

Virtual Reality-A Helping Hand for Referees

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Abstract

In today's competitive world of sport, it is essential to have an unbiased decision making technique. In this paper we review some of the technologies that help in decision making with the help of augmented reality. Augmented reality is a technology that provides a composite view by superimposing a computer-generated image on a user's view of the real world. By having another set of eyes match official's subjectivity, corruption and bias can be eliminated and controversial and questionable calls can be corrected if needed. Techniques like 'goal line technology' in football combat the issue of ghost goal. Similarly using the 'Hawk eye' technology in cricket solves ambiguities in leg before wicket calls and comes to rescue in close lines calls in tennis. The paper explains the working of these technologies and how it helps overcome human error.

Keywords: Virtual Reality, Goal-line Technology, Hawk-Eye, GoalRef, Hot Spot, GoalControl, Sports

1. Introduction

High level of accuracy in sports monitoring systems is vital. In the past many instances have occurred wherein in the game of football a deserving goal was not awarded to the respective team due to the referee's faulty decision or there was a big debate on the umpires call for a leg before wicket call. There is intense pressure on the referees of any sport to make accurate decisions. With a worldwide of viewers that judge each call a referee makes, there is a need for an unbiased and reliable technology that is advanced enough to eliminate human error.

Human error is a challenge of the human eye and vantage point. Explaining it further using the example of football, the human eye has the capacity to capture up to 16 images per second, which means the ball needs to be behind the line for at least 60 milliseconds. But, in some cases the ball is behind the goal line only for a about few milliseconds before a player kicks it out of the goal post or it rebounds back, with the result that the human eye cannot see whether the ball has crossed the line. The ball can be detected by the human eye at a speed of less than 12km/h, whereas nowadays players can shoot up to a speed of over 120km/h. Another necessity of such a technology is because of the challenge of vantage point. The referee's decision is usually based on his view angle. In some cases a view from another angle would suggest contradicting results. Thus a three-dimensional view provided by virtual reality is required to eliminate ghost goals.

The three dimensional simulation of the ball trajectory shown during a game of cricket uses the virtual reality concept. This is done by a technology called Hawk-Eye.

Sports like cricket and tennis have now become dependent on this technology to make leg before wicket or close line calls. There are various technologies that are used today like the Hawk-Eye and Hot Spot technique in cricket, Goalref and GoalControl in football etc. However how reliable are these techniques and how they work is not known to all.

2. Goal Line Technology

In 2012 IFAB (International Football Association Board) authorized the use of goal line technology. Goalline technology is essentially a bundle of technologies that together monitor the path of the ball and detects when it crosses the goal line. Once a goal is detected the referee is notified within a seconds time via a vibration and on his wearable technology around his wrist. There are four leading goal line technologies GoalControl, Hawk-Eye, GoalRef and Cairos GLT system. GoalControl and Hawk-Eye are camera-based technologies whereas Goalref and Cairos GLT system are magnetic field based technologies.

2.1 Goal Control Technology

Goal Control System was developed by a German company and was first used in the FIFA 2014 Brazil world cup. This technology uses 14 cameras in all, with seven focused on each goal. These cameras are connected via cables to a central computer. The seven cameras track the shot and send precise data back to the computer, which then triangulates the ball's position in relation to the goal line. If a goal occurs a vibration and a visual signal is transmitted within fractions of a second to the watches worn by referees on the field. GoalControl takes a lot of guesswork out of the game. Players, viewers and the

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coaches can now be rest assured that when a call is made about a goal, it's made as accurately as possible.

