Volume 6, Issue 10, October 2016 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Survey on Hawkeye Technology

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Abstract— These days, Hawkeye technology is one of the most commonly used technologies in sports. It falls in the category "Tecathlon Technology in sports". Nowadays we commonly see visualizations and attractive graphics in cricket analysis shows. These include wagon wheels, pitch maps, reliable software predictions for Leg before wicket predictions. It is also seen very commonly that important decisions, during the course of the game, sometimes go wrong due to human error in judgment. These decisions can alter the way the game progresses. The Hawkeye is one technology which has really shown the promise and can help us in making very accurate decisions. There is a lot of image processing, plenty of mathematical calculations and other aspects of engineering which need to be used in order to allow for the development of such a robust and reliable system. The paper attempts to explain all these aspects in some detail.

Keywords—OUT, BWF

I. INTRODUCTION

Hawk-eye is the name of a line-calling system which traces a ball's trajectory and sends it to a virtual-reality machine. Hawk-Eye uses six or more computer-linked television cameras situated around the court. The computer reads in the video in real time, and tracks the path of the ball on each camera. These six separate views are then combined together to produce an accurate 3D representation of the path of the ball. The Hawkeye system was invented by a young British computer expert Paul Hawkins, and was launched in 2001. It was first used in television coverage of sporting events such as Test cricket, and has now reached the stage of being used by officials in tennis to assist in adjudicating close line calls [1]

The Nasdaq-100 Open in Miami was the first tour event to officially use the technology. The 2006 US Open was the first Grand Slam event to feature the system, followed by the 2007 Australian Open. At the Australian Open, only centre court matches utilize the technology. [5]

II. WORKING

Hawk eye is the name of a line calling system, which traces a ball's trajectory and sends it to a Virtual reality machine.

It is a complex computer system which works via 6 or 7 high performance camera normally positioned in predefined places around the stadium. These cameras track the ball from different angles the video from the cameras is triangulated and combined to create a 3 dimensional representation of the trajectory of the ball. It is accurate within 5mm but is generally trusted as an impartial second opinion in sports. [9]

Cricket is a ball game played within a predetermined area. A system comprising of video cameras mounted at specific angles can be used to take pictures. These pictures are then used to locate the position of the ball. The images are then put together and superimposed on a predetermined model to form a complete visualization of the trajectory of the ball. The model includes, in this case, the pitch, the field, the batsmen and fielders etc. For this to be possible, we need to sample images at a very high rate and thus need efficient algorithms which can process data in real time. Such technologies are widely used today in various sports such as Tennis, Billiards which also fall in the category of ball games played within a restricted area. Our discussion will mostly contain applications which specific to the game of cricket, however in some cases, we will mention how similar techniques are applied in other games.

The figure 1. Shows the flow of hawk eye technology. It started with the calibration of the cameras. This is required to deal with the problem about the non-uniform distance of the cameras from the playing area due to various sizes of the pitch. The next step is to start processing the video input which we get from the cameras. In each of the images obtained, the first aim is to find the ball in it. Once this is done, a geometric algorithm is used to look at multiple images (which are 2D) and then combine them cleverly to get the co-ordinates in 3D space. This process is now repeated for multiple times every second (typically at the rate of 100 times per second). Thus, we have the position of the ball in 3D space at many moments in every second. The final step is to process these multiple positions and find a suitable fitting curve which best describes the flight of the ball. As we have sampled the positions of the ball at very short time intervals, the flight of the ball can be very accurately determined. This is the outline of Hawkeye technology.[6]

