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# Hawk Eye Technology

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**Abstract:** This paper describes the implementation of Hawk Eye Technology. Hawk Eye Technology is a complex computer system used in cricket, tennis and other sports to visually track the path of the ball and display a record of its most statistically likely path as a moving image. It is also used in some instances to predict the future path of a ball in cricket.

**Keywords:** Triangulation, Kalman filtering, Tracking System, Video Replay System

## 1. Introduction

Hawk-Eye has proved one of the most successful and innovative technologies in the sporting history, with most notable sports such as Tennis and Cricket implementing the system. It was developed by the engineers of Roke Manor Research Limited in 2001. This technology was created by Dr. Paul Hawkins, who invented the ball tracking system in order to improve the quality of sporting decisions, providing a quick, reliable and accurate system which could support match officials when making vital decisions in real game situations. This technology was used first during test match between Pakistan & England on 21st May.

- It is a suite of high-speed cameras and software used to track a ball's path.
- Hawk-Eye is most innovative technology in sports broadcasting world is a development that will reinforce the group's presence and influence.
- Make the game interesting and fair.


Fig.1 Roke Manor Research Ltd

## 2. What it can Do

- *Hawk-eye* can track any type of bounce, spin, swing and seam movement of the ball.
- Give a prediction as accurate as 99.99 percent.
- Hawk-Eye was used for referring decisions to the third umpire in LBW.
- In tennis Hawk-Eye generates the impact of the ball whether the ball is "IN" or "OUT".

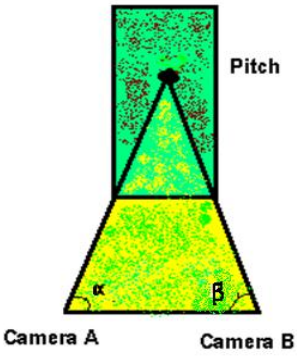
- Chances of wrong decisions will make right after seeing the actual movement.

Fig.2 Hawk- Eye technology

The technology Hawk-Eye was initially developed for cricket, with an aim to broadcast reviews of umpires LBW (*Leg before Wicket*) decisions. This would be done by creating a 3D virtual simulation, where the event could be played back from different angles to assess the incident. Judging whether the umpire made the right decisions or not.

## 3. Principle

Hawk Eye system based on the principle of "TRIANGULATION". Triangulation is the process of determining the location of a point by measuring angles to it from known points at either end of a fixed baseline, rather than measuring distances to the point directly. The point can then be fixed as the third point of a triangle with one known side and two known angles.




$$l = \frac{d}{\tan\alpha} + \frac{d}{\tan\beta} d = l / \left(\frac{1}{\tan\alpha} + \frac{1}{\tan\beta}\right)$$

Fig.3 Triangulation

## 4. How does it Work

Hawk-Eye takes 2 inputs:

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A. Video provided by 6 different cameras placed at 6 different places.
B. The speed of the ball.

The system rapidly processes the video feeds by a high speed video processor. This part of the system can be further divided into major parts:

1) To identify the pixels representing the cricket ball in every image taken by each of the video cameras: An algorithm is used to find the pixels corresponding to the ball in the image obtained. The information which is used in order to achieve this is the size and shape of the ball. After this stage, we have as output the x and y co-ordinates of the ball in each image.

2) Geometric Algorithm: The data of and co-ordinates from each camera is obtained by the Geometric Algorithm which is at work inside the HAWKEYE system. Now, knowing the exact positions of the cameras in space, and the co-ordinates of the ball in more than one of the images taken by these cameras, one can determine accurately the position of the ball.

KALMAN FILTERING: A 3D trajectory of the ball is created from the image data using a process called Kalman Filtering. From this 3D trajectory, you can determine the speed, angle and deviation of the ball's flight.

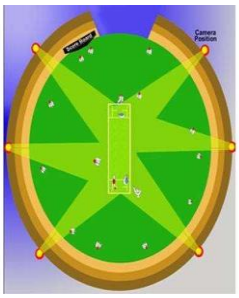

Fig.4 Visual Representation

## 5. Technology of Hawke Eye

- Hawk-Eye takes 2 inputs
  1) Video provided by 6 different cameras placed different places.
  2) The speed of the ball.
- The system rapidly processes the video feeds by a high speed video processor.
- Hawk Eye incorporates both image analysis and radar technology.

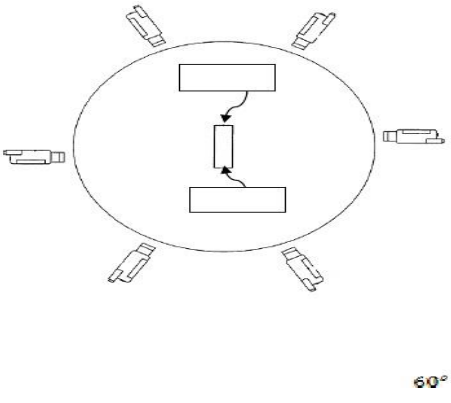


Fig.5 Camera technology

- Frame rate of camera is 120MHz.
- It tracks the ball's entire trajectory, right from the point where it is released from the bowler's hand to the point the ball is considered batsman.