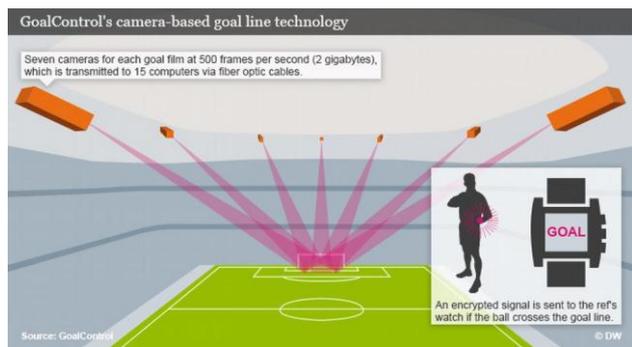


Fig.1 Positions of Cameras per goal

GoalControl installed 14 high-speed cameras each in 12 Brazil football stadiums this year for the 2014 FIFA World cup. The cameras were affixed on the upper levels of the stadiums and roofs as shown in figure 1. The principal was the same in all stadiums. Seven cameras raid around each of the goal and form the sensory system of the GoalControl technology; the cameras are arranged in line to provide complete coverage of the entire penalty areas at each end of the field. As soon as the ball enters the penalty area it is automatically picked up by the seven cameras at that end of the field and then tracked continuously in real time in three dimensions. Action situations are captured by up to 500 image sequences per camera per second. The image sequences are transmitted with real time via fiber optic cable to the central evaluation unit comprising of 2 high performance computer stacks located in the server room. The evaluation unit using special detection software processes individual image sequences. The ball is filtered out from the image sequences and its real time position calculated as x y z coordinates plus speed, so it's in 4D. The technician can optionally monitor the functionality of the fully automated system. If the ball completely crosses the goal line the central evaluation unit transmits an encrypted signal to the referees goal control receiver watch within less than a second. The margin of error is plus/minus 5mm.

The viewers want to see proof, replays from TV-cameras are not clear enough to make close calls, Using Goal Control real camera sequences from all 7 angles can be replayed. The system automatically renders a 3D view of the ball on a virtual pitch without any time delay. A virtual camera moves across the pitch and displays to the crowd, right at the goal line, if the ball really has passed the line or not. It shows accurate 3D-position of the ball every 2 milliseconds. This can also be broadcasted to the viewers at home or shown on the big LED board in the stadium. GoalControl technology was successfully used in all 64 matches, it came to rescue in the match of France v/s Honduras where the referee and the commentator had contradicting opinions, a goal was awarded and a rendered video was displayed in order to support the decision. The only disadvantage of this technology being, 25% of the football must be visible at all times in order for the technology to work accurately. Figure 2 is a flowchart explaining the working of GoalControl.

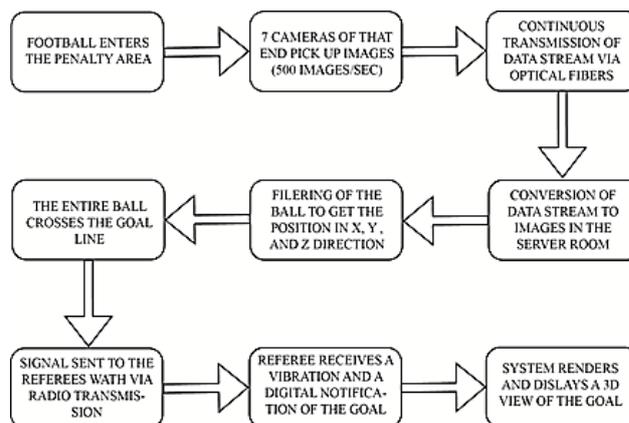


Fig.2 Flowchart of GoalControl System

2.2 GoalRef

GoalRef is a goal-line technology system developed by German research institute Fraunhofer in association with Select Sport. It has been tested in the Danish Superliga and at the 2012 Club World Cup. It works by detecting the passage of the ball using magnetic induction. GoalRef is a bit like an invisible curtain that hangs behind the crossbar and the goal line. When the ball fully passes through this curtain, it is considered as a goal and a message is The GoalRef system relies on the principle of electromagnetic induction. In the Goalref technology a passive electric circuit is embedded in the football, between the outer leather jacket and the inner inflatable layers. The goalmouth is lined with three magnetic strips on the outside and sensors are placed inside the goalposts and the crossbar. A low frequency magnetic field is generated around the goal, which is monitored by coils installed in the goal posts and crossbar. A computer using special software monitors the condition of the magnetic field in the goal. Once the football crosses this there is a change in the magnetic field due to the embedded chip crossing interrupting the field.

