

Real-Time Locus Indication System for a Flying Golf Ball

By Y. Yamanouchi, K. Enami, D. Kato, T. Yamada, and T. Kageura

This paper describes a newly developed real-time locus indication system for a golf ball in flight. The system, named Shot View, detects the three-dimensional position of the ball according to triangulation principles using the motion angle of two cameras to track the ball, and indicates the locus on a course layout background. The system has been applied to long drive shots at a distant hole during several golf broadcasts and was well received by TV audiences. The principles of the Shot View system, the experiments conducted to ascertain its applicability to golf, the system configuration, the technology, and some examples of broadcasts using the system are presented.

Recently the demand for new, effective products for live TV sports programs, such as the Olympic Games, has been increasing. It is important to make the action of the games easy to understand on sight and to provide TV audiences with the feeling that they were actually there. In showing the motion of players or a ball up close, the programs provide a sense of being there as well as the speed of the ball. However, it is difficult to visualize the exact position of the players or the ball. The authors have developed a new system called Shot View, described below. This system has been applied to display the flight of a golf ball and has been used in actual golf broadcasts.

The Principles of Shot View

The Shot View system uses the principles of triangulation, which allow the calculation of the three-dimensional position of an object from the interior angles of the triangle created by the object and the two cameras shooting it, and the distance between the two cameras. Figure 1 shows a conceptual diagram of the system. When the distance between

the two cameras is d , the panning angles of the two cameras shooting the object are $P1$ and $P2$, and the tilting angles are $T1$ and $T2$. The three-dimensional position of the object is represented by Eq. 1.

$$\begin{aligned} x &= \frac{d \cdot \tan(P2)}{\tan(P1) + \tan(P2)} \\ y &= x \cdot \tan(P1) \\ z &= \sqrt{(x^2 + y^2)} \cdot \tan(T1) \end{aligned} \quad (1)$$

Shot View applies these principles of triangulation to determine the operation angles of the cameras so as to calculate the three-dimensional position of the object, under the condition that the object is kept in the center of the picture of both cameras. By executing the process from the

detection of the operation angles to the calculation of the position in real time, it is possible to show the locus of moving objects simultaneously with the real shot image.

Preparatory Experiments for Shot View

In sports programs, it is especially difficult to tell where golf balls are when they are flying through the air. If it were possible to show the locus of the ball while it is in flight, the programs would be easier for TV audiences to understand.

On a practice day of a pro golf tournament held in October 1993, the authors installed angle-detection equipment and conducted experiments to examine the relationship between angle detection and triangulation in displaying the locus of the ball. Cameras were set up to shoot tee shots (Fig. 2). The locus of the ball was obtained as shown in Fig. 3. Although there are some errors in the patch display around the point of impact, the locus display in the latter half is about the same as the actual flight of the ball. The reason for the errors is that when the angle of the

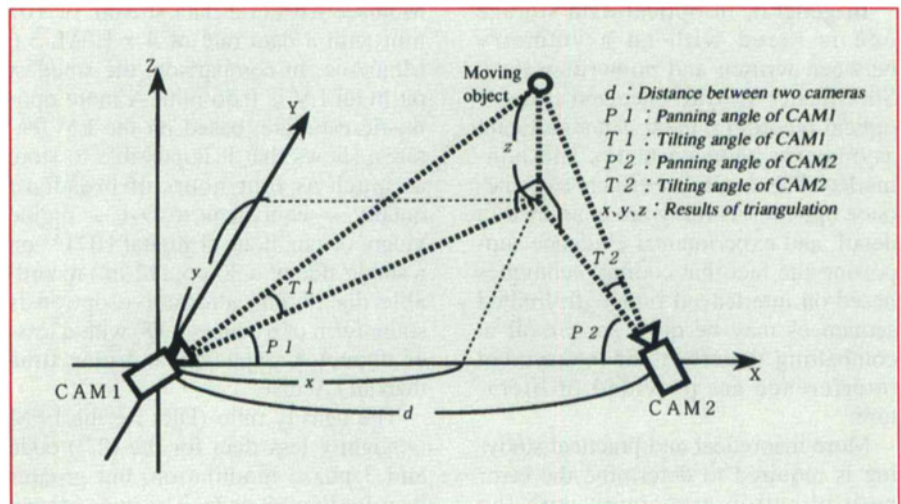


Figure 1. Principles of triangulation.

Presented at the 136th SMPTE Technical Conference in Los Angeles (paper no. 136-75) on October 15, 1995. Y. Yamanouchi (who read the paper), K. Enami, D. Kato, and T. Yamada are with NHK Science and Technical Research Laboratories; T. Kageura is with NHK Technical Service, Tokyo 157, Japan. Copyright © 1995 by the Society of Motion Picture and Television Engineers, Inc.

