A New Method of Motion Detection with Biological Intelligence

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Abstract

The detection of moving object is the hot topic of computer vision research. In this paper, we propose a new method to detect moving object in surveillance video based on the visual features of frog eyes. The method used the principle of entropy which derived from information theory. First, we filtering out the noise and some unnecessary information in the frame images sequence used smoothing filter; Second, detecting the edge point of the smoothed image obtained in the first step by Canny operator; At last, spatial-temporal sliding windows are built for each edge point, then calculating the entropy of spatial-temporal windows and comparing the value in adjacent frames, in which the difference exceeds a certain intensity is considered as a part of moving object. Experimental results show that the proposed method can detect the edge of moving object effectively and has lower computational complexity.

Keywords: *Frog's Visual Characteristic, Spatial-temporal Entropy, Moving object detection, Canny operator*

1. Introduction

Computer vision has been studied for 40 years, but many difficulties are encountered when applying traditional theory of computer vision into the development of actual system. Many people begin to doubt about the traditional theory and turn to search for new theory. To research the vision behavior of human and animals is one kind of exploration.

Moving target detection is the forward direction in the field of computer vision in recent years. It is widely used in military and civilian areas, such as: equipment of weapons, security, traffic control and so on. Therefore, it has important practical value and broad development prospects. However, it is also bring a huge challenge to design computer vision system because of many interference factors in reality when people put forward higher requirements on it capability of real-time and robustness [1].

After a long-term evolution, various biological visual system provide a good reference to solve the problems [2].And the frog is dependent on the eye as the main means of subsistence and have a relatively simple brain, Therefore, it is may be a better way to solve the present encountered problems by simulating the frog’s visual behavior [3].

Currently, the research and application on the behavior of frog vision is relatively narrow in the areas of computer simulation. Zhi-ling Wang have proposed A Fuzzy Region Understanding Tactic for Object Tracking Based on Frog's Vision Characteristic [4].in his method, it was noticed that frog is myopia and concern on the contour, he used mean-shift algorithm to track the target profile after fuzzy the image sequence by smoothing. This

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method has better robustness, but he wasn't discussing the mechanism of the frog's visual nerve.

We propose a method of motion detection by combining the Canny edge operator and spatial-temporal entropy based on the features of frog's visual system in this paper. It is seemed that this method is highly adaptive to static environment. This paper is organized as follows: Section 2 introduces the features of frog vision. Section 3 introduces the related works. Section 4 presents our motion detection method. Experimental results are analyzed in Section 5, and conclusions are given in Section 6.

2. The Features of Frog Vision

Wiener and his colleagues did a large number of physiological experiments on numbers of organisms (including frogs) as a basis for the creation of control theory in 1948. 1960s, the representatives of researching physiology and behavior of frog's vision have Ingle D , Ewert JP ,Speery RW and so on [3]. A new round of the study on the frog's vision began based on the original study with the development of neural networks in 1980s.

Frog is known for the unique visual characteristics ,it rely mainly on the vision to prey and find their natural enemies, it's sensitive to the moving object, but don't focus on the static details of surrounding, so it may even starve to death in a pile of static food [4]. Researchers found that frogs rely mainly on the movement and size of external objects to prey or escape and so on. We also can easily make the frog to respond by swinging the meat or small moving objects. Moreover, it's not easy to transfer the attention of one frog when the frog's eye is focus on the target [3]. However, the frog's eyes are unable to act as human's eyes. Compensatory motion of eyes will be achieved when the frog's body position change, or its entire visual world flips. Besides, the frog can't see distant objects clearly, because the surface will be formed in frog's eye when the light comes from far away. Figure 1 shows the Frog Visul sysyerm.

