AUTOMATIC THIRD UMPIRE LEG-BEFORE-WICKET DECISION MAKING USING IMAGE PROCESSING

A PROJECT PHASE I REPORT

Submitted by

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(18ECR187)

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(18ECL256)

in partial fulfilment of the requirements

for the award of the degree

of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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BONAFIDE CERTIFICATE

This is to certify that the Project Phase I report entitled **AUTOMATIC THIRD UMPIRE LEG-BEFORE-WICKET DECISION MAKING USING IMAGE PROCESSING** is the bonafide record of project work done by SELVAVIGNESH S (18ECR187), THARUN BALAJI S (18ECR223), VIJAY E (18ECL256) in partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Electronics and Communication Engineering of Anna university of Technology, Chennai during the year 2020 – 2021.

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MAY 2021

DECLARATION

We affirm that the Project Phase I report entitled **AUTOMATIC THIRD UMPIRE LEG-BEFORE-WICKET DECISION MAKING USING IMAGE PROCESSING** being submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering is the original work carried out by us. It has not formed the part of any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABSTRACT

Cricket is the most interesting game watched by the people all over the world. It has two in-field umpire who makes decisions throughout the game. If the in-field umpires are not sure about their decision, a third umpire review will be called. A third umpire is a person who has access to the recorded videos and checks the actual thing happened. Only a shorter duration will be provided for third umpires to make his decision. Third umpire sitting on the review panel watching slow motion video may not be able to make actual decision in all cases. Human will make errors time-to-time on such shorter duration. Such errors may change the rest of the game. It’s a rule that a team can call third umpire decision only twice throughout the match.

There are situations that a team/batsman is sure that there is no dismissal, but they cannot call third umpire decision because the couple of chances have been used. Every batsman has the right to have a third umpire decision call when he wanted to make sure of his dismissal irrespective of chances. These drawbacks can be resolved by implementing image processing technologies. It provides quick, no biased and accurate decisions, so it will not affect the phase of the match and maintains the integrity of the game.

One of the batsman dismissal rules is Leg-Before-Wicket and it is the hardest decision to make for the third umpire. The proposed system implements the detection of ball and pad using contour and color masking techniques respectively and finds intersection of ball and pad, to make decisions depending on the requirement.

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LIST OF ABBREVIATIONS

Abbreviation		**Expansion**
LBW	-	Leg Before Wicket
SVM	-	Support Vector Machine
CNN	-	Convolutional Neural Network
UDRS / DRS	-	Umpire Decision Review System

CHAPTER 1

INTRODUCTION

Cricket is an international game played using bad and ball with several rules between two teams. It most commonly played sport all over Asia. As each and every ball decides the winning or losing of the game, the decisions made on each ball is very crucial. This can be made automatic and accurate with the help of Image Processing techniques.

1.1 CRICKET FIELD

Cricket field is grass field, typically oval in form where the game is played. A curvy line alongside the outer most field is called boundary line. At the middle of the field, a rectangle region referred to as Pitch in which the batting, bowling, run, wicket will take place. In pitch, there will be two wickets (Stumps) at the two ends of the pitch. There are lines called as Batting Crease and Bowling Crease which separates the stump from batsman and bowler respectively. A schematic view of the Cricket field and the pitch is shown in Fig.1.1 and Fig 1.2 respectively.