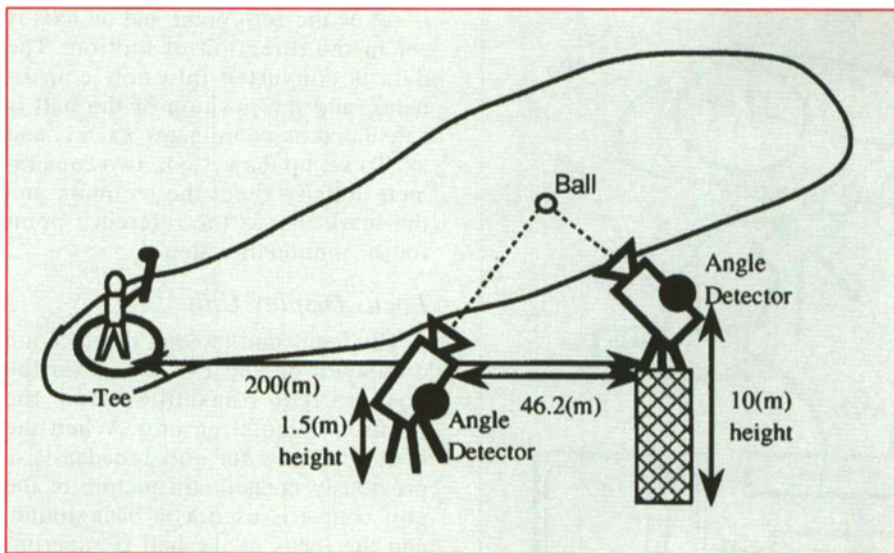


Figure 2. Experimental camera setting position.

two cameras is close to 0 or 180°, then the margin for error is greater. The area near the tee was located where errors were likely to occur, and because the velocity of the ball is high at the point of being struck, it becomes difficult for cameramen to shoot the ball and keep it in the center of the screen. In order to overcome these problems, it was decided to develop a system with a smoothing and cutting function, which will be described in a later section.

The problems in developing the system were divided into methods to detect the operation angle of the cameras, methods to calculate the position of the ball, and methods to display the locus of the ball. An important consideration was how the system could be used on-site easily without making too many modifications to existing equipment.

System Configuration

Figure 4 shows the overall configuration of Shot View. The angular velocity of two cameras is detected from a gyrosensor and is then sent to an analog-to-digital (A/D) conversion box. The angular velocities are then serially transmitted to a position calculation unit and a locus display unit in the outside broadcast (OB) van. The position calculation unit determines the three-dimensional position of the ball according to triangulation principles, then transmits the position information to the locus display unit, which displays the locus and flight distance of the golf ball in real time.

Angular Velocity Detection Unit

Gyrosensors are easily attached to the sides of cameras, as shown in Fig. 5. The angular velocity of the gyrosensors is detected in analog signal

form. To transmit the data to the position calculating unit in the OB van, an A/D conversion box installed near the camera converts the analog signal into 12-bit digital data in the television field rate, then transmits the digital data over long distances using RS422 in serial form. To maintain the process from angular velocity detection to locus display within the same frame, the gyrosensors are driven using video synchronization from the OB van.

The gyrosensors were selected for their compact size, which would be an advantage in outside broadcasting equipment. Because they do not have to be attached to the rotating shaft of the camera base, as is the case with rotary encoders, there is no need to modify broadcasting equipment beforehand. Only the gyrosensors have to be prepared for attachment; they can be used immediately on-site without limiting the equipment to be used, and can be easily maintained.

Position Calculation Unit

A notebook-type personal computer installed in the OB van is used for position calculations. To obtain angular velocity data that is transmitted in the field rate, the personal computer (PC) is synchronized with the angular detection unit.

The angular velocity data are integrated to determine the panning and tilting angles of the cameras so that the three-dimensional position of the object can be calculated, after which the calculated data is sent to the locus display unit over an RS232C line.