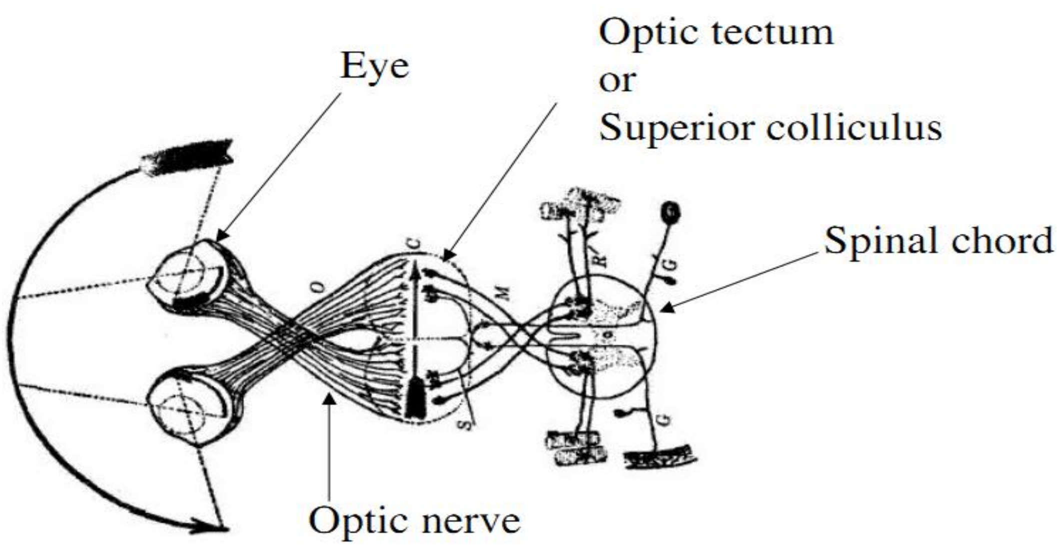


Figure 1. Frog Visul sysyerm

Neuroscience researchers made a detail research and description about its amphibian's physical structure, such as the brain structure, nerve distribution, visual characteristics and behavior. With a lot of speculation and various kinds of visual stimulation experiment in analysis of retinal ganglion cells, Lettvin, Maturan, Pitts and McCulloch divided its ganglion cells into five types [3]:

- Edge or contrast detector: Response to the local comparison between the bright and dark.
- Motion convex edge detector: Response to the dark convex side which have entered the receptive field.
- Moving side or change of contrast detector: Response to the movement of border between light and dark area.
- Darken detector: It don't need boundary stimulation, this cell responses to darking of the whole receptive field.
- Dark detector: Tension discharge and its discharge frequency is inversely proportional to the diffuse light felling in its larger receptive field.

3. Related Algorithm

3.1. Smoothing Filter

Tukey proposed the concept of median filter during the time series analysis in 1971, and it is introduced into the image processing later. This filter is famous for its simple and fast, it's good at filtering out superposed white noise and long tail superimposed noise, and has a well protection on image edge information [12].

Median filter is a nonlinear smoothing technique, it set each pixel value to the mid-value of all pixel gray scale value in its certain window. It is could be executed as follow: Step 1, sorting out odd number of data from the sampling window in the image. Step 2, replacing the data to be processed with the median of sorted data.

Fast two-dimensional median filtering algorithm [11] get mid-value from the histogram of image base on the histogram of pixels in the statistics window, window A=[m n]will move over one row when get the output pixel of median filter from the next window . The new pixels is obtained by deleting n pixels of the most left row in the original window, meanwhile adding n pixels to the most right row of the window, the other mn-2n pixels remain unchanged, then the original histogram is amended, and mid-value of the new window is obtained. Practice shows that the fast algorithm and conventional algorithms have the similar treatment effect under the same condition, but the fast algorithm is faster.

3.2. Edge Detection Operator

Edge is the basic characteristic of images, it contains valuable target boundary information, which can be used for image analysis, target recognition and so on. The method of edge detection usually divided into based on the differential, based on wavelet and fractal theory and based on mathematical morphology. With the development in recent years, based on fuzzy study, neural network, the genetic algorithm and other kinds of method have been proposed.

