골프공 궤적을 검출하기 위한 고속 영상 시스템 개발

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Development of vision system for the detection of golf ball spin

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요   약

In this paper vision based system for detection of golf ball position and spin velocity in screen golf game is introduced. Firstly, an algorithm is presented for finding ball position and its initial linear velocity on the golf court, and secondly, golf ball spin is calculated. These parameters are vital for simulator in order to simulate a real golf environment. Finally, these algorithm have been implemented with acceptable result.

1. Introduction

Nowadays, indoor golf screens have been popular not only as a game, but also as trainer for beginner golf players. Indoor systems enable golf players to play with the maximum similarity with the real golf game. These new approach of simulators, cause lower cost, and need less space to setup. Because golf ball usually has high velocity, in order to measure initial angle and velocity of shoot, optical sensors are used. J.E. Bae et al present new and low cost set of transmitter and receiver sensor for finding initial dynamics value of ball [1]. The downside of this system is that in order to measure initial velocity and angle of ball, it should pass the sensor line. So, in the case that ball is near the hole and shoot is soft, finding the ball initial parameters are almost impossible. On the other hand, as any fan of golf sport knows, ball spin plays an important role in estimating the trajectory of the ball after being hit. Also, air resistance can change both linear ball velocity and its spin during its travel which can also change the in-flight trajectories of ball as well. Thus, golf simulator should have these initial values to fulfill the simulation more precisely.

In order to increase the ball dynamic motion simulation and estimate final position accurately, we propose a hybrid vision based golf simulator system. This simulator in addition to optical sensors takes advantage of a camera and computer based program to determine the initial position and velocity of golf ball, and additional stereo vision system for ball spin detection.

2. Ball detection process

In order to detect ball an algorithm is applied on the captured video. In this algorithm, first of all, frames are captured from the golf course and then, based on background subtraction and image segmentation, objects are detected in each frame. Then, up on golf ball features and object classification, non-ball shapes are ignored and finally by using camera calibration, ball position in the world coordinate is determined. This algorithm can be seen in figure [1]. This algorithm is divided into two main processes. First is preprocess and camera calibration and second is ball detection and coordinate transformation.
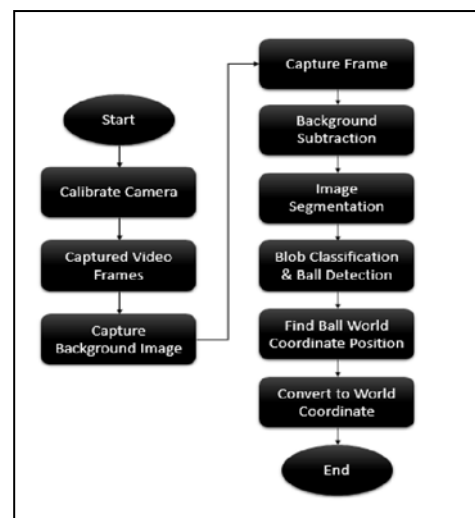

(Figure 1) Ball detection algorithm

2.2. Ball detection and coordinate conversion

As can be seen from second column of figure [1], in this level, frames are captured and subtract from the background image which is captured in previous step. One typical captured frame from golf player and his/her club in golf course is depicted in figure [2.a].

After subtraction a median filter is applied on result image to smooth image and remove some unwanted noise. The result image is shown in figure [2.b]. Now by choosing proper threshold this image is changed into binary image to find binary large object (Blob). For finding objects, first binary image should be segmented to different ones. After segmentation, each object should be classified as either golf ball or non-golf ball shape. For achieving this goal, ball properties should be taking into account. Area, circularity and distance between objects are the features having significant effect for ball detection among the non-ball detected objects.

<table>
<tr><td>(a) Typical frame</td><td>(b) Subtraction result</td></tr>
</table>
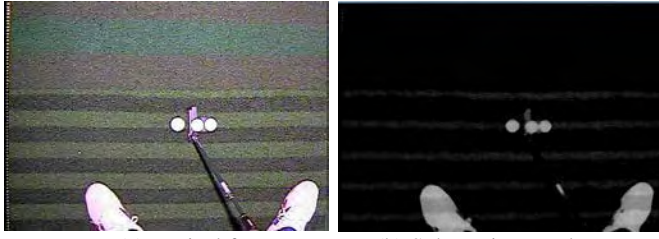
(a) Typical frame　　　　(b) Subtraction result

(Figure 2)

The result of ball detection has been shown in figure [3]. As can be seen although there is similarity between golf ball and this type of club, real ball has been detected and its center position has been highlighted with the red circle. In case of slow shoot, difference between initial and final position based on the time of motion results in the initial velocity.