In actual operation, the initial position (in the case of golf, the tee mark)

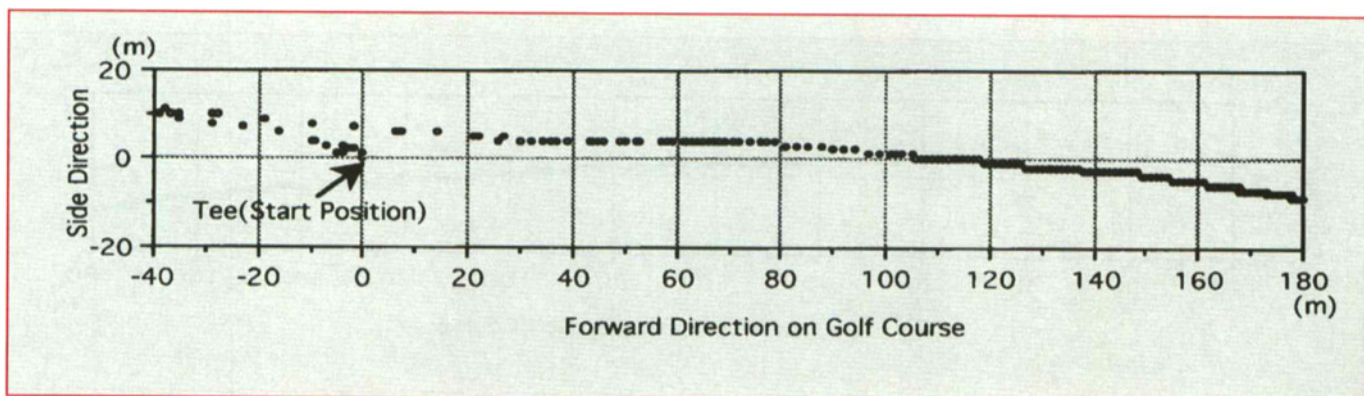
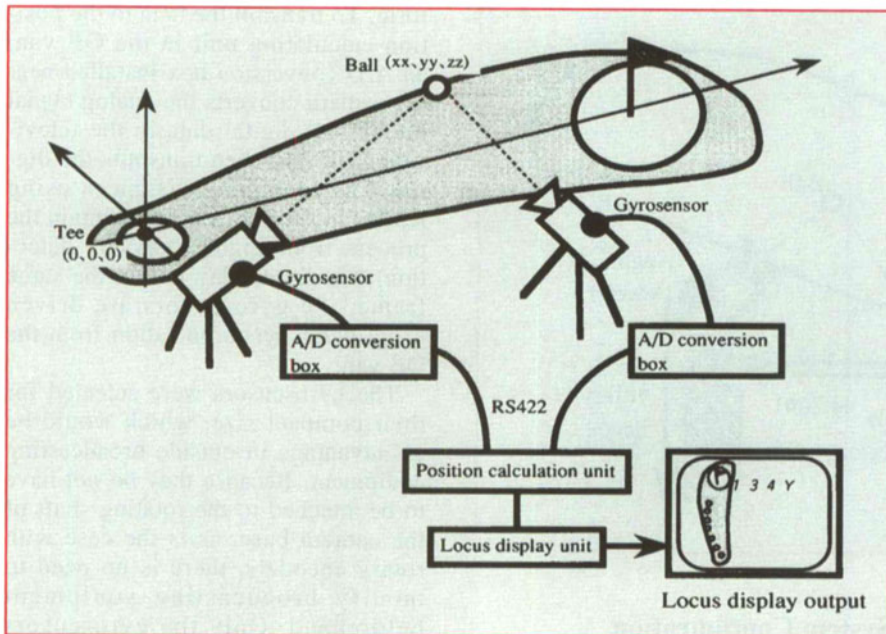


Figure 3. Top view of ball locus calculated using triangulation principle.



is set as the zero point and an axis is set in the direction of motion. The data is converted into new coordinates, and the position of the ball is calculated as coordinates xx , yy , and zz . To set up the system, two cameramen initially shoot the tee mark and the mark that is the reference point for the motion direction.

Locus Display Unit

The locus and moving distance are displayed on the PC, based on the position data transmitted from the position calculating unit. When the system is used for golf broadcasts, a previously used still picture of the golf course is used as a background, and the locus of the ball is superimposed on it later. The locus display unit has functions such as the ability to set the display position, expand and reduce the size, etc. The system can display the locus of a fast-moving object such as a golf ball, as it contains a smoothing function to display the locus of the ball fluidly, and a cutting function to remove any impossible ball paths due to errors caused by manual operations.