Canny [9] operator is the most commonly used edge detection operators, and also recognized as the one with excellent performance, It is often cited by other operators as the standard operator for comparative analysis of the advantage. Although the Canny operator is a first-order differential operator, but extend it. It is added non-maximum suppression and dual-threshold on the basis of original first-order differential operator. Using non-maximum suppression can not only suppress unnecessary edge effectively, but also can improve the positioning accuracy of the edge; taking advantage of dual-threshold can effectively reduce the rate of undetected the edge.

3.3. Spatial-temporal entropy

In information theory, entropy represents the size of information of the data contained. The greater the entropy value, the more information contained. Shannon who found the information theory proposed an information measure based on probability and statistics model in his “A Mathematical Theory of Communication”. Since entropy is a measure of information, indicating the diversity of events, so it can be used to characterize the diversity of pixels state, thus reflect the strength of pixels movement.

Entropy has been widely used in the field of image segmentation, but less in the target detection. Ma and Zhang proposed a motion detection method based on the spatial-temporal entropy [5]. In their method, a spatial-temporal entropy image (STEI) is built, and those pixels with larger entropy in the STEI are considered as part of moving objects. It is more robust to noises than traditional difference based methods owing to that the STEI method is a statistical measurement of variation. This method is easy put some of the edge detection error for the moving target, due to the diversity of spatial structure. Moreover, it has a high computational complexity. Therefore, In [6], Jing et al. proposed a motion detection method based on the difference-based spatial-temporal entropy image (DSTEI). It is obtain the spatial-temporal entropy image after frame difference. It wipe the disturbance of static background edge out to some degrees. Meng and Yang propose a motion detection by using entropy image and adaptive state-labeling technique [7].These methods overcome the shortcomings of STEI algorithm to a certain extent.

4. The Proposed Method

4.1. Steps of the Algorithm

In this paper, we mainly focus on the three characteristics of frog visual system:(1) The frog's eyes have 500,000 ganglion cells, it can filter out irrelevant information in the environment and focus on moving target directly.(2) The frog identify the target mainly according to the size of the target and profile characteristic [2-4]. (3)Frog's eyes have a certain memory. It can detect four different states of the target by detectors constituted of four kinds sensory cells, then it can get a clearly moving object by put them together.

Many experiments show that the first processing stage of biological visual system is nonlinear. In this paper, based on the three features of frog's eye above, we first remove the noise as well as some unnecessary information in video sequences by using non-linear median filter and retain the information of edge mainly, because frog's eyes are sensitive to the edge of object., here, we use a fast two-dimensional median filtering technique, which can smooth the image real-time, and maintain the profile well. Second, we pick up the edges and contours from the smoothed image by canny operator. Third, we determine whether it belong to the moving object or not according to the calculation of the spatial-temporal entropy of contours. Since the spatial-temporal entropy calculation is based on the contour detected, it reduce the computational complexity and improve the robustness of the algorithm.

The specific steps are as follows:

Step 1: Smooth the t^{th} frame $F_1(t)$ in video sequence by fast two-dimensional median filter to remove noise and unnecessary information, but keep the major profile information, then obtain the smoothed frame $F_2(t)$.

Step 2: Detect the edge of smoothed image $F_2(t)$ by canny's operator, and Get the corresponding coordinate set A_t .

Step 3: The spatial-temporal entropy for all pixels corresponding to A_t in $F_2(t)$ is gathered to form a set E_t , likewise, the entropy set E_{t-1} according to the previous frame $F_2(t-1)$ is formed.

Step 4: taking into account the difference between $E_t(x,y)$ and $E_{t-1}(x,y)$, point(x,y) will be considered as part of moving object if the difference is greater than threshold E_{th} , Then whole moving object by compare all points in E_t and E_{t-1} is obtained.

As shown in Figure 1, Figure 2, due to the difference between the target and background, if the target move, the information of spatial-temporal window in edge points will change, the greater the movement, the greater the change. Therefore, the spatial-temporal entropy method can simulate the frog eye's movement detector very well, meanwhile, combining with the edge detection operator, the contours of moving target can be effectively detect.

