Moving Object Tracking System Based On Camshift And Kalman Filter

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***Abstract*—To accomplish real-time tracking of moving objects requirements, and overcome the defect of occlusion in the process of tracking moving object, this paper presents a set of real-time tracking system. The tracking system uses a combination of camshift and kalman filter algorithm. When the moving object is a large area blocked, the velocity of moving object is applied linear prediction to kalman filter tracking. When the camera moves, we can quickly find the target in this tracking system. The experimental results show that : this system designed for tracking moving targets has good robustness.**

Keywords-camshift; kalman filter; tracking system; occlusion

I. INTRODUCTION

Moving target tracking is an important research topic in the field of computer vision. In the security monitoring, intelligent perception and object-based video compression and other areas of computer vision is widely used. The actual problem of tracking process to solve is the rotation of PTZ(Pan/Tilt/Zoom) caused by changes in target tracking problem of size, and tracking occlusion encountered in the tracking process. This paper presents a set of tracking system based on camshift and kalman filter.

More current research and the use of tracking methods are meanshift algorithm, camshift algorithm and Kalman filtering, particle filtering. In [4] meanshift and kalman-based algortithm is used to solve occlusion occur. In[5] acceleration model which is effective solution to fast tracking is used to predict the emergence of target. Meanshift algorithm is an efficient pattern matching algorithm with no parameter estimation, and can be combined with other algorithms. It uses the kernel function histogram model of the target object. Meanshift is not sensitive for part of block rotation and deformation, but the track is easy to lapse when blocked a large area on the target. Meanshift algorithm will be extended to a continuous image sequence to form a camshift algorithm. Like meanshift, camshift based on the color probability distribution of the target. By calculating similarity of the color probability distribution, the moving target in the current frame image location is taken as the initial location of the next frame. The disadvantage of camshift is affected by the probability distribution of the color image, and it is mainly applied to target tracking of the obvious different background color.

Kalman filter is an efficient recursive filter, and provides an efficient method to calculate the state estimation process, and make the minimum mean square error estimation. It can estimate of the unknown past and current state of the signal, even to estimate the future state. This paper combine camshift and kalman algorithms by using the moving target information to improve the matching accuracy of the candidate target and object target. Hybrid algorithm with occlusion handling is more robust and achieve a good tracking..

II. CAMSHIFT ALGORITHM

A. *Meanshift Algortithm*[1]

Because the HSV color space are better able to express the color information, the RGB space of target area is converted to HSV space firstly. Secondly we extracted the component H and divided it into m shares with each corresponding to a sub-characteristic value. Lastly the whole target region can be characterized by these values. For each sub-feature, kernel-based density distribution function is exploited to calculate the probability distribution, and then the u-th characteristic probability can be denoted as

$$q_u = C\sum_{i=1}^{n} k\left(\left\|\frac{x_0 - x_i}{h}\right\|^2\right)\delta[b(x_i) - u] \tag{1}$$

where x_0 is the center of search window, x_i is the position of i-th pixels, $k\left(\|x\|^2\right)$ is kernel function, h is window radius（half of the width）, b and δ function determine whether the pixel in point x_i accord with the u-th characteristic value. The normalization constant C is derived by imposing the condition $\sum_{u=1}^{m}\hat{q}_u = 1$, from where

$$C = \frac{1}{\sum_{i=1}^{n} k\left(\left\|\frac{x_0 - x_i}{h}\right\|^2\right)} \tag{2}$$

since the summation of delta functions for u = 1…m is equal to one.

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Like formula (1), assume y_0 as the center of the target candidate region in current frame, then the probability of u-th characteristic value. is

$$p_u(y_0) = C\sum_{i=1}^{n} k\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)\delta[b(x_i) - u] \cdot \tag{3}$$

Similarity function characterizes the similarity between the initial target model and target candidates, Similarity measure methods commonly used include Bhattacharyya coefficient, Fisher measure of information, and histogram intersection technique[8]. Here we use Bhattacharyya coefficient, the sample estimate is given by

$$\hat{\rho}(y) = \rho(\hat{p}(y), \hat{q}_u) = \sum_{u=1}^{m} \sqrt{\hat{p}_u(y)\hat{q}_u} \tag{4}$$

Using now (4) the distance between two distributions can be defined as

$$d(y) = \sqrt{1 - \hat{\rho}(y)} \,. \tag{5}$$

The statistical measure (5) is well suited for the task of target localization. If $d(y)$ was smaller, the similarity between the two color distribution histogram would be higher.

