How Feasible is Officiating Technology in Football?

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ABSTRACT
Technology in football has been debated by pundits, players and fans all over the world for the past decade. FIFA has recently commissioned the use of ‘Hawk-Eye’ and ‘Goal Ref’ goal line technology systems at the 2014 World Cup in Brazil. This paper gives an in depth evaluation of the possible technologies that could be used in football and determines the potential benefits and implications these systems could have on the officiating of football matches. The use of technology in other sports is analyzed to come to a conclusion as to whether officiating technology should be used in football. Will football be damaged by the loss of controversial incidents such as Frank Lampard’s goal against Germany at the 2010 World Cup? Will cost, accuracy and speed continue to prevent the use of officiating technology in football? Time will tell, but for now, any advancement in the use of technology in football will be met by some with discontent, whilst others see it as moving the sport into the 21st century.

Keywords
Technology, sport, football, Hawk-Eye, multi-camera trajectory tracking, video referee, Goal Ref, Offside rule, decision review system, decision referral system

1. INTRODUCTION
Technology affects sport in a number of ways. One of the main controversies surrounding sport is the incorrect decisions made by match officials. Introducing technology to officiate sporting matches could improve the accuracy of decision making and can potentially reduce the number of controversial incidents.

Officiating technology is already used in almost all major sports, yet football has been slow to respond to this change. Technology includes multi-camera based ball trajectory analysis, electronic field manipulation, video replays and many more. These systems could be used to determine any number of refereeing decisions across a number of sports. This paper focuses on two of the most crucial systems used to govern decisions in football; goal and off-side detection systems.

To determine if any or which technologies should be embraced by football, a number of questions must be considered. Will officiating technology prove to be more accurate than traditional methods, providing a fairer system to all participants involved? Will delays in technological processing give spectators a decreased amount of excitement and satisfaction, or will this increase through broadcasting virtual reality images? Are these systems feasible in terms of deployment, cost and intrusiveness[1]?

Section 2 evaluates the use of Hawk-Eye systems in cricket and tennis to help determine the potential effectiveness of its application in football. Sections 3, 4 and 5 analyse three other solutions to goal line officiating, whilst section 6 explores the use of technology to determine whether a player is offside. Finally, section 7 weighs up the benefits and drawbacks of using technology in football to determine whether it should be implemented in the near future.

2. HAWK-EYE
Hawk-Eye is a leading multiple-camera based ball tracking system used in the officiating of sports including cricket, tennis, GAA and snooker [2]. Hawk-Eye has recently developed and tested a goal line technology system to be used in football using the same technique as the systems seen in other sports. Previous work has been conducted using multiple-camera based tracking systems for the benefit of broadcasting, but never have they been capable of real-time goal detection [3].

2.1 Cricket
In cricket, six fixed cameras are used at specific locations around the pitch. Three cameras are used at each wicket, with two at a 30 degree angle and another camera at the side of the pitch, as illustrated in Figure 1. This covers the entire wicket from numerous angles, allowing for the greatest coverage of the balls trajectory. It also reduces the possibility of the interference from the players on the pitch obscuring the camera view.

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The six synchronised cameras track the ball's trajectory once it has left the bowler's hand until it stops moving. These images are then processed into virtual reality 3D images by the Hawk-Eye system which can then be used to calculate where the ball was pitched, its movement in the air and its velocity and bounce [4]. From these images, it can be determined exactly where the ball hit the batsman’s pad; a feature used to determine leg before wicket (LBW) calls as part of the Decision Review System (DRS). Having technology like Hawk-Eye, as well as HotSpot® for LBW decisions gives the umpire a tool to assist in decision making rather than being a referral system which would take the final decision away from the umpire.

One argument against this system, presented by Steen, is that technology contravenes the integrity of the game. Despite Hawk-Eye’s broadcasting benefits, some argue it should not be used for officiating. A batsman should simply ‘walk’ if they know they are out, or the umpire should give them out [1]. Not doing so compromises the integrity and tradition of the game.

2.2 Tennis

Hawk-Eye is also used in tennis officiating as an aid to the umpire, much like its use in cricket. Hawk-Eye in tennis is a referral system, rather than the review system seen in cricket.

The first call is made by the line judge but players are now able to challenge this decision. Ten high-speed cameras (1000 frames per second) are situated around the court to determine where the ball has bounced within five seconds of landing – whether it is in or out. Each player has three incorrect challenges per set with an average of 30% of calls being overturned. The system has a mean error of 3.6mm and is resistant to wind, sunlight, artificial floodlights and overcast conditions [5].