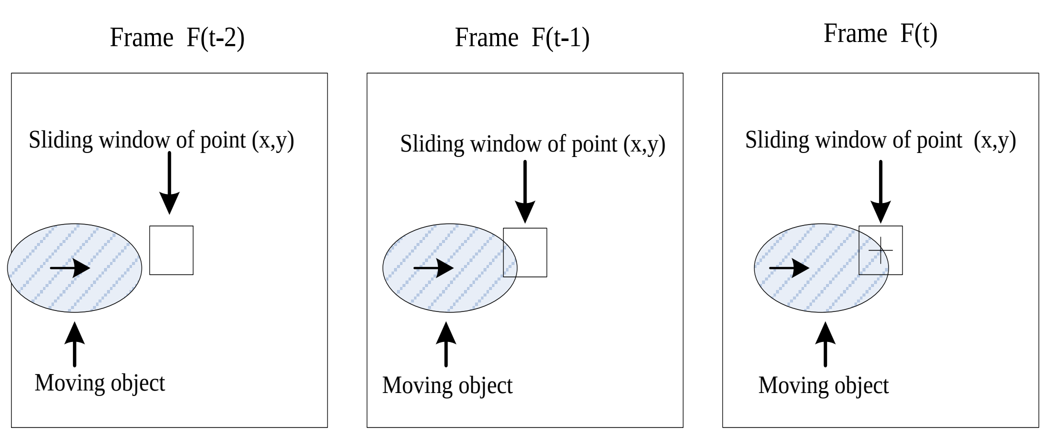


Figure 2. Motion Detection

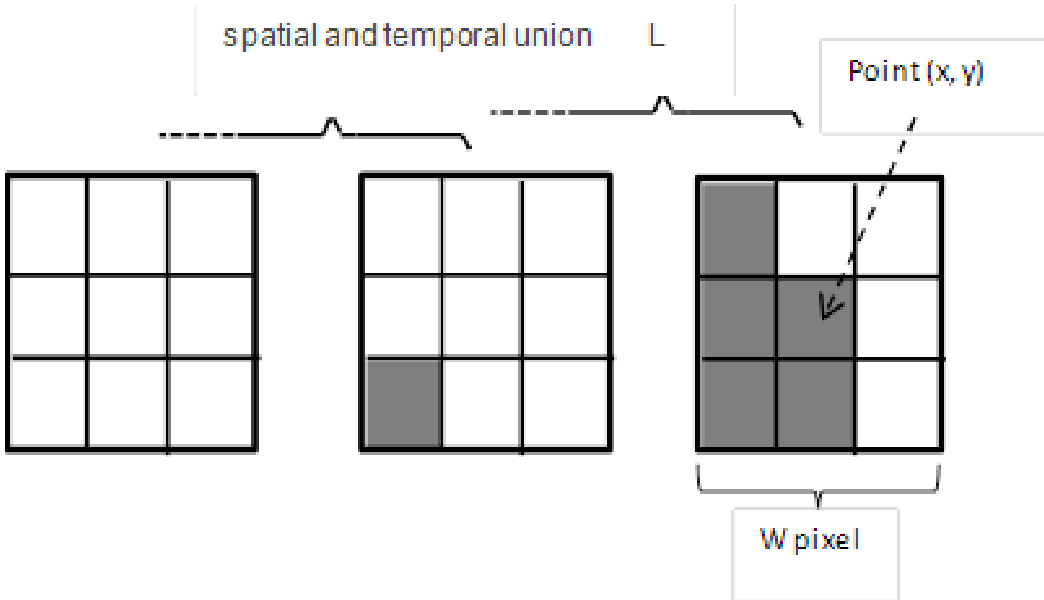


Figure 3. The Spatial-temporal Sliding Window

4.2. Canny Edge Detection

Step 1: Image denoising.

Step 2: calculation on Gradient amplitude and direction angle. Computing the gradient M_x and M_y in the x and y direction of the image respectively after denoising.

Gradient amplitude:

$$|\nabla f| = \sqrt{M_x{}^2 + M_y{}^2}$$

Direction angle:

$$\theta = \arctan(\frac{M_y}{M_x})$$

Step 3: Non-maximum suppression. For each point, comparing the two gradient amplitude along the gradient direction. If one is the largest, retain it and remove the other. Through all gradient amplitude, the candidate image M is obtained.