2.1. Flow diagram of Hawkeye

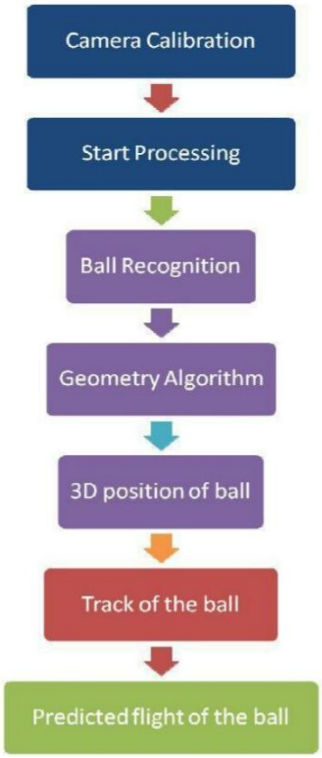

Fig. 1: Hawk-Eye Flow Diagram

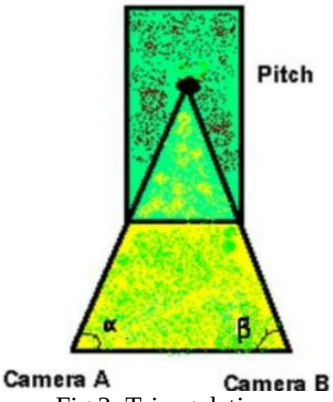

Fig 2: Triangulation

$$l = \frac{d}{\tan\propto} + \frac{d}{tan\beta} \quad \text{---------- (1)}$$

$$d = l/\left[\frac{1}{tan\propto} + \frac{1}{tan\beta}\right] \quad \text{---------- (2)}$$

The Hawk-Eye system is based on triangulation principles that make use of visual images and timing data provided by high-speed video cameras placed at strategically locations and angles around the sports arena.

2.2. Triangulation

Triangulation is the process of determining the location of a point by forming triangles to it from known points. It involves angle measurement instead measuring distances. The point can then be fixed as the third point of a triangle with 1 known side and 2 known angles.[6]

Hawkeye takes 2 inputs:

A. Video provided by different cameras placed at 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 of the cricket ball in every image taken by 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. Now, knowing the exact positions of the cameras in space, and the co-ordinates of the ball in more than one of the images, one can determine accurately the position of the ball.

Hawkeye incorporates both image analysis and radar technology. It tracks the balls entire trajectory, right from the point where it is released by the bowlers hand, to the point where the batsman hits the ball.

2.3. Features

The main features of hawk eye are:-

- Tracking system.
- Video replay system.

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 :-
  - First it calculates the speed of the ball at the moment it leaves the bowlers hand.
  - It then calculates the reaction time of the batsman in response to the ball.
  - It also calculates the swing of the ball from the bowler's hand to where the ball pitched.
  - Where the ball was bowled from.
  - How much the ball bounced?
  - How much the ball deviated sideways off the wicket (i.e. seam or spin).
  - And finally A prediction of where the ball would have passed the stump. [7]

III. APPLICATIONS IN SPORTS

3.1. Cricket

3.1.1 LBW

Hawkeye can accurately figure out the trajectory of the ball and predict the direction of the ball using mathematical calculations. This is used to decide whether a batsman was out. Thus, the system determines the exact point at which the ball struck the batsman. Using the trajectory of the ball up to that point, the system predicts the path the ball would have taken had the batsman not been present in the way. Thus one can know the lateral position of the ball with respect to the stumps as well as the height of the ball at the point when it reaches the line of the stumps. The figure 4 gives an example of the trajectory of the ball being predicted.

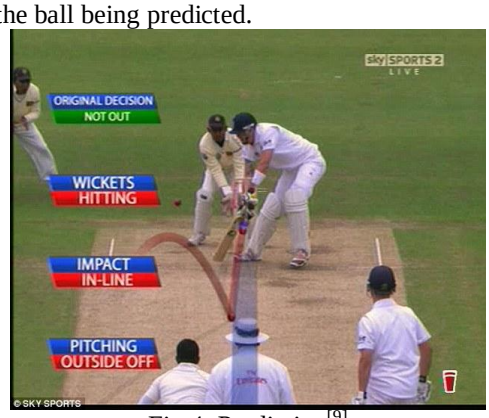

Fig 4: Prediction[9]

Note that in this picture, the system has got rid of the batsman from the picture so as to give us a complete view of the path of the ball since it left the bowler's hand. This is exactly what one needs to decide if the ball would have hit the stumps and if that is the case, the batsman has a chance of being given out. [6]

