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Real-time Auto Tracking System using PTZ Camera with DSP

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Abstract

In this paper we proposed a PTZ camera system which automatically detect and track moving objects in the image. Once a moving object is detected the PTZ camera traces it in real-time. We proposed the control system which does not depend on camera focusing functionality but uses the object's center, moving direction, distance and speed. We implemented the system with the TI DM6446 DSP chip. The experimental result shows that the system has excellent performance for high speed vehicles.

Key words: Embedded, Object Tracking, Meanshift, PTZ Camera, DaVinci DSP.

1. INTRODUCTION

The number of auto tracking cameras based on video analytics has increased enormously in recent years worldwide. As an application in computer vision, the automatic tracking system detects the moving objects in the images from cameras and tracks the objects motion according to their trajectory. The aim is to develop intelligent visual surveillance to replace the traditional passive video surveillance that is proving ineffective as the number of cameras increases. In short, the goal of visual surveillance is not only to put cameras in place of human eyes, but also to accomplish the entire surveillance task as automatically as possible.

Pan-tilt-zoom (PTZ) cameras are able to dynamically modify their field of view (FOV). This video analytics functionality introduces new capabilities to observe the moving objects by its PTZ movements and increases accuracy in its main surveillance purpose.

Many automatic tracking algorithms can have high accuracy in exchange of high computational cost, which makes the system difficult to operate in real time. In order to overcome the high computational complexity, we adopted the DSP chip to control PTZ functionality and process the Mean-Shift algorithm.

This paper is organized as follows. Section 2 explains existing object tracking methods. In section 3 we explained the DSP based tracking system. In section 4, we obtained the experimental result and discussed its performance. The last section summarizes the paper.

2. RELATED WORKS

Mean-Shift[1] tracking algorithm measures the color similarity by Bhattacharyya coefficient between reference model and candidate model and then estimate the object's position by probabilistic method. Collins[2] suggested the variable kernel size method in Mean-Shift by applying the scale-space method. Yang[3] obtained the object's position by using the PTZ camera. Kang[4] suggested the geometrical transformation and mosaicking for object tracking, but real time processing was not easy because of the computational complexity. The object description by feature space the images with discretely changing frame sizes during the zoom operation[5]. Yi[6] used the two particle filters to track both the target object and the environment around the object, but computational but the computational complexity is high.

One[7] of the network camera systems adopted the Davinci chip. Other smart camera implemented the automatic video surveillance system by same chip[8]. The former types focus on software[5][6] and the latter ones focus on real time system[7][8].

In this paper we took the two research focuses into account

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when we develop the automatic real time object tracking PTZ camera systems.

3. Object Tracking System based on DSP Chip

3.1 PTZ camera by DaVinci DSP chip

The proposed system is as shown in Fig.1. The automatic detection and tracking algorithm is embedded in PTZ camera by using Davinci DM6446. The system consists of PTZ camera, monitor and controller keyboard. The keyboard communicates with camera through RS-485 serial interface.

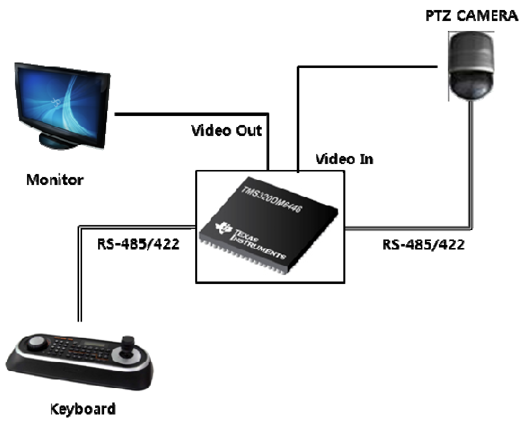


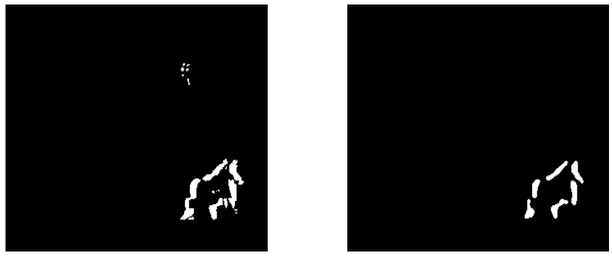
Fig. 1 The proposed system configuration

We partly used libraries provided by vendor. Those are named IMAGE LIBRARY, VISION LIBRARY and IQMATH LIBRARY[10][11][12].

3.2 The real time implementation of the system

The detection function comes first before tracking starts when certain object appears in the observation camera. In order to detect the moving object, we used the simple frame differencing method which saves computation time. Fig2 shows the result of frame differencing. Fig2(a) shows the previous frame, and Fig2(b) shows the current frame. Fig2(c) is the difference signal and Fig2(d) is the result after noise reduction by morphological operation on difference signal.

(a) (b)



(c) (d)

Fig. 2 Detected image (a) previous frame (b) current frame (c) difference image (d) result after morphological operation

Fig3 shows the block diagram of proposed camera system. We used the gray input image with the size of 640 x 480. We used LPF to reduce noises and applied morphological operation for difference signals. At the end of the detection module the obtained signal shows distinguishable object in the image. After labeling procedure for the detected object, we derived the position, height, area, and histogram. The histogram information was obtained for use at Mean-Shift tracking step. We used all those information to control the PTZ camera which locates object in the center of images. At the tracking module RGB image is used for Mean-Shift tracking. All of these processes were implemented by intrinsic command of DSP chip we used[10][12].