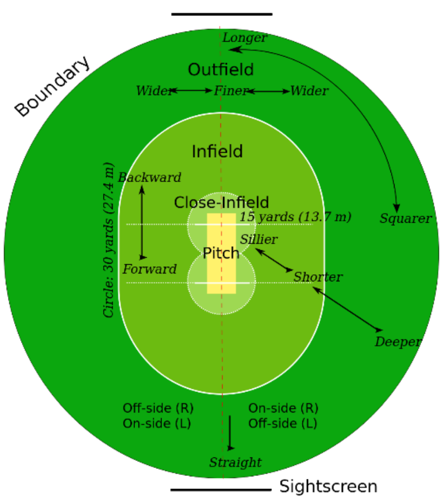

Fig.1.1 Cricket Field

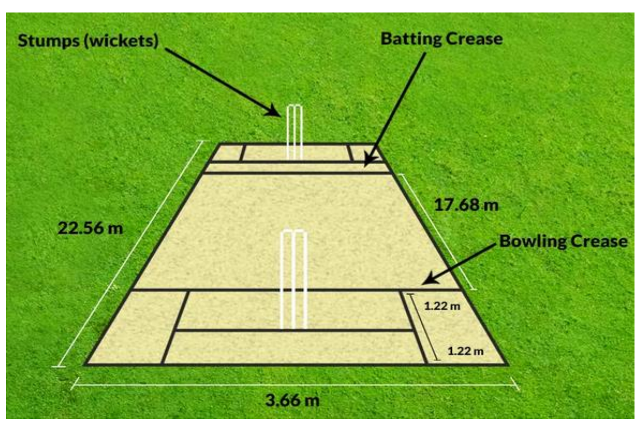

Fig.1.2 Pitch

1.2 CRICKET

In cricket, two teams consisting of 11 players each. At the beginning of the game, a coin will be tossed to determine which team ought to bat and bowl first. A team will bat first with batsmen on the pitch and other participants of the identical team might be called after the dismissal of the previous player. the other team will do fielding and bowling to dismiss the batsman. Bowler will bowl the ball and batsman saves the stump through hitting the ball using the bat in order to hold his wicket. If the ball hits the stump, then the batsman is dismissed and next one could be called. otherwise, via hitting the ball, if the ball reaches boundary directly without pitching anywhere on the field, 6 runs (points) will be given for batsman. If it pitches at the least once within the field and reaches the boundary, then four runs could be provided. In either of the cases, batsman can reach the opposite crease on the way to get one run.

There are several rules for batsman dismissals such as Run-out, LBW, Catch-out etc., There will be an in-field umpire to make decisions based on the rules. When all the batsman gets dismissed, then the other team will start batting chasing the run acquired by their opposite team. Equal number of ball deliveries will be provided for both the teams called innings. Even, the innings for a team gets over, the batting gets over.

1.3 NO-BALL

A no-ball is an illegal delivery of ball to a batsman. No-balls are due to overstepping the bowling crease. The bowler should step on or before bowling crease. If it is no-ball a run will be provided to the batsman as a penalty for the bowler. Even, it the batsman gets dismissed by any mode, if it is found to be no-ball, then the wicket will not be taken. So, no-ball plays an important role in every dismissal of batsman. A typical no-ball is shown in Fig 1.3.

Fig.1.3 No-Ball

1.4 LEG-BEFORE-WICKET

Leg-Before-Wicket (LBW) is one of the rules for batsman dismissal. As when the ball hits the batsman stump the wicket is taken. In this aspect, the batsman is considered to be an imaginary object. A batsman should not interrupt the ball after bowled with his body. If he does so, then his wicket is taken out. He can only save his wicket with the help of bat. In order to regulate the LBW, Law 36 has been updated. Fig.1.4 shows the LBW out.

According to the law, before a batsman can be dismissed LBW,

- the fielding team must appeal to the umpire.
- If the bowler delivers a no-ball, an illegal delivery, the batsman cannot be out under any circumstances.
- Otherwise, for the batsman to be adjudged LBW, the ball must pitch in line with or on the off side of the wickets.
- Then the ball must strike part of the batsman's body without first touching his/her bat, in line with the wickets and have been going on to hit the stumps.

Fig.1.4 LBW out

CHAPTER 2

LITERATURE REVIEW

Baljinder Singh Bal, Gaurav Dureja (2012) proposed a logical innovative technology use in sports for effective decision making. Hawk-eye technology has been used in several sports like tennis, cricket, football etc., for better decision making. Although Hawkeye was very accurate in measuring the actual path of a ball, when it comes to predicting the future path of the ball, such as in LBW decisions, it was not as clear. If the ball heading to the pitch, there's no way Hawk-eye can tell if a delivery is going to skid a bit more than normal or hit a crack, bit of grass, or worn patch of the pitch. The predicted path of the ball was based on the average and expected pathway. There were lot of development undergoing in betterment of Hawk-eye. Some other drawbacks where a lot of high-speed cameras were involved and it costs high to make Hawk-eye setup. This method will not work on some natural conditions like wind, pitch conditions. There were lot of drawbacks in Hawk-eye method and expense of implementing it.

