MVA '96 IAPR Workshop on Machine Vision Applications, November. 12-14, 1996, Tokyo, Japan

Pitched Baseball Image Extraction in Natural Color TV Scene and Its Trajectory Pursuit

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Abstract—A flying ball is observed by stereo TV cameras on which its images are extracted by using color distance algorithm along with background scene cancellation method. A flying ball spatial coordinates are calculated by the triangulation, and the ball arriving position on the batter plane is forecast by applying adaptive forecast functions. All these procedures are made in real time by conventional personal computers.

1 INTRODUCTION

Various reports have been published on specified moving image extraction in natural color TV scene, on the analyses of motion pattern, and on shape time variations.[1]~[6] Especially designed high speed processors have been reported to be utilized in order to pursuit special moving objects such as a ping-pong ball, and to hit it with a robot racket. The pursuit of moving objects by optical flow technique has also been reported using a computer simulation.

One of the applications of stereo-vision in this technical field is to measure the spatial position of a flying ball as time functions and to forecast its destination. This enables the robot catcher to quickly move its mitt toward the ball, or the robot batter to swing its bat for a hit. This system can do the umpire's job. It can also be used for the evaluation of the players' ability and for their training.

This paper proposes a system that works solely on conventional personal computers without other special aid. Therefore, in order to minimize the calculation time, ball searched area is being limited. Also, to get reliable results of ball positions, color distance algorithm is being used along with background cancellation method. In addition, to forecast the ball arriving position as accurately as possible, adaptive forecast functions have been effectively utilized.

2 SYSTEM CONFIGURATION

Fig.1 shows the system configuration. Frame synchronized and stereo arranged two cameras shoot the baseball ground.. The cameras are placed 8[m] apart, 10[m] behind the batter plane, and 1.5[m] from the ground level. The batter plane stands perpendicular to the line connecting the centers of the pitcher's plate and the home-base, touching the pointed end of the home-base.

Ball images in natural color scene obtained from these cameras are extracted, and then the ball center coordinates on each monitor are obtained respectively by the processing device. These data are sent to the ball position calculation device. There, three-dimensional ball position at each time frame is calculated.

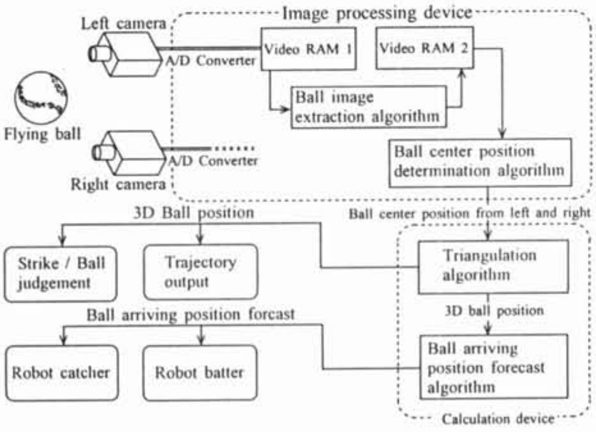

Fig. 1 System configuration

3 BALL IMAGE EXTRACTION AND COORDINATE DECISION

Prior to the ball image extraction experiment, ball color information on the TV monitor is

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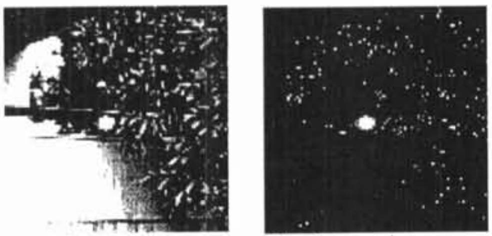
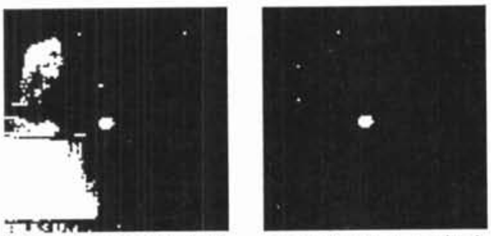
recorded, which consists of 24 bit RGB basic color components of the ball. At the ball image extract experiment, detected color information is compared with the pre-recorded basic color components, by which logical color distance between the two color components is observed. The judgment, then, is made whether the monitored object is a part of a ball or not.

The color distance method is effective in extracting a certain object within multi-colored scene such as a ball in the baseball ground. However, sometimes it extracts objects other than a ball which have colors similar to a ball. Background scene cancellation method is effective in extracting only the moving objects within a stationary scene, but sometimes it extracts other moving objects such as other players, or even leaves swaying in the wind. By using these two methods simultaneously, near to perfect ball image extraction can be obtained. Figure 2 shows the effectiveness of ball extraction by these methods.