(Figure 3) Detected golf ball

Preprocess and Camera Calibration

Before any advance in algorithm, camera first should be calibrated. In order to calibrate camera, as can be seen in figure [4], a dot sheet is used. This calibration dot sheet includes 45 points which the distance between 2 adjacent points equals to 100 mm in both horizontal and vertical direction. This calibration sheet can be seen in figure [4.a]. Now by assumption that [u v] is camera coordinate and world coordinate equals to [x y], and there is a quadratic relation between camera and world coordinates, equation [1] will be obtained:

$$\begin{cases} x = a_1 u^3 + b_1 u^2 v + c_1 uv^2 + d_1 v^3 + e_1 u^2 + f_1 v^2 + g_1 uv + h_1 u + i_1 v + j_1 \\ y = a_2 u^3 + b_2 u^2 v + c_2 uv^2 + d_2 v^3 + e_2 u^2 + f_2 v^2 + g_2 uv + h_2 u + i_2 v + j_2 \end{cases} \quad (1)$$

In equation [1], [x y] is the position of each point center in dot sheet, expressed in world coordinate and [u v] is corresponding coordinate based on image pixels. Thus, the 12 unknown a1, b1... j1 and a2, b2... j2, parameters can be calculated from given data. When there are N points in dot sheet, the following matrix will be made between the [x y] and [u v] coordinates:

$$\begin{bmatrix} x_1 & y_1 \\ \vdots & \vdots \\ x_n & y_n \\ \vdots & \vdots \\ x_N & y_N \end{bmatrix} = \begin{bmatrix} u_1^3 & u_1^2 v_1 & u_1 v_1^2 & v_1^3 & u_1^2 & v_1^2 & u_1 v_1 & u_1 & v_1 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ u_n^3 & u_n^2 v_n & u_n v_n^2 & v_n^3 & u_n^2 & v_n^2 & u_n v_n & u_n & v_n & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ u_N^3 & u_N^2 v_N & u_N v_N^2 & v_N^3 & u_N^2 & v_N^2 & u_N v_N & u_N & v_N & 1 \end{bmatrix} \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \\ \vdots & \vdots \\ i_1 & i_2 \\ j_1 & j_2 \end{bmatrix}$$

Now camera parameters can be calculated by following formula, where P is position of points in world coordinate and A is a non-square coefficient matrix, obtained from equation [1]:

$$x = (A^T A)^{-1} \cdot A^T \cdot P \quad (2)$$

After calibration next step is capturing background Image. This image should be captured from the golf field. Illumination and lightening is so important for having accurate result. Improper illumination can cause shadow and fault detection. Background image also, has been shown in figure [4.b]
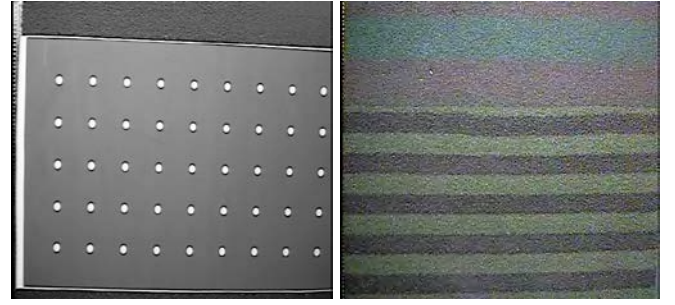
(a) Calibration dot sheet　　　　(b) Background image

(Figure 4)

3. Golf Ball Spin detection

Typical Stereo vision system utilizes two cameras for depth calculation in captured frames. Depth of detected object in captured images is determined via camera geometry and image formation equations. As can be seen in figure [5], unlike conventional stereo vision system, our introduced system uses four cameras.

Actually, each two cameras form independent stereo vision. These two capturing systems have been installed in different height to have wide field of view (FOV). The cameras are high-speed enough which are able to capture 180 frame/second with the resolution of 480x640. Black Center line is added to the golf ball as a recognizable feature can be detected within the captured frames. Angles variation of center line is an important key of our proposed method for spin calculation. This center line has different angle in subsequent frames. Thus, ball spin is calculated up on the angular velocity of this center line. The division of difference between tow angles and time of captured frames results in the ball spin.