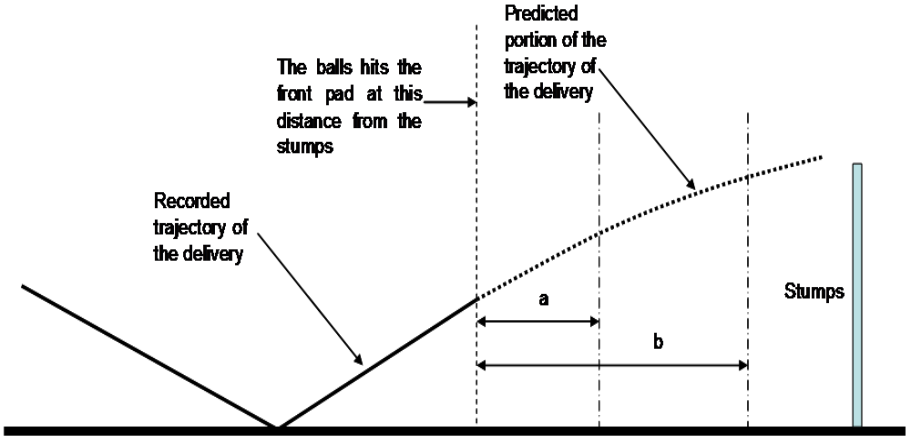

Fig 5: Cricket pitch

3.1.2. Wagon Wheels:

The trajectories which the ball has taken after being hit by the batsman are recorded by the hawkeye system. This is used to generate a graphic showing 1s, 2s, 3s, 4s, and 6s all in different colours for a batsman. These details allow the commentators, spectators and players to analyze the scoring areas of the batsman and also judge if he has played more shots along the turf or in the air. Such information is vital for a fielding captain, who might alter his field placement in subsequent matches to adapt to the hitting pattern of a particular batsman.[8]

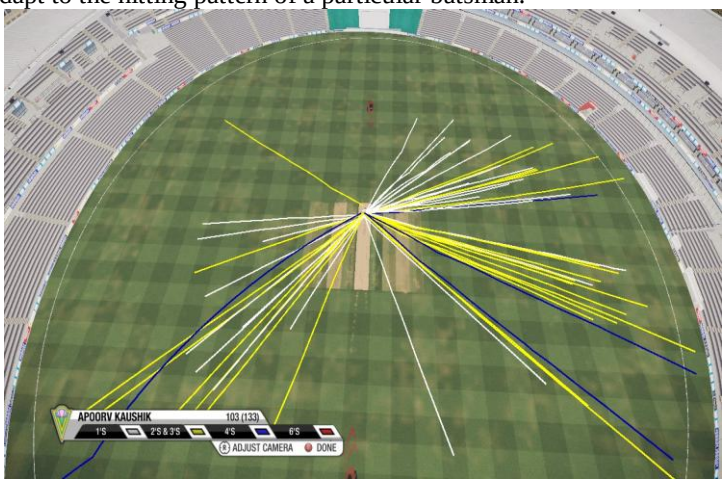

Fig 6: Wagon wheel

3.2. Tennis

Hawk-eye was first used in tennis in the year 2004(US open tennis). In tennis Hawk-eye generates the impact of the ball whether the ball is "IN" or "OUT" the line of tennis court. [3]

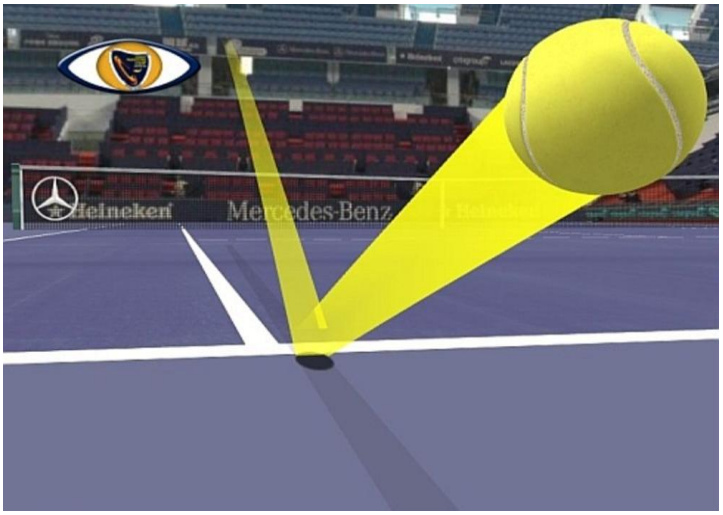

Fig 7: Tennis court

3.3. Football

The much anticipated GOAL LINE TECHNOLOGY is gradually brought into the foray in the game of football.