Figure 2 is an illustration of how the Hawk-Eye tennis system works. Its application is very similar in cricket, with both systems focusing on the areas of the pitch that will determine the outcome of play. The focal point in tennis is the lines of the court, as opposed to cricket wicket which is the wicket and stumps. In football, the obvious area to focus on is the goal line in which the ball would have to cross in order for a goal to be scored.

Figure 1 Multi-Camera Ball Tracking System

There are effectively four steps in determining where the ball has bounced. The first step is to identify where the centre of the ball is within each frame of each of the cameras through the use of 2D pictures. The lines of the court are also tracked in order to compensate for any movement in the camera (PTZ – Pan, Tilt, Zoom) [6]. This data is sent to the ‘Image Plane Ball Tracking’ system. The second stage is to form a 3D position of the ball by processing the information from each camera. The third stage is to repeat the process for each frame of each camera in order to provide a combined, single trajectory of the ball. The trajectory of the ball is used to calculate the exact position in which the ball landed and generate a definitive umpiring decision, as shown in Figure 3. This image is shown through virtual reality 3D images which are displayed to the umpire, players, crowd and broadcasters [5]. This is therefore a referral system (Hawk-Eye decision is final); whereas as the Hawk-Eye system used in cricket is a review system, meaning the umpire still possesses the final decision.

Figure 2 Hawk-Eye Ball Trajectory System [6]

Figure 3 Hawk-Eye Line Judge System

Maher [8] conducted research into the 1473 challenges made during 15 ATP tennis tournaments during 2006 and 2007. The research shows that 39.3% of the challenged line calls were

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1. http://pcquest.ciol.com/content/cricket/103030404.asp
The research also showed that 8.2% of all line judge calls were incorrect, highlighting the need for a system such as Hawk-Eye in order to reduce the effect of human error on the officiating of football matches.

2.3 Potential Usage in Football
Hawk-Eye has developed a multiple camera based method for football matches to provide a goal line technology system which can determine if a goal has been scored within one second. A license agreement between FIFA and Hawk-Eye has been signed to install this system worldwide as it meets the requirement of being accurate to +/-3cm [9].

The multi-camera based system places six high speed cameras at each end of the pitch. This consists of two cameras above the goal, two in front of the goal and two at the byline, as shown in Figure 4.

![Figure 4 Hawk-Eye Goal line Technology System](http://www.bbc.co.uk/news/10435958)

Much like the tennis system, the images from the cameras are triangulated in order to calculate the trajectory of the ball and where it went. Cross-referencing this to the dimensions of the pitch allows us to see if the ball crossed the line or not. This process is completed within a second and an encrypted signal is sent to the referees watch within if the ball has crossed the line [10].

2.3.1 Further Developments of Hawk-Eye in Football
There are a number of issues with Hawk-Eye in its use for officiating cricket and tennis matches that would also be present in the football system. Firstly, as the accuracy of the system is not 100%, there is still a need for aumpire, meaning human error has not been eliminated. A second issue is the robustness of the system and the difficulty in calibration. The cost to setup Hawk-Eye at a tennis tournament is between $40,000 and $50,000 a week per court, meaning Hawk-Eye is only used in the highest level of cricket and tennis [11]. The cost of installation of the football goal line technology solution is between £100,000 and £125,000 per stadium. Although this is not an issue for Premier League teams, lower league teams may struggle to meet these costs [12].

3. GOAL REF
Goal Ref is a second goal-line technology system that has reached an agreement with FIFA to be installed in football grounds around the world having surpassed the initial standards set out by FIFA. The technology is very different to that of Hawk-Eye. It uses a microchip which is embedded inside the ball. If the ball crosses the line, it interrupts the magnetic field in the goal net and a signal is sent to the referee to indicate a goal [13]. Its speed and accuracy, like Hawk-Eye, mean it shares many of the same benefits of Hawk-Eye.

Three magnetic strips are located in the outer lining of the ball and sensors are placed inside the goalposts and the crossbar. These sensors in the goal send out electronic waves which are disrupted if the ball crosses the line and a message is sent to the referee within a second [14], as shown in Figure 5.

![Figure 5 Goal Ref in Use](http://www.bbc.co.uk/news/10435958)

Although Goal Ref is cheaper to implement than Hawk-Eye’s system, special footballs have to be used. There are still issues concerning football manufacturers allowing this technology to be implemented into their footballs. Another common issue is that this technology could not be implemented at grass roots level, meaning the difference in levels of officiating at each level of the game would grow even further [15].