(Figure 5) Vision based system

3.1 Golf Ball Spin detection algorithm

In this section the spin detection of golf ball is described. Figure [7] depicts two angles can be measured from captured frames. Pitch angle can be calculated by finding α angle. On the other hands, roll angle is determined by finding the length of line, passing from ball and black line centers. By division of this line length per ball radius, β will be resulted. Algorithm for finding α and β is shown in figure [8]. First of all, ball circle is detected by Hough circle transform algorithm. Therefore, ball center and its radius is determined. Up on these parameters, new ROI is generated, and ball area is set as new ROI for next steps. Then, This ROI is inverted to focus on the desired center line. After that, the corners of the center line are

extracted. Finally, by calculation of the centerline slope, pitch angle and corresponding angular velocity will be resulted based on frame rate.
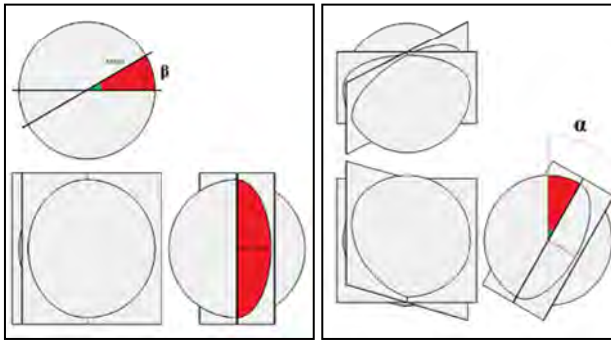
(Figure 7) Ball roll and pitch angles model

In order to determine α in each frame after finding the center line corners, mid-point of two corners is calculated. In next step, using edge detection algorithm, center line contour is obtained. Sweeping pixels in the direction of passing line from ball center and corners mid-point, and finding of counter entry and exit pixels, center of black line is obtained. The length of this line is used to calculate β angle and corresponding roll angular velocity up on frame rate.
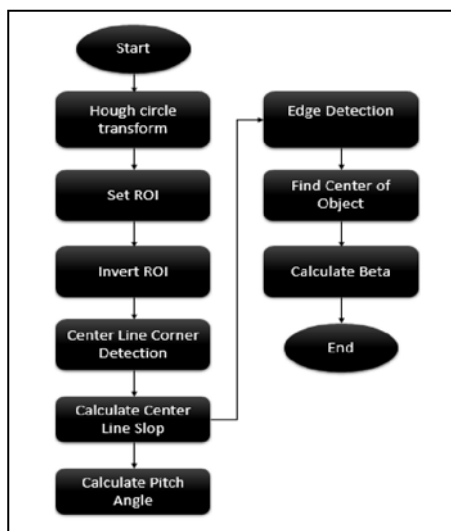

(Figure 8) Algorithm of ball roll and pitch calculation

In figure [9] typical captured frame has been shown. Figure [10.a] shows the inverted ball ROI. In Figure [10.b], green line and red line are corresponding line for roll and pitch angle calculation respectively. The difference of angles between sequential captured frames is used to determine of angular velocity as well ball spin velocity.


(Figure 9) Typical captured frame
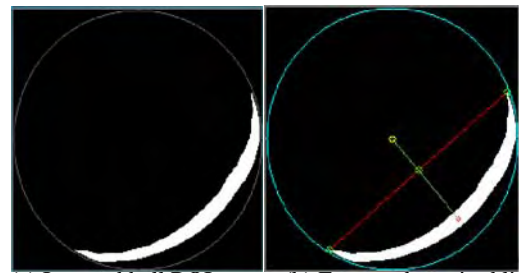
(a) Inverted ball ROI   (b) Extracted required lines

(Figure 8)

4.   Conclusion

In conclusion, introduced golf ball detection algorithm in this paper, has been implemented by using OPEN CV library and visual C++ MFC environment. This program is used as a part of golf simulator program to detect and track golf ball when the ball is near the hole and ball cannot pass sensor line. So, its initial position and velocity is measured, and final ball position can be estimated by simulator program. Also, this system uses stereo vision based system to find the shoot ball spin. Acceptable results demonstrate that this program is able to be used in commercial screen golf.
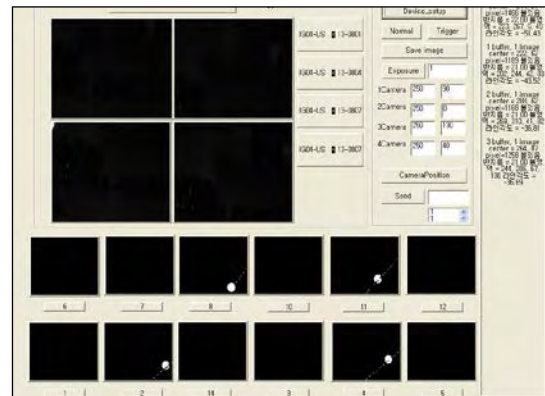
(Figure 11) MFC based Software

Reference

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Acknowledgement