Step 4: Double threshold. A high threshold T_h and a low threshold T_l are first set for the candidate image M. If the gradient amplitude of any pixel in M is greater than T_h, it will be considered as the edge, and non-edge if less than T_l. For the pixel whose gradient amplitude is between T_h and T_l, it will be marked as the edge if the gradient amplitude of it's 4- adjacent or 8-adjacent pixel is greater than T_h ,otherwise, it will be not.[10]

4.3. Spatial-temporal Entropy

Figure 3 shows the spatial-temporal sliding window, there are three steps for calculating the spatial-temporal entropy in gray image [7]:

Step 1: A spatial-temporal sliding window is first formed for each pixel to obtain the corresponding spatial-temporal histogram. The spatial-temporal sliding window S($w \times w \times L$) for (x,y) is defined as:

$$S = \{(i, j)_k \,|\, |i - x| < \lfloor w/2 \rfloor, |j - y| < \lfloor w/2 \rfloor, 0 \le t - k < L\}$$

Step 2: The w×w×L pixels in the sliding window are then classified into Q bins according to their intensity, and are accumulated to obtain the spatial-temporal histogram. Let $H_{x,y,q}$ denote the number of pixels belonging to bin q in the sliding window of pixel (x,y).

Step 3: The corresponding probability density function (pdf) for component q can be calculated by:

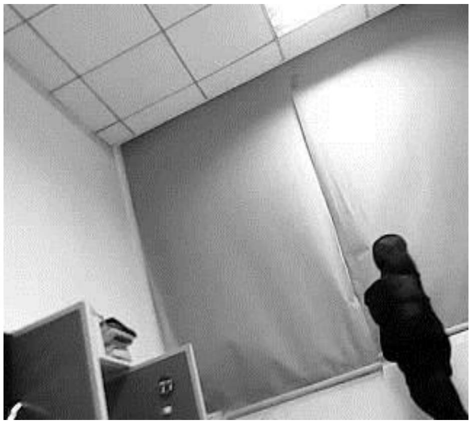
$$E_{x,y} = -\sum_{q=1}^{Q} P_{x,y,q} \log(P_{x,y,q})$$

5. Experimental Results

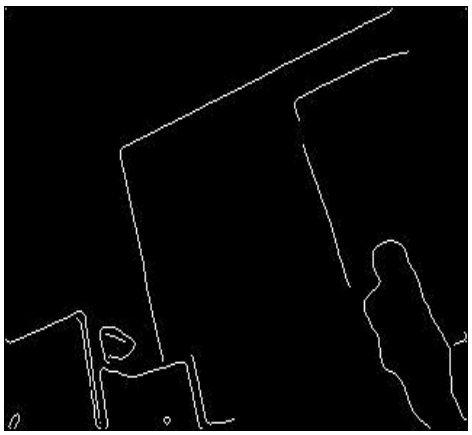
The proposed method was tested using various real video sequences. Figure 4 show the experimental results for the indoor video:(a)is the input image of 14th frame of original sequence,(b)is the image smoothed by two-dimensional median filter,(c)is the result of edge detection,(d)is the edge of moving object detected by spatial-temporal entropy. Moreover, we have conducted the same experiment for the outdoor images sequence. Figure 5 show the experiment results for the auto surveillance video:(a)is input image of 14th frame of original sequence,(b)is the image smoothed by two-dimensional median filter,(c)is the result of edge detection,(d)is the edge of moving object detected by spatial-temporal entropy.

From the experiment results, we can see that through the smooth filter and the right edge detection algorithm, some unnecessary information are suppressed, but the counter of target are effective reserved, such as: the edge of ceiling was not measured in(c) of Figure 4. The edge information of moving object was detected effectively by using spatial-temporal entropy. We can see the result from(c) to (d), it shows that this method can detect the edge of moving target well.