Broadcast Applications

Golf or Other Sports

According to the principles of triangulation, the closer the angle of the two cameras shooting the ball is to 0 or 180°, the larger the error. Therefore, the relations between the locations of the cameras and the area in which the ball flies must be considered. If the system is to be used in golf broadcasts, however, the layout of the course and the speed of the ball will limit the possible camera instal-

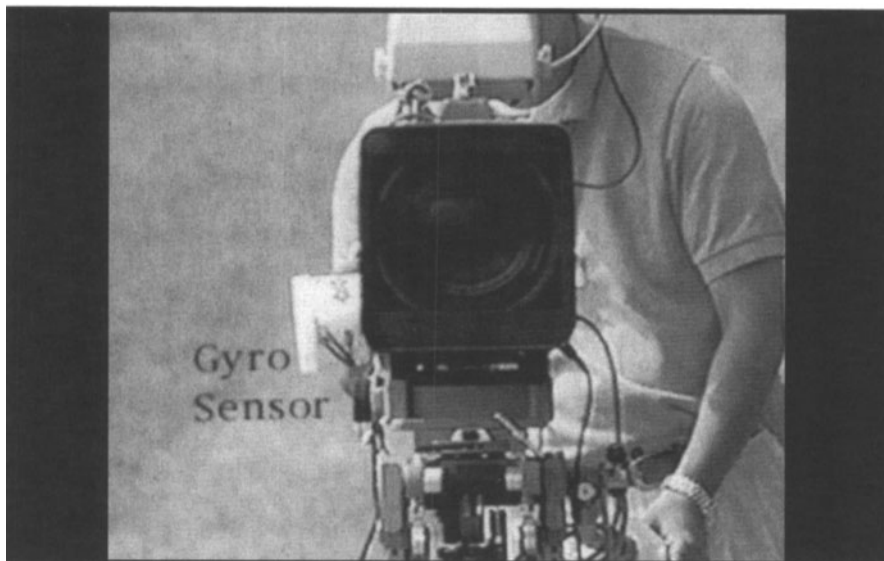


Figure 5. Gyrosensors attached to the camera.

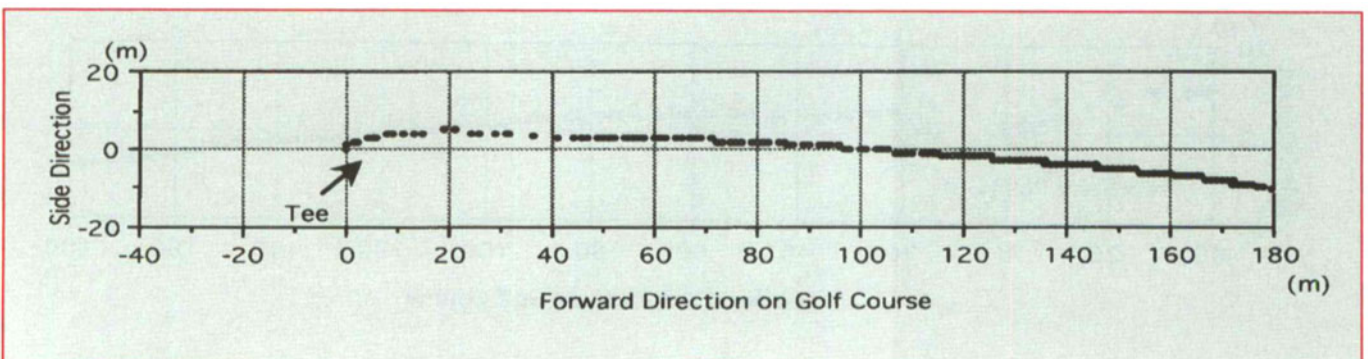


Figure 6. Top view of ball locus with 40-tap filtering and cut error data.

lation positions. Thus, the aforementioned smoothing function and cutting function of the locus display unit are used.

Figure 6 shows a calculation result of triangulation and the results from the low-pass filtering with 40 taps for the smoothing function. Additionally, the cutting function reduces errors arising from calculation results caused by angle errors. These errors arise because cameramen find it difficult to keep the ball centered in the screen at the time of the impact. In practice, it was found that if the cameramen can keep the ball around the center of the screen, then the smoothing function and cutting function will allow a smooth display of the locus.

Although gyrosensors are compact and easy to use, they have the problem of drifting, so that the offset value changes with time. As a result, there is a tendency for the integrated camera angle to deviate slightly from the actual angle. In practice, the offset value has to be calibrated frequently.

Examples of Use in Broadcasts

The Shot View system was used for the tee shots from the 18th hole of the Pro Senior Golf broadcasts on June 4 and 5, and the Philanthropy Golf broadcasts on July 2 and 3, 1994, in Japan.

