High Performance Object Tracking System Using Active Cameras

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Abstract

This paper describes a high performance object tracking system for obtaining high quality images of a moving object at video rate by controlling a pair of active cameras mounted on two motor droved pan-tilt units. For tracking object on image space, we propose a pixel clustering based algorithm called "K-means tracker" that makes use of both target and non-target information for realizing robust and fast object tracking. The PID control scheme is employed for controlling the angular position and speed of the pan-tilt units according to the results of the "K-means tracker". Moreover, by using two cameras, the 3D position and velocity of the moving object can be estimated, which is used for adjusting the focus and the zoom of the camera. With this system, we can obtain in focus and motion-blur-free images of a moving object.

1 Introduction

Figure 1: Moving object taken by a still camera.

It is difficult to monitor a moving object with a still camera. Since the object moves, its image may be blurred or out of focus, its size in the image may be improperly large or small. Moreover, it may disappear from the image. (See Fig.1)

Figure 2: Moving object taken by our active camera system

This paper describes a new method for capturing high quality images an object that moves fast in a complex background by using two active cameras whose pan, tilt, focus and zoom can be controlled. The "high quality image sequence" here means that the image of the object is in focus and not blurred, the S/N ratio is high enough (the image is not too dark) and both the size and the position of the object in the image is kept unchanged. (See Fig.2)

To achieve this goal, we first developed a high performance object tracking algorithm called "K-means tracker". It makes use of both target and non-target information to realize robust and fast object tracking in complex background scenes. We use the output of the K-means tracker to control the angular position and speed of the pan-tilt units by employing PID control scheme. The purpose of this control is to make the object appearing at the image center and its speed in image space to be zero. This operation has the effect of stabilizing the object in the image. This effect makes it possible to take motion-blur-free images with relatively low shutter speed, which ensures the high S/N ratio of the image. By using two cameras, binocular stereo vision algorithm can be used to obtain 3D position and velocity of the object. These results are used for adjust the focus and the zoom to ensure that the object appeared in focus and in the desired size.

2 K-means tracker

Figure 3: Some results of object tracking using K-means tracker.

K-means tracker is a novel visual tracking algorithm developed by us. It is robust against the interfused background by discriminating "target" pixels from "background" pixels in the tracking region by applying K-means clustering to both the positive and negative information of the target. Three ideas are introduced into our K-means tracker: 1) both the color and position information of pixels in the image are described uniformly by a $5D$ feature vector. During tracking the position and the color information about the target object are updated simultaneously. This makes K-means tracker being robust against the changes of target object. 2) By using a variable ellipse model to represent both the shape of the target and the surrounding non-target pixels, the algorithm can cope with the change of the scale and shape of the target object flexibly. 3) An automatic tracking failure detector and a failure recovery module are developed and used. To achieve the video-rate processing speed, we replace the original K-means clustering algorithm with a newly developed $N+1_\infty$ clustering algorithm.

Fig.3 shows some experimental results obtained by the K-means tracker.

3 Image stabilization through visual feedback control

In order to stabilize the object in the images, we mount the camera to a motor droved pan-tilt unit. The block diagram of our system is shown in Fig.4.

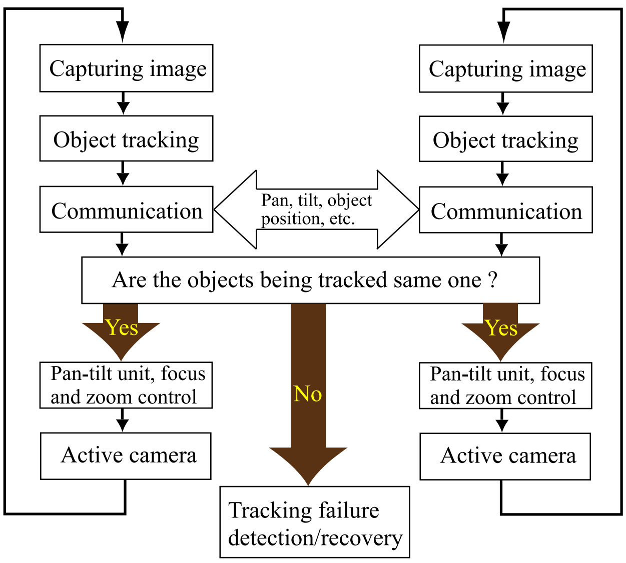

Figure 4: Block diagram of the system

The pan-tilt unit is carefully designed and adjusted to ensure that the optical center of the camera will not move the pan or tilt angle changes. We call it as "Fixed Viewpoint Active Camera". By using the K-means tracker, we can obtain the position and the velocity of the object in image space. We use a visual feedback control algorithm to make the object keep appearing at the image center and its speed being zero. Although controlling the position of the object in image space is enough for chasing the moving object, it is necessary to control the speed of the object in image space to suppress oscillation for capturing motion-blur-free images. We employ the PID control scheme for controlling the pan-tilt unit. We let the angular velocity of the object be the P component, the angular position be the I component and the angular acceleration be the D component. Then the PID control can be used for controlling the angular speed and position of the pan-tilt unit simultaneously.

4 Binocular active camera system

3D information of an object is very useful for stable object tracking. The 3D position can be used for adjusting focus and zoom of the camera, the 3D position and velocity can be used to predict the velocity in the image space, etc. In this research, we use binocular active stereo camera (Fig .5) to estimate 3D information of the object.

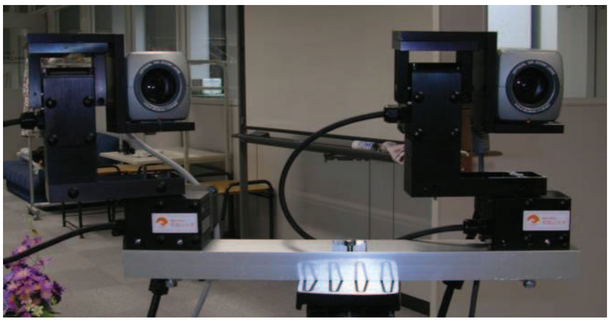

Figure 5: Binocular active cameras

When the geometric relation between the two active cameras has been calibrated and the information about the rotational transform of each camera is shared by two active camera control module, it is possible to gaze at the same point on the object while tracking it and estimating its 3D position and velocity.

Also, by sharing the tracking information between the two cameras, the epipolar constraint can be used to predict the position where the object should appear at in one camera from the position of the object in the image of the other camera. Therefore, if the object tracking failed in one camera, it can start an target searching module that tries to find out the object around the position of the object predicted from the tracking information of the other camera.

5 Summery

A high performance object tracking system using two active cameras has been proposed and built. In this system, a powerful object tracking algorithm called "K-means tracker" and a high performance active camera control system have been realized. Though extensive experiments we confirmed that high quality images of a moving object can be captured at video rate.

6 Acknowlege

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References

[1] D.Comaniciu, V.Ramesh, P.Meer: Kernel-Based Object Tracking, PAMI, Vol.25, No.5 ,pp.564-575, 2003.

[2] D.Coombs and C.Brown: Real-time Binocular smooth pursuit, International Journal of Computer Vision, 11:2, pp.147-164, 1993.

[3] P.I. Corke and M.C.Good, Dynamic effects in visual closed-loop systems, IEEE Trans. Robotics and Autom, 12.(5), pp.671-683, 1996.