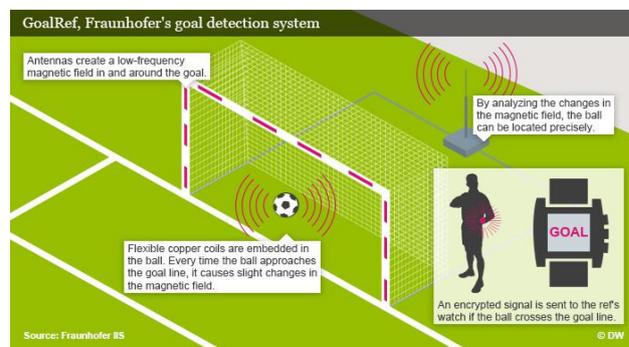


Fig.3 GoalRef System

When a goal is detected, the system sends an encrypted radio signal in real time to a wristwatch worn by the referee, which vibrates and displays a visual message that a goal was scored. GoalRef is comparatively cheaper than GoalControl, because image processing need not be done, although it has its cons as well. GoalRef cannot be used to

display of a 3D view for the viewers to agree with the decision of the referee. Also special footballs need to be manufactured and there are issues concerning football manufacturers allowing this technology to be implemented into their footballs. Along with that this technology could not be implemented at grass roots level, the difference in levels of officiating at each level of the game would grow even further. Figure 3 denotes a summarization of the working of Goalref technology.

3. Technology used In Cricket

3.1 Hawk Eye

Hawk-Eye Innovations, based in Basingstoke and owned by Sony, was founded by Dr. Paul Hawkins and first used by Channel 4 for its cricket broadcasting during the 2001 Ashes. Hawk-Eye is a technology that now a lot of companies rely on. The technology is although not 100% error free it is essential in the game of cricket. The working of Hawk-Eye is fairly simple. There are 6 cameras placed in the stadium, with 3 focusing on each side of the pitch. In cricket terms the 6 cameras are placed at long on, long off, deep point, deep square leg, deep third man and deep fine leg as suggested by engineers at Roke Manor Research. In technical terms they are placed three cameras are used at each wicket, with two at a 30 degree angle and another camera at the side of the pitch, as shown in the picture. With the help of these cameras, images of the complete ball trajectory is taken, that is from the time it leaves the bowlers hand high up till the ball is dead on the ground. Hawk-Eye uses the technique of triangulation to form a 3D view of the ball trajectory using images with a time stamp and a video processor. Using dedicated video processors, databases and multiple processing computers the simulation can be done at a faster feed. This is how the technology works, after capturing the images, the system identifies in each frame, from each camera, group of pixels corresponding to the image of the ball. For each frame computation of 3D position of an image thus identified using ball image data from at least 2 different cams is done. Later it predicts the ball flight-path from the said 3-D ball position as computed in successive frames. And in the end it maps the predicted flight-path on the modeled area as shown in figure 4.

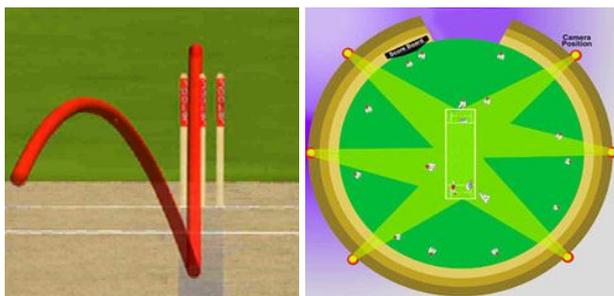


Fig.4 Placement of Cameras in the stadium and a view of the ball trajectory

Hawk-Eye also considers a few external factors that would affect the ball trajectory. Hawk-Eye is used for a variety of

purposes, like prediction of leg before wicket. The future trajectory of the ball can be predicted in the 3D view, showing if it would hit the stumps had it not been interrupted by the cricketer's leg. Wagon Wheel - shows where the batsman has made all his runs on the field. DeSpin - shows how much a ball has deviated after pitching compared to a ball which hasn't spun away. Pitch Maps - shows where a specific bowler has pitched the ball on the wicket to a batsman. Ball Speeds - compares two of more bowling deliveries, comparing the speed of which they are travelling. The system has an overall mean error of 3.6mm of its true location.