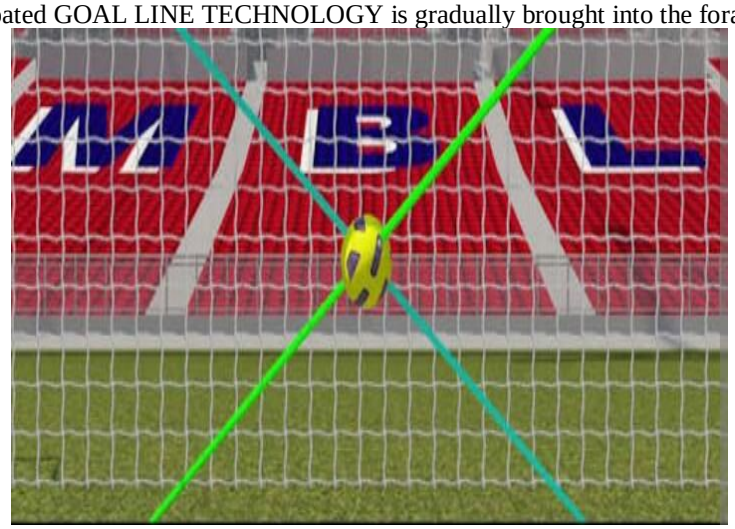

Fig 8: Football goal

3.4. Badminton

After testing various instant-review technologies in recent months, the Badminton World Federation has contracted Hawk-Eye Innovations to provide instant-review services for the World Super series as well as for BWF Major Events. This includes Hawk-Eye's popular graphics implementation which pinpoints the exact spot on which a ball – or in badminton's case, a shuttle – lands. These are often shown in sports venues worldwide and broadcast to fans elsewhere.[4]

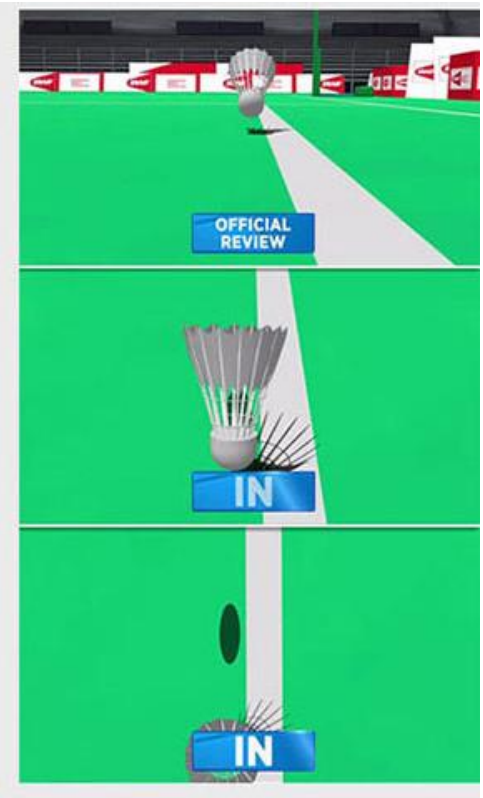

Fig 9: Badminton court

IV. CONCLUSION

Hawkeye technology is a great innovation, which puts technology to good use in the field of sports. The accuracy which can be achieved with the use of this system is making the authorities think seriously about reducing the human error component involved in important decisions. As the system runs in real time, there is no extra time required to see the visualizations and graphics. The system is also a great tool which can be used by players, statisticians, tacticians, coaches to analyse previous games and come up with strategies for subsequent ones.

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