4. THE CAIROS/ADIDAS SYSTEM
Cairos Technologies developed a goal-line technology solution in partnership with Adidas to be used in football. The technology runs electronic cables under the pitch; placed around the penalty area and behind the goal line to create a magnetic field. The football has low range sensors fitted inside it which measures the magnetic field and transmits encrypted information on the balls exact location to a central computer system. When the location data suggests the ball has crossed the line, a radio signal is transmitted to the referee in a split second [16].

Figure 6 shows the microchip inside the football produced by Cairos and Adidas. One issue in manufacturing the ball is to protect the chip and ensure it does not move. Another is similar to the Goal Ref issue that specific types of football have to be used and not all manufacturers may be willing to produce footballs with this technology inside it.

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4 http://www.bbc.co.uk/news/10435958
5. VIDEO REFEREE
In Rugby Union, the referee has the ability to call on video footage to decide if a try has been scored. This basic technology is cheap and easy to implement but there are a number of drawbacks. It is often inconclusive and slows down the match for as long as four minutes whilst waiting for a decision to be made, which does not fit the nature of football [17]. These flaws in the system are one of the reasons why Goal Ref [14] is being explored as a potential new officiating aid in Rugby Union.

6. OFFSIDE DETECTION TECHNOLOGY
Another controversial issue in football is the off-side rule. The simplest explanation of what constitutes offside is; a player who is closer to the goal line in the oppositions half than all but one or none of the opposition players. There are also other deciding factors including; whether the player is interfering with play, the direction in which the ball was passed and the half of the pitch they are in.

Figure 7 shows a proposed system to capture the movements of the referee, players and the ball. From this information, it could be determined if a player is offside or not by comparing their position in comparison to the opposition. The system works through the use of video analysis and the projection of individual player reference points onto an image.

The proposed system [18] first tracks the dimensions of the football pitch. The second stage is to extract any motion which is done through background subtraction – identifying moving objects that differ from the background significantly. Feature extraction is executed in order to classify the players, separating the two teams through the use of RGB and HIS colour models. From the location of the players and the ball, this information can be used to determine if a player is offside.

The basis of this technology is to project a line from each player into a global reference point, where all players’ projections will be contained. These reference points of each player can then be compared to determine if a player is offside. The classification of players is above 90% average accuracy, making it a potentially viable system if further work was conducted to enhance its accuracy [18].

7. CONCLUSIONS
There has long been a debate as to whether technology is needed to assist in officiating football matches. FIFA have now acknowledged the fact that goal line technology is needed, but there is much more that could be done to aid the referee in decision making. The accuracy and speed of both Hawk-Eye and Goal Ref make them appropriate goal line technology solutions and are to be used at the 2014 World Cup in Brazil. Further work is needed to ensure these systems are even closer to 100% accuracy which would ultimately dispel any argument not to include technology in football.

The accuracy of both Hawk-Eye and Goal Ref is above the 90% required by FIFA. Precision is to within +/- 3cm. However, some will argue that as these solutions are not 100% accurate, they give false transparency to the officials and viewers as the result is displayed as fact without highlighting the potential for error. The system does not provide fairer decision making as individuals will benefit at the expense of others. As the size of the ball, markings of the pitch and many other factors vary, technology in sport should not replace the referee until it is 100% accurate [19]. Although human error will not be completely eliminated, technology will significantly improve the accuracy of

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3 http://www.gizmag.com/adidas-intelligent-football/8512/
decision making and should therefore be adopted as a review system, giving the referee the final decision. A counter argument is that there are much greater issues currently in the game and this is an insignificant step in its future [20].

The speed in which the Hawk-Eye and Goal Ref systems determine when a goal has been scored will have a very limited effect, if any, on the game, alleviating one of the main concerns with the introduction of technology into football. This is perhaps the main reason why video refereeing has not been introduced as an officiating technique in football and has been used solely for broadcasting purposes.

In terms of competition between the goal line technology solutions, one major advantage Hawk-Eye has is that images can be broadcast to the officials, participants and audience. This can potentially increase the viewing experience of the audience members, making sponsorship of the solution a lucrative opportunity, which will help to offset the £100,000 cost of installation. This will only affect those games screened live on television, meaning the cost to implement these systems in lower division team stadiums is unlikely to be recuperated. This could mean a difference in officiating at various levels of football, going against the current attempts by FIFA to ensure the game is as similar as possible at every level.

In order for offside tracking systems to be implemented, a number of improvements must be made. The accuracy of the system must be increased if it is to be used in real time decision making.

Goal line technology is likely to be the first step of many in integrating technology into the officiating of football matches. Its use at the 2014 World Cup could perhaps be followed by player tracking and offside decision technology at the 2018 World Cup in Russia.

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9. REFERENCES