In the search process we employ mean-shift iterations to achieve the maximization of $\hat{\rho}(y)$, the steps list below[2]:

step1. Derive the weights of points in present search area according to (5)

$$w_i = \sum_{i=1}^{m} \sqrt{\frac{q_u}{p_u(y_0)}}\delta[b(x) - u] \tag{6}$$

step2. calculate the next new position of target candidates

$$y_i = \frac{\sum_{i=1}^{m} x_i w_i g\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)}{\sum_{i=1}^{m} w_i g\left(\left\|\frac{y_0 - x_i}{h}\right\|^2\right)} \tag{7}$$

step3. If $\|y_i - y_0\| < \varepsilon$ or reach the maximum of iteration counts, stop. Otherwise, set $y_0 \leftarrow y_i$ and return to Step 1, continue to search the eligible target candidate position.

B. Camshift[3,5,6]

If we extended meanshift to a continuous image sequence, thus CamShift algorithm is formed. The basic idea of camshift is to make all the video frames MeanShift operations. And the results of the previous frame is taken as the initial value of the Search Window of the next frame's MeanShift algorithm. If this iteration continues, target tracking can be achieved. The iteration steps list below:

Step1: Set the image as the search area.
Step2: Initialize the size and location of the search winndow
Step3: calculating the probability distribution of color in the search window.
Step4: Run MeanShift to obtain a new location and size of search window.
Step5: In the next frame of video images, initialize location and size by step3. And Jump to step3 continue to run.

III. KALMAN FILTER[4,7]

Kalman filtering algorithm is that predict the most probable object location in the current frame according to the results of targets tracking in the previous frame, then search target location in the neighbor area of the location. If there is a target existing in the search area, continue to process the next frame. The key of kalman filter is prediction and update.

We define the state vector X_k=[x, y, v_x,v_y], measurement vector Z_k=[x,y]^T, Where x and v_x are the target image in the horizontal direction of the position and velocity; y and v_y are the target image in the vertical position and velocity. Kalman Filter model is as follow:

Motion equation:
$$X_k = F \cdot X_{k-1} + W_k \tag{8}$$

Observation equation:
$$Z_k = H \cdot X_k + V_k \tag{9}$$

Where W_k and V_k are movement and measurement noise vectors which obey Gaussian distribution $p(w) \sim N(0, Q)$, $p(v) \sim N(0, R)$, F is state transition matrix , and H is measurement matrix.

Prediction equation and the update equation are as follows:

Prediction equation 1
$$X_k' = F \cdot X_{k-1} \tag{10}$$

Prediction equation 2
$$P_k' = F \cdot P_{k-1} \cdot F^T + Q \tag{11}$$

kalman-gain equation
$$K_k = P_k' \cdot H^T \cdot (H \cdot P_k' \cdot H^T + R)^{-1} \tag{12}$$

update equation 1
$$X_k = X_k' + K_k \cdot (Z_k - H \cdot X_k') \tag{13}$$

update equation 2
$$P_k = P_k' - K_k \cdot H \cdot P_k' \tag{14}$$

The values of state transition matrix *F*, measurement matrix *H*, process noise covariance matrix *Q* and measurement noise covariance matrix *R* list as follow:

$$F = \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, Q = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix},$$

$$H = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}, R = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$$

IV. SYSTEM OVERVIEW

As the relative speed moving targets at sea is more stable, the tracking system uses a combination of camshift and kalman algorithm. In the experiment, we assume a threshold α. If Bhattacharyya distance $d(y) > \alpha$, it is inferred that the object has been occluded. If the target appears occlusion, system track object by using the speed detection and prediction of kalman. Otherwise, system track object by using camshift.

The system uses the method of linear prediction to handle occlusion. Linear Prediction is be utilized to search the target location. Moving target can be divided into horizontal and vertical velocity components. Horizontal component and vertical component, respectively, can be predicted by the following two equations:

$$\hat{V}_x = \alpha_x \sum_{i=n+1}^{n+f} (x_i - x_{i-1}) / f \tag{15}$$

$$\hat{V}_y = \alpha_y \sum_{i=n+1}^{n+f} (y_i - y_{i-1}) / f \tag{16}$$

Where x_i, y_i are the i-frame's center position of the horizontal and vertical coordinates, and α_x, α_y are the scale factor, f is the number of frames in a row.

