neighborhood of (x, y) . u^0, v^0 are the starting values of optical flow, which are usually 0. In the equations (3) and (4), I_x, I_y, I_t are defined as three finite difference expressions by Horn-Schunck.^[1]

In 1990, NEC's N.Ohta^{[2],[3]} put forward a computing model based on *RGB* color model. In this model, every color image is considered as the mixture of the three independent images *R, G, B*. Therefore, we can calculate the optical flow of every pixel in images by the information of *R, G, B*. According to the grayscale optical flow method, three color components are put into the optical flow formula. Then we can get the equations as:

$$\begin{cases} \frac{\partial R}{\partial x} u + \frac{\partial R}{\partial y} v + \frac{\partial R}{\partial t} = 0 \\ \frac{\partial G}{\partial x} u + \frac{\partial G}{\partial y} v + \frac{\partial G}{\partial t} = 0 \\ \frac{\partial B}{\partial x} u + \frac{\partial B}{\partial y} v + \frac{\partial B}{\partial t} = 0 \end{cases} \quad (5)$$

3 Improved Optical Flow

Method

rgb is a normalized color model which is transformed by familiar *RGB* color model, defined as:

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B}$$

The production indicated that the components of the *rgb* color model keep invariable in white illumination^[4]. According to this invariability, an improved optical flow method is proposed in this paper to eliminate the disturbance of changing illumination in the conventional optical flow method. Similar to equation (5), it is assumed that the following equations exist,

$$\frac{\partial r}{\partial x} u + \frac{\partial r}{\partial y} v + \frac{\partial r}{\partial t} = 0 \quad (6)$$

$$\frac{\partial g}{\partial x} u + \frac{\partial g}{\partial y} v + \frac{\partial g}{\partial t} = 0 \quad (7)$$

$$\frac{\partial b}{\partial x} u + \frac{\partial b}{\partial y} v + \frac{\partial b}{\partial t} = 0 \quad (8)$$

We can get the result as:

$$U = (A^T A)^{-1} A^T b$$

Here,

$$U = \begin{bmatrix} u \\ v \end{bmatrix}, A = \begin{bmatrix} r_x & r_y \\ g_x & g_y \\ b_x & b_y \end{bmatrix}, b = \begin{bmatrix} -r_t \\ -g_t \\ -b_t \end{bmatrix}.$$

The above hypotheses (equations (6), (7) and (8)) are testified as follows:

Put $r = \frac{R}{R+G+B}$ into equation (6), and then we can

get a derivation as:

$$\frac{\partial \left(\frac{R}{R+G+B} \right)}{\partial x} u + \frac{\partial \left(\frac{R}{R+G+B} \right)}{\partial y} v + \frac{\partial \left(\frac{R}{R+G+B} \right)}{\partial t}$$

$$= \frac{\left(\frac{\partial R}{\partial x} u + \frac{\partial R}{\partial y} v + \frac{\partial R}{\partial t} \right) (R+G+B)}{(R+G+B)^2}$$

$$= \frac{\left(\frac{\partial R}{\partial x} u + \frac{\partial R}{\partial y} v + \frac{\partial R}{\partial t} \right) R - \left(\frac{\partial G}{\partial x} u + \frac{\partial G}{\partial y} v + \frac{\partial G}{\partial t} \right) R}{(R+G+B)^2}$$

$$= \frac{\left(\frac{\partial B}{\partial x} u + \frac{\partial B}{\partial y} v + \frac{\partial B}{\partial t} \right) R}{(R+G+B)^2}$$

Put equation (5) into the above result, then we can prove equation (6). At the same time, equations (7)

and (8) can also be proved by the same method.

In the case of the too little contrast between moving object and background image or the random noise existing in the image, the FAR will be very high, if the optical flow method is applied in the initial images. In order to get a better gradient estimation in optical flow method, Gaussian kernel adaptive smooth filter is used to preprocess the images and smooth the images in time domain and space domain.^[1]

The main steps of computing is shown as follows:

Firstly, the images are preprocessed by the Gaussian kernel adaptive smooth filter.

Secondly, the color model of the sequence of images is converted from *RGB* model to *rgb* model.

Finally, in the *rgb* color model, $u(x, y), v(x, y)$, the components of the horizontal and vertical velocities of the moving points in each frame are worked out by the optical flow method. According to this result, we can work out the vector sum of the two components. Then, \bar{V} , the average velocity of the cloud in the frame can be worked out as:

$$\bar{V} = \frac{1}{S_A} \sum_{(x,y) \in A} V(x, y)$$

Here, the unit of \bar{V} is pixel/frame; A is the area which include moving points; S_A is the number of the moving points.

4 Application

The image sequences of FAE whose resolutions are 256×240 were shot by the high-speed camera whose frequency of exposure are 1000 frames per second. Now we use 2 frames of the image sequences (Fig1. frame 800 and Fig2. frame 801) to analyze the result. If the conventional optical flow method is used in the estimation, the result is shown as Fig

3, where due to the disturbance of the changing illumination, a lot of motionless areas have been detected as the moving ones. Comparing with the conventional method, the improved one is used in this experiment. At first, the two frames are preprocessed respectively by the smooth filtration. Then the color model of the two frames is converted from *RGB* model to *rgb* model. Finally, the improved optical flow method is used in the estimation of the velocity of the cloud. We can get the result shown as Fig 4.



Fig. 1: The explosion image of Fig. 2: The explosion image
frame 800 of frame 801



Fig. 3: The result of the conventional method

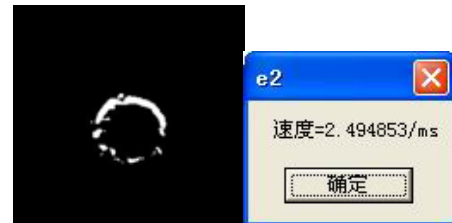


Fig. 4: The contour of the cloud diffusion and the initial result
of the improved method

Here, the white area is the moving area, and the black area is the motionless one. The clouds radiate around. The pixels inside the cloud images are always high-brightness. Therefore, during the exploding period, the color information kept almost invariable in the sequence of frames. The outer contours of the clouds diffused radially. During the time between frame 800 and 801, the velocity of the cloud was

2.495 pixel/ms. After the parameters conversion, we can get the velocity of the cloud as 109.78m/s.

According to the velocity of the cloud in each frame, we trace out the curve of the velocity in order to provide the advantages to the researchers in the correlative areas.

5 Conclusion

According to the illumination invariability of *rgb* color model, the improved optical flow method, which can be applied in the situation of changing illumination, is proposed and applied in the estimation of the velocity of the cloud diffusion in FAE explosion in this text. Through the analysis to the experiment, the aim of estimating the velocity of the cloud diffusion is achieved, and there is a considerable robustness in the situation of changing illumination. Therefore, it is an efficient and effective method of estimating the velocity of a moving object, and it also has a wide prospect in application.

Reference

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