Original image

Background scene cancellation method



Color distance method

Simultaneous method

Fig. 2 ball image extraction experiment

4 BALL SEARCHING TIME

In order to minimize the ball searching time and to realize real time processing of the ball image extraction, ball searched area limitation algorithm is utilized effectively.[1] The searched area is limited to cover only the possible passage of a pitched ball. The initial searched area which is fixed waits for the pitched ball. As soon as the ball is detected within this area, its center position is measured and recorded. The second searched area is determined by shifting the initial searched area toward the ball moving direction. Then, the second ball image is observed and its center position recorded. This procedure is repeated till the ball reaches its destination.

As shown in Fig.3, experimental results show that ball search time is proportional to the size of searched area. This can be as short as half a millisecond.

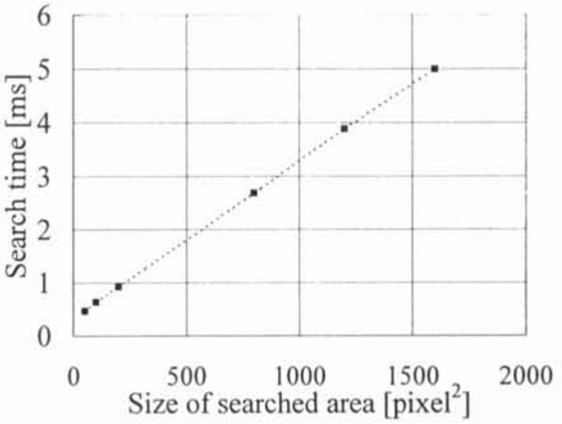


Fig. 3 Relation between the size of searched area and search time

5 BALL POSITION ON MONITOR AND SPACE COORDINATES

Experiments have been carried out to evaluate the measurement accuracy of the calculated ball center positions. Using 60 natural color scenes with balls within, three algorithms have been carried out—namely background scene cancellation method, color distance method, and color distance method together with background scene cancellation method. Then, ball center positions determined by the above three algorithms respectively and those determined manually have been compared and r.m.s. errors measured. Measured results are shown in Fig.4. Among the three algorithms, it has been observed that the simultaneous method exhibits best accuracy, and that largely irrelevant to the size of the searched area.

Therefore, when the two cameras placed as mentioned in section 2 shoot the pitched ball, the simultaneous method is utilized to define the ball center positions from the left and the right. The obtained two sets of two-dimensional coordinates at every TV frame are then converted one by one into three-dimensional coordinates by the triangulation algorithm on its trajectory. Through experiment, real time three dimensional ball positions have been successfully determined.

Such ball trajectory searching system solves one of the typical problems of moving objects' extraction processes. The reliability of the trajectory is due to the accuracy of the two sets of the two-dimensional coordinates, r.m.s. error being 9~21[mm]. As for the three-dimensional coordinates, r.m.s. error should be 18~42[mm].

Apart from the trajectory, this system can also measure the speed as well as the movement of the ball with accuracy, and therefore, can be useful for players' evaluation and training, and sports analysis, not to mention "strike or ball" judgment.

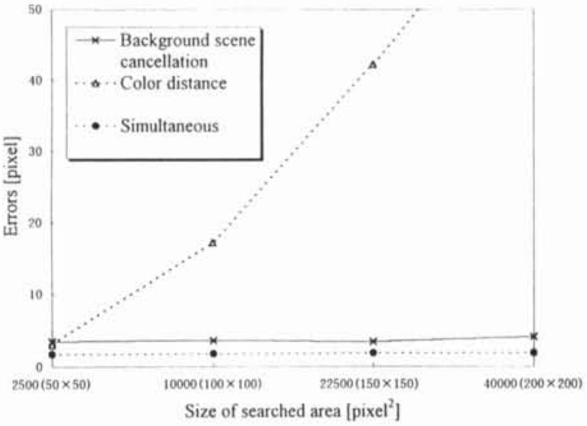


Fig. 4 Measured ball position accuracy

6 BALL ARRIVING POSITION FORECAST

The following item of this paper is to forecast the ball arriving position on the batter plane defined in section 2.

The three-dimensional ball positions are utilized not only to get the trajectory but also to forecast the ball arriving position on the batter plane, several hundred milliseconds prior to the ball arrival.

The principle of this forecast is as follows. After the ball clears three TV frames, three positions are recorded. From this, two second-order algebraic equations exhibiting parabolic curves on both horizontal and vertical planes can be obtained. The cross point of these curves and the battér plane forecasts the arriving position.