Fig.6 Radar Gun

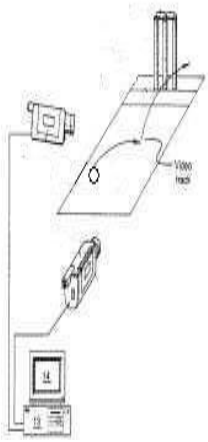

Fig.7 Trajectory measurement

## 6. Features of Hawk Eye

The Hawk-Eye system consists of two significant parts:

- Tracking System
- Video Replay System

## 6.1 Tracking System

- There are 6 high speed vision processing cameras that track the ball from the bowler's hand to batsman.
- The system will automatically calculate the following step:
    1. The speed of the ball leaving the bowler's hand.
    2. The reaction time for the batsman.
    3. The swing of the ball from the bowler's hand to where the ball pitched.
    4. Where the ball was bowled from.
    5. How much the ball bounced?
    6. How much the ball deviated sideways off the wicket (i.e. seam or spin)
    7. A prediction of where the ball would have passed the stump.

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Fig.7 Tracking System

## 6.2 Video Replay System

- Though the tracking data provides the coaches and players with the information for how they have performed. The hawk-eye cricket System can incorporate more video replay camera for better analysis from different camera angles, which can be controlled remotely. The video is captured and stored digitally in hard disk.


Fig.8 Video Replay System

## 7. Accuracy of the Technology

- During testing in 2006 Hawk-Eye made the correct call in 100% of all tests, showing an average error of only 3.6mm.
- Tests have always been conducted outdoors, encompassing situations that take the following factors into consideration:
  - Wind (and therefore camera wobble)
  - Bright sunlight at different times of the day
  - Shadows covering part or the majority of the court
  - Dark or overcast conditions
  - Artificial floodlights

## 8. Applications

- Its applications mainly in sports:
  - Cricket
  - Tennis
  - Snooker
  - Football
  - In Some TV games(e.g. Cricket 2007)

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- Used in Military power
- Used in Automobile Industry

## 8.1 In Cricket

Hawk – Eye help to resolve the following issue:

- Would the ball have hit the stump??
- Did the ball pitch the line?
- Did the ball hit the batsman??
- The single, 2s, 3s, 4s, 6s that make up quick-fire 50s or centuries are represented by the different colors of the wagon wheel.

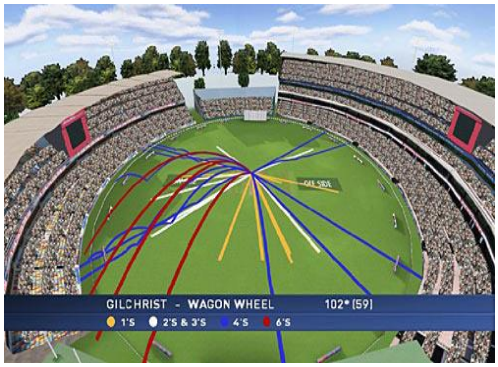


Fig.9 Wagon Wheel

## 8.2 In Tennis

In tennis Hawk-Eye generates the impact of the ball whether the ball is “IN” or “OUT”.

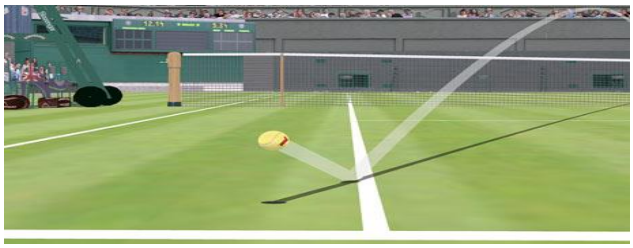

Fig.10 Tennis Wagon Wheel

## 8.3 In Snooker

This technology is useful in cases where the cue ball touches the specified ball first or any other ball.

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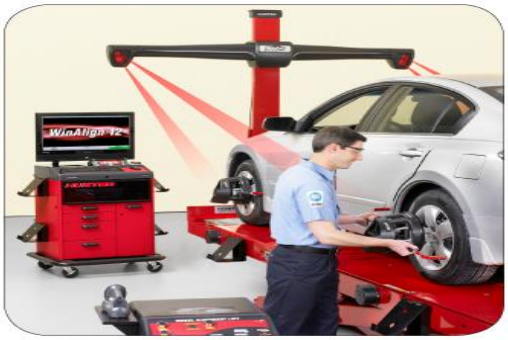
Fig.11 Snooker Wagon Wheel

### 8.4 In Automobile and Military Power

- The wheel alignment can be done by use of this technology in automobile industries.
- Track the enemy location from far away distance.
- The E-2C aircraft used by US army use this technology.



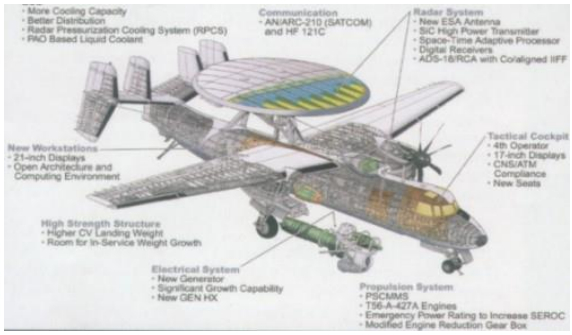




Fig.12 Automobile & Military Wagon Wheel

## 9. Conclusions

- This technology has met the accurate and high reality features.
- Hawk- Eye is currently developing a system for FOOTBALL.
- This technology can be implemented in any type of game in our day to day life.

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