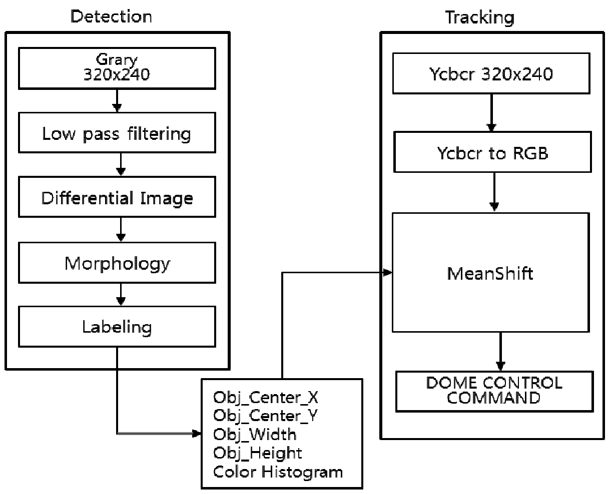


Fig. 3 The proposed system for detection and tracking

3.3 Tracking Algorithm

The detection function comes first before tracking starts when certain object appears in the observation. When there are multiple objects in a scene, the largest one is selected and its position, size, color information are updated. We used the Bhattacharyya coefficient to measure the similarity of two color histograms to keep track of the object. This is called as Mean-Shift method of which the algorithmic procedure is as follows.

Target model : $\hat{q} = \{\hat{q}_u\}_{u=1...m}$ $\sum_{u=1}^{m} \hat{q}_u = 1$

Candidate model : $\hat{P}(y) = \{\hat{p}_u(y)\}_{u=1...m}$ $\sum_{u=1}^{m} \hat{p}_u = 1$

1) Distribution

$\hat{p}_u(\hat{y}_0)_{u=1...m}$, u: number of bins in histogram

Calculate the color distribution model $\hat{p}_u$ at previous position $\hat{y}_0$

2) Calculate the weight w_i which is used at Mean-Shift operation. $\delta()$ is Kronecker delta function, $b(x_i)$ means the color bin index at x_i .

$$w_i = \sum_{u=1}^{m} \delta[b(x_i) - u] \sqrt{\frac{\hat{q}_u}{\hat{p}_u(\hat{y}_0)}}$$

3) A new position is obtained by using Mean-Shift vector. $g(x)$ means monotonically decreasing kernel profile, and h is the kernel width.

$$\hat{y}_1 = \frac{\sum_{i}^{nh} x_i w_i g\left(\left|\frac{y_0 - x_i}{h}\right|^2\right)}{\sum_{i}^{nh} w_i g\left(\left|\frac{y_0 - x_i}{h}\right|^2\right)}$$

The updated color distribution model $\hat{p}_u(\hat{y}_1)_{u=1...m}$ and Bhattacharyya coefficient are expressed by

$$\rho[\hat{p}(\hat{y}_1), \hat{q}] = \sum_{u}^{m} \sqrt{\hat{p}_u(\hat{y}_1), \hat{q}_u}$$

4) The two Bhattacharyya coefficients of the previous and the new position are compared

If $\rho[\hat{p}(\hat{y}_1), \hat{q}] < \rho[\hat{p}(\hat{y}_0), \hat{q}]$, then

$$\hat{y}_1 \leftarrow \frac{1}{2}(\hat{y}_0 + \hat{y}_1)$$

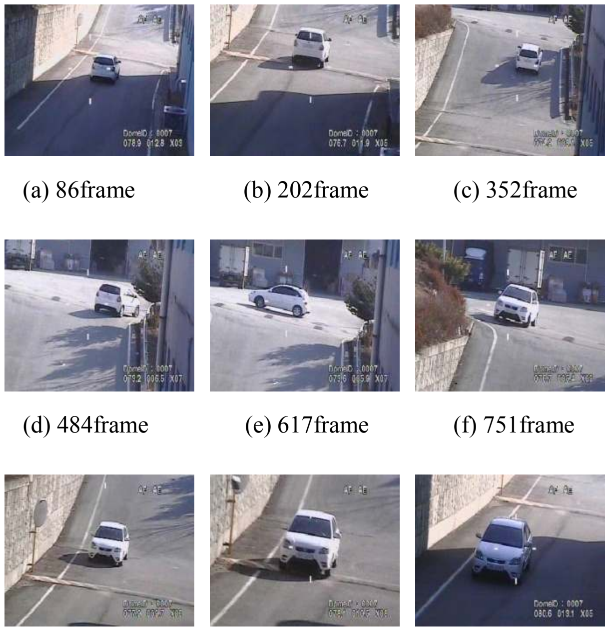
5) If $|\hat{y}_1 - \hat{y}_0| < \varepsilon$, the stop.

else, $\hat{y}_0 - \hat{y}_1$, return to 1)

For the labeling, the connected component labeling library is used.

4. EXPERIMENTAL RESULTS AND COMMENTS

Fig.4 shows the experimental result for the proposed system.



(a) 86frame (b) 202frame (c) 352frame

(d) 484frame (e) 617frame (f) 751frame

(g) 862frame (h) 903frame (i) 980 frame

Fig. 4 Result images

The system shows excellent tracking capability even at the high vehicle speed. Table1 shows the numeral result of our system.

Table 1. Numerical performance

Tracking accuracy	1/2	2/3	1
Number of Tracking trial	8	11	31
Assessment	X	O	O
Success Rate		84%	

Table1 shows the performance assessment results. The starting point and the arrival point is same. The tracking accuracy 1/2 means that the tracking fails in halfway. The accuracy 2/3 means that the tracking succeeds up to the point 2/3 in total motion range. If the tracking is successful more than 2/3 of total range, the accuracy is 2/3.

5. CONCLUSIONS

In this paper we proposed an embedded PTZ object tracking system. Without calibration, our system traces the objects depending only on centroid, direction and speed. We proved the good performance at outdoor condition using real time prototype system.

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