3.2 Hot Spot

Hot Spot, this technology is based on the technology in military use, to track jets, missiles and military planes. Later on BBG Sports, a company based in Melbourne, along with Sky Sports developed Hot Spot using the similar concept to be used in cricket. It was initially developed for cricket and later used for various sports. Hot Spot is a technology that uses thermal imaging. In cricket it is used to make leg before wicket decisions. It is used to check if the ball hit the batsman's gloves, bat, pad or the ground or the stumps. It also tells the order in which the ball strikes the above-mentioned things. This technology helps the third umpire to make close calls. It makes use of two infrared cameras located above the field of play, behind the bowler's arm at either end of a ground. These cameras sense minute change in thermal energy. Using thermal infrared imaging, they can detect when the ball makes a contact. This is due to the friction that the ball creates when it strikes the bat glove ground stump or pad. The system instantaneously converts the thermal radiation into electrical signal. The images are formed by amplification of temperature. Later using subtraction technique the position of the ball is indicated in the black and white frames via a red dot. Hence this technology is known as Hot Spot.



Fig.5 Goalref System

In case the ball hits the bat first and then the pad, this is indicated by two dots, the bat dot will be signified by the first dot followed by the dot on the pad. This technology is

not only expensive it has its drawbacks. It has proved not to be a 100% accurate. The technology fails when there is friction due to external factors, such as the batsman thumping his bat. Certain stickers applied on the bat also emit radiations that interrupt with the readings. In many cases if the speed of the bowl is relatively fast and the batsman bat just brushes against the ball the technology fails to notify so and thus is not very reliable.

5. Hawk-Eye in Tennis

Hawk-Eye in tennis is similar in working to that of Hawk-Eye technology used in cricket. Hawk-Eye technology is not used for every on line decision made by the referee. Each player can call for a Hawk-Eye decision thrice in each set, the video is displayed and made available for the players referees and the public 5 seconds after the ball touches the line. This system consists of 10 high-speed cameras capturing 1000 images per second as shown in figure 6. The cameras are so placed so as to cover the entire court including the boundaries. When the player decides to challenge a decision the process starts. It's a four-step procedure. First the coordinates of the center of the ball are sent for each frame, this is done by taking the tilt and zoom of the camera in consideration (compensation done by tracking the boundaries as well). These coordinates are sent to Image Plane Ball Tracking where the projectile of the ball is plotted in 2D. The 2D image is sent to the 3D reconstitution unit, where the system triangulates to find the ball track by visualisation software to display and analyse the simulation. Later the tracks of all cameras for all frames are combined in this stage to form the 4D ball trajectory. This trajectory is used to find the location of contact made by the ball on the ground, whether it was on the line inside or outside. Hawk-Eye technology is more than 90% accurate. It has an error of only 3.6mm, it takes into considerations other factors also like wind, bright sunlight at different times of the day, shadows covering part or the majority of the court, dark or overcast conditions and artificial floodlights.

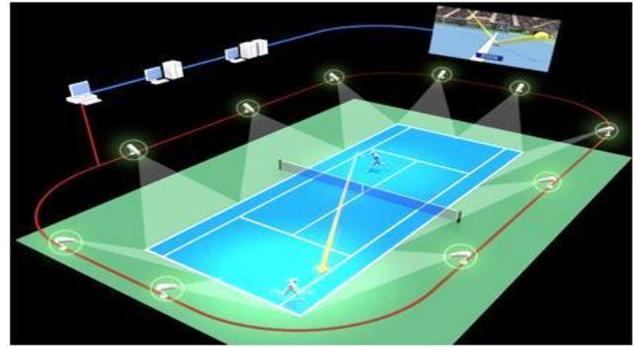


Fig.6 Hot Spot virtual image

Conclusion

To conclude, in this paper we reviewed the various technologies that help eliminate ambiguities and biasness from sports. We understood how these systems work, how accurate they are, their advantages as well as their disadvantages. To summarize these technologies are merely a helping hand to the referees. Some may protest that it is replacing the referees, but one must note that these systems are not to undermine the status of the referees but merely a system to remove human errors. All these systems although very expensive are also used today to evaluate a sportsman's performance and help him to grow. The future scope being technologies that eliminate the existing drawbacks, making the systems a 100% accurate and also minimizing cost to a great extent. These technologies could also be used in other sports.

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