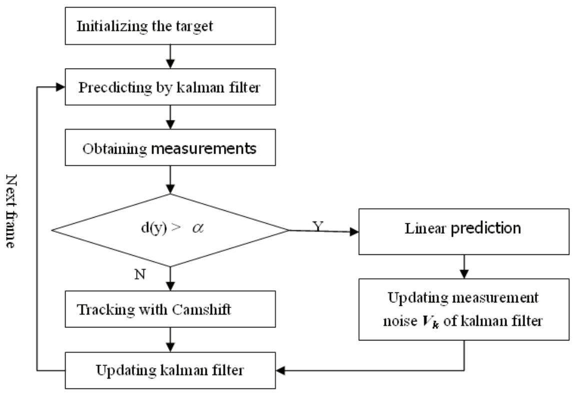

Figure 1 Flow chart of tracking algorithm

V. EXPERIMENTS & ANALYSIS

Tracking system hardware platform consists of two parts. The first part is a PC with Intel core2 duo E8300 2.83Ghz processor and 2G main memory, built-in video capture card. In the IDE Vs2008, We finish the video capture program based on DirectShow and use C++ and OpenCV to develop the tracking algorithm. The second part is formed by the SU-450 Digital PTZ and camera installed on top of the PTZ. Camera resolution is set to 320 * 240, image acquisition frame rate is 25 frames per second. This system uses serial communication mode and RS485 is supported by the communication interface of numeric control PTZ. Through the RS232/RS485 conversion interface host computer could communicate with lower computer under the condition that the baudrate of serial port communication is 9600 b/s. The operations of sending and receiving data are carried out between superior machine and serial port through the API functions supplied by Windows CE, and actuate the SU-450 numerical control PTZ.

To verify the tracking system of effectiveness and robustness , we select a video in Xiamen Zhenzhuwan Bay. In the experiments, the Bhattacharyya distance α= 0.45. The results are shown in the figure where the red rectangle is tracking window and the white cross denote the center of target. From Figure 2 & Figure 3, we can see the vessel was partially blocked until completely blocked, and then partly separated until completely separate from the Obstacle. It can be seen from the tracking results when the target occlusion occur that there is a certain bias between track window and actual location. However, quickly adjust to accurately track the location of the target, which shows strong robustness of camshift.

If the target is about to move out of range, it will control PTZ to rotate or zoom to ensure target in the camera's field of vision. Figure 4 shows the movement of vessels to the boundary of the camera view, and head rotation caused by digital PTZ. At that moment, the tracking window deviated from the actual target location just as the Figure.4 shows. This is because camera's movement produced local disturbance to the tracking region. However, the object was tracked stably over again at once. It is manifested that the proposed algorithm has good robustness.

The results can be seen that better tracking system designed in this paper to solve the target occlusion, system has strong predictive power of the follow-up status. When the camera moves, you can quickly find the target, reflecting the robustness of the system is better.

Figure 2 Tracking the moving object with camshift and kalman filter under the condition of occlusion

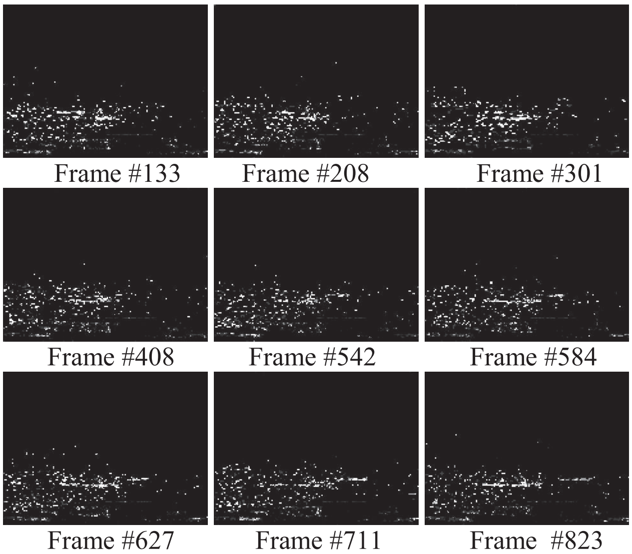

Figure 3 Backproject of the corresponding graph

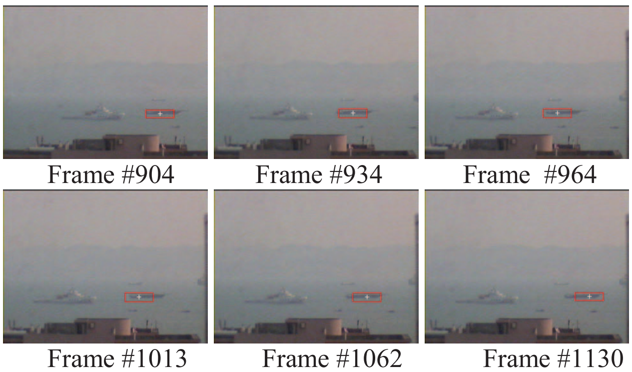

Figure 4 Tracking the moving object under the condition of camera rotating

VI. CONCLUSIONS

To deal with the actual process of tracking moving objects appear in occlusion and interference problems caused by camera movement, moving object tracking system is designed by using the algorithm based on camshift and kalman filter. In the occlusion processing, we use the program of linear prediction combined with kalmanfilter. This approach improves robustness when moving object is under occlusion. Experiments show that the system can be stable for a long time tracking moving object, even if under the condition of occlusion or camera movement. The algorithm is based on the color histogram, and therefore to ensure that the unique nature of the target color is necessary. Future works include robustness improvement of target location under the lighting condition of abrupt changes.

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