Figure 6 shows the motion detection results of three methods. (a)shows the original image from the video sequences, (b) is the result of STEI method, (c) is result of DSTEI method, the result of our method is showed in (d). In the methods, the various parameters are set as: the width of the sliding window w is set to 3, the frame length of the sliding window L is set to 3 too, and parameter Q is set to 33.



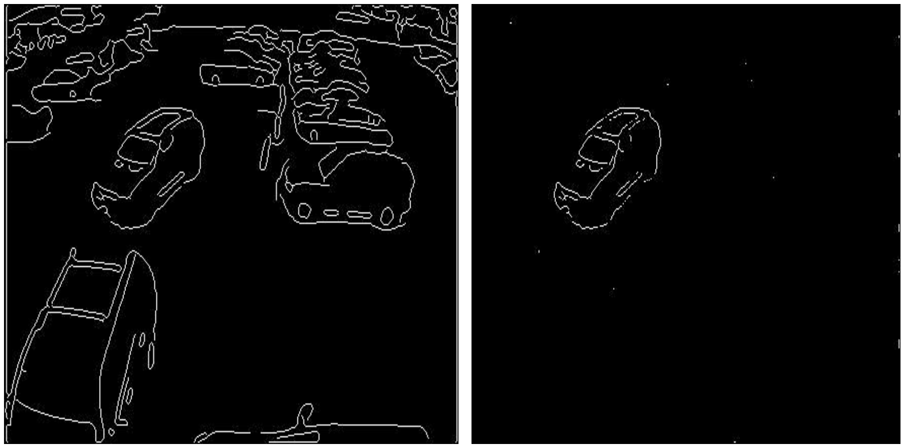
（a）Original sequence (b) Smoothed image



(c) Edges detection (d) Moving detection of edges

Figure 4. Experimental Results in Indoor Video

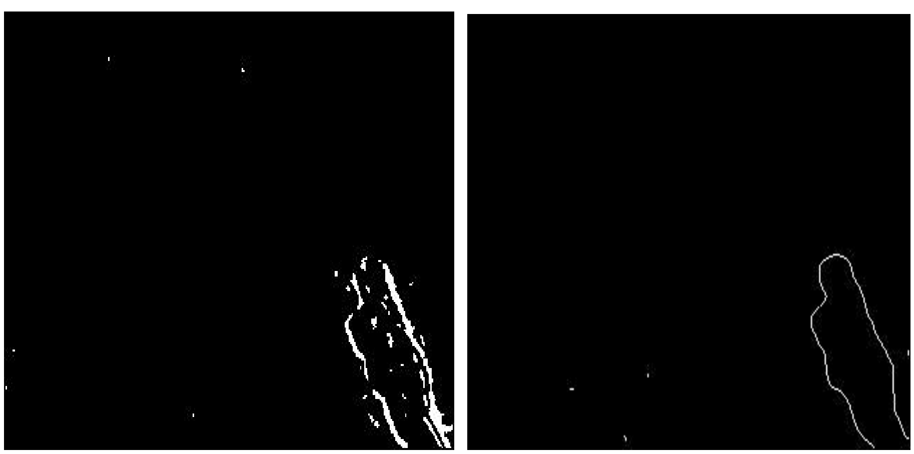
(a) Original sequence (b) Smoothed image



(c) Edges detection (d) Moving detection of edges

Figure 5. Experimental Results in Outdoor Video

(a) Original sequence (b) Result of STEI method



(c) Result of DSTEI method (d) Result of our method

Figure 6. Experimental Results of Three Algorithms

6. Conclusions

Based on the visual characteristics of frog eyes, in this paper, we propose a moving object detection algorithm using Median filter, Canny operator and spatial-temporal entropy calculations to simulate the frog eye's detector and the mechanisms of integration. The main features of the algorithm is:(1) We Learn from the frog visual system, and simulate part of the visual neural mechanisms of frog eyes; (2)We use a fast median filter, and only calculate the spatial-temporal entropy based on the detected edges, which reduce much computational complexity; (3)The motion detection is executed after filter smoothing, and it is built on the basis of the edge which has been detected, meanwhile, we use the statistical properties of spatial-temporal entropy, so it has better robustness.

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