When another ball position is recorded, third-order algebraic equation can be formulated with a curve exhibited. Then, the ball arriving position should be renewed. Repeating this process, theoretically speaking, the accuracy can be improved constantly. Thus, the perfect forecast position should be obtained, if there are no errors in all the coordinates.

However, the situation is far from perfect. The coordinates contain unavoidable errors due to TV camera pixel quantum observing errors and ball center calculation errors due to its distorted image. Such errors result in severe error in forecasting the arriving position, especially when using higher order mathematical equations as forecasting functions. The problem, then, is how forecast errors can be minimized with the unavoidable quantum errors in concern.

Air stream on the rotating ball surface makes friction with its seams, and this causes the trajectory projected on the horizontal plane to deviate from a straight line. On the vertical plane, gravity causes the ball trajectory to deviate downwards. Also on the vertical plane, the air friction causes trajectory deformation.

For the purpose of forecasting the arriving position on the horizontal plane, a simple algebraic equation is enough. For that on the vertical plane, gravity acceleration effect should be taken into consideration.

In fact, the forecast error is larger with the earlier frames, but it decreases as the frames proceed. It is important that the error should decrease gently, and that the arriving positions do not change dramatically as the ball clears each frame. This is crucial, for the forecast will be used by robot catchers and batters. Robots usually have time constant of 10~100 milliseconds. Therefore, after the ball is pitched, information concerning arriving position should reach the robots within the required time limit.

As each forecasting function has its merits and demerits depending on the distance between the ball and the cameras, the most suitable forecasting function should be applied for each frame. The following conclusion has been obtained through experiment. In the former half of the ball traveling distance, first-order algebraic equation is suitable for the forecasting on the horizontal plane, and the first order algebraic equation with gravity acceleration effect added is suitable for the forecasting on the vertical plane. In the latter half, the least square second-order algebraic equation is suitable for both horizontal and vertical planes.

By using different forecasting functions at each frame, r.m.s. errors for the arriving positions have been observed. The results are shown in Fig.5 and Fig.6. Fig.5 shows the errors on the horizontal plane, and Fig,6 the vertical plane. The abscissa of the figures indicate the distance of the ball from the batter plane, and the ordinates are the errors from the actual arriving position. It is clear from these figures that the forecasting function should be switched 10 to 8 meters before the batter plane.

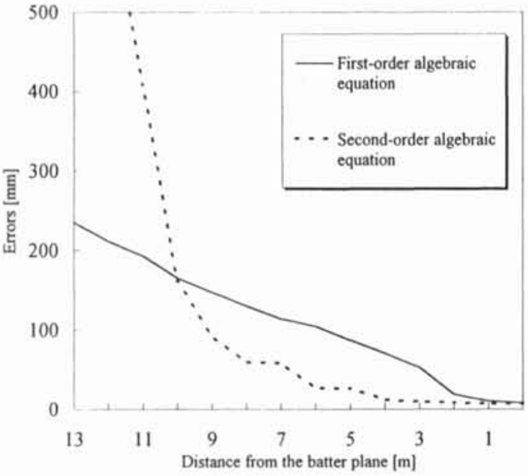


Fig. 5 Averaged accuracy of arriving x position forecast

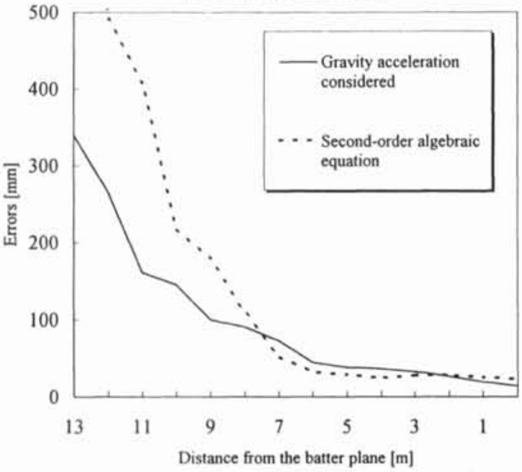


Fig. 6 Averaged accuracy of arriving y - position forecast

7 CONCLUSION

Considering the bat width and the ball diameter, both about 70[mm], and the catcher mitt width of 200[mm], the obtained forecast errors are acceptable.

By using color distance algorithm and background scene cancellation algorithm simultaneously, the ball image has been extracted on TV monitors with high accuracy. Using the results, three-dimensional coordinates are obtained one frame after another by triangulation. Then, the ball arriving position has been determined using suitable forecasting functions. Experiments on various movements of the ball have been carried out, and it has been proved that errors can be minimize by switching the forecasting function.

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