Figure 7 shows an example of the use of the Shot View in the Pro

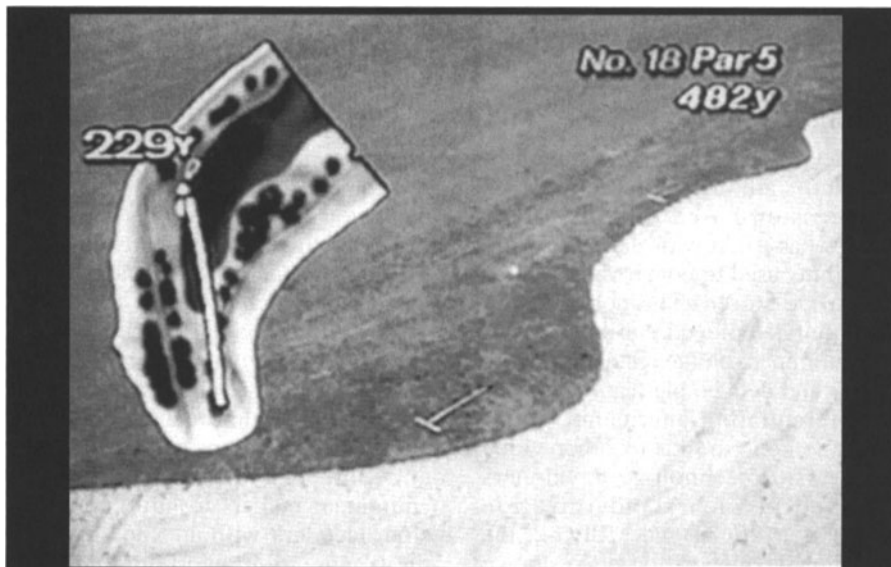


Figure 7. Live picture using the Shot View in Pro Senior Golf broadcast.

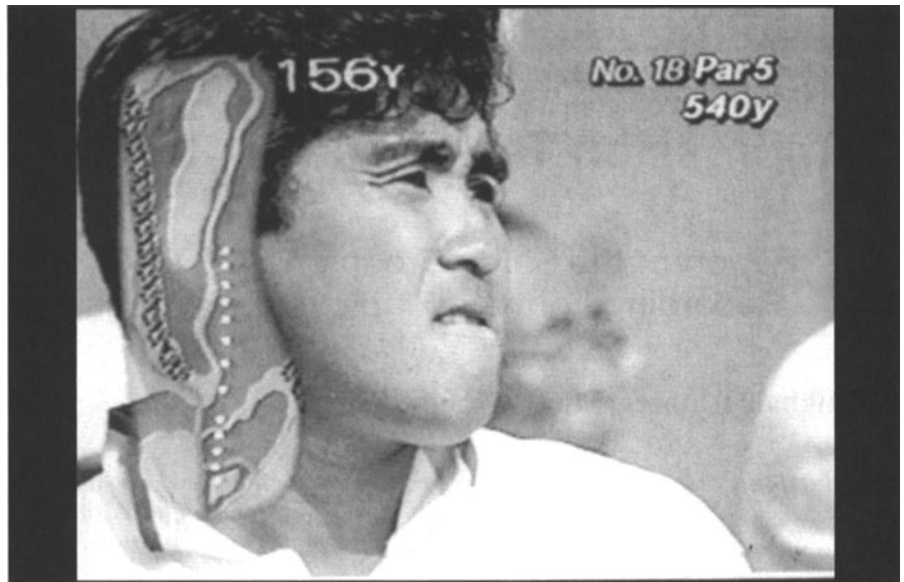


Figure 8. Live picture using Shot View in Philanthropy Golf broadcast.

Senior broadcasts. The system showed clearly whether a shot was hooking or slicing, or whether it looked as though it would hit a bunker. This could be seen while the ball was in the air, so that the display was easy to understand. The flight distance display, which changes in real time, increases the feeling of reality.

In the Philanthropy Golf broadcasts the display was changed from a solid line to a dotted line. As shown in Fig. 8, this enhances the image of a ball flying through the air and thus was

very popular. The system also made it possible to display the distance remaining from the ball to the green, which helps viewers to determine whether a player could shoot directly for the green with a second shot.

Conclusion

The Shot View system, developed at NHK, detects the operation angles of two cameras following a moving object, calculates its three-dimensional position, and displays the locus of the moving object in real time. This system was applied to a golf broadcast, and new program effects were created.

Although there are limitations on the possible installation locations of cameras and their operation, the authors were able to make the locus smoother by some improvements to the locus display unit. As a result of using a gyrosensor in the angular velocity detection unit, the system is also well suited for use in outdoor broadcasting situations.

Because Shot View allows the calculation of the three-dimensional position simply by following an object with two cameras, it can be used in other TV programs in the same manner as in the golf program. In the future, the authors hope to conduct research on image processing and incorporate it into automatic tracking cameras.