Ashok Kumar P (2012), proposed a method by using Sensors like Ultra-edge detection in-order to find whether the ball hits the pad. There will be some error while detection due to noises. The batsman may move, so that the cricket pad and the sensor get disturbed. Even when the ball and bat get interrupted, there will be detection by the sensor in the pad. So, the LBW detection will not so accurate and reliable.

Aftab Khan, Syed Qadir Hussain, Muhammad Waleed, Ashfaq Khan, Umair Khan (2019) proposed, An automated snick detection and classification scheme as a cricket decision review system. It implemented classification algorithms like Support Vector Machine (SVM) and Neural networks to find the intersection of bat and ball, ball and pad and stump and ball using Snicko-meter readings placed on several places near the stump. The classifier model worked on given trained datasets of 1000 snicko-meter readings and its decisions. The model will classify out or not based on the trained model. But the main drawback of this method was the noises added to the input signals. The Noises in the background, noises due to batsman or player's move and technical noises are unavoidable. There were works undergoing to improvise the performance of the sensor and to cancel the background noises. But there were several problems associated with removing noises.

Kowsher, M., Alam, M. A., Uddin, M. J., Ahmed, F., Ullah, M. W., & Islam, M. R. (2019) proposed a method using Deep learning Convolutional Network in order to classify whether the batsman was out or not. This method worked well on No-ball detection but not on LBW. The accuracy of the LBW detection using CNN varies from 50 to 60%. So, this can't reliable on every situation. This introduced new technical errors which may change the whole game. This method never works on when the bat is involved in the LBW decision making.

Alex Joseph, Alistar Fernandez, Jasir Ahamed P.A, Treesa Joseph (2018) proposed Artificial Eye (A-Eye) to detect Run-out decisions using object detection and object tracking. This method used Motion detection algorithms using Object tuner and object detection modules. It detected and tracked the bat, crease line and the stump coordinated with time constrains. At the point of stumped, it checks the intersection of bat edge on the crease line and the rest was done by decision module. It has been successfully implemented for Run-out only, not for LBW.

CHAPTER 3

EXISTING METHOD

3.1 IN-FIELD UMPIRE DECISION

In cricket, an umpire is someone who has the authority to make selections about events at the cricket discipline, in step with the legal guidelines of Cricket. Historically, cricket fits have two umpires on the sphere, one standing on the cease in which the bowler delivers the ball (Bowler's cease), and one at once opposite the dealing with batsman.

At some stage in play, the umpire on the bowler's end makes the decisions, which they particularly suggest the usage of arm signals. Some selections need to be on the spot, whereas for others they'll pause to suppose or discuss it with the square leg umpire, in particular if the latter may additionally have had a better view.

If the umpire is unsure of a ‘line choice’ (that is, a run out or stumped decision) or if the umpire is unsure whether the ball is a 4, a six, or neither, they'll refer the problem to the third Umpire. The umpires might also additionally refer decisions to the third Umpire regarding Bump Balls and catches being taken cleanly (but most effective after the on-field umpires have consulted and both have been unsighted). Additionally, the players may also determine to refer a dismissal selection to the third Umpire. The on-field umpire signals a referral using both hands to mime a tv screen via making a box shape.

If the third Umpire decides that the on-field umpire made an incorrect decision then they'll tell the on-field umpire, through headsets, of what they've seen and tell them to either change their choice or to live with their original selection. The Fig 3.1 shows the in-field umpire calling third review.

Fig.3.1 In-field umpire calling third review.

3.2 UMPIRE DECISION REVIEW SYSTEM

The Umpire decision overview system (UDRS or truly DRS) is a technology-based device utilized in cricket to help the match officials with their decision-making. On-field umpires may additionally pick out to seek advice from the third umpire (called an Umpire review), and players might also request that the third umpire take into account a selection of the on-field umpires (known as a player review).

The main elements that have been used are television replays, technology that tracks the path of the ball and predicts what it would have done, microphones to detect small sounds made as the ball hits bat or pad. The Fig 3.2 shows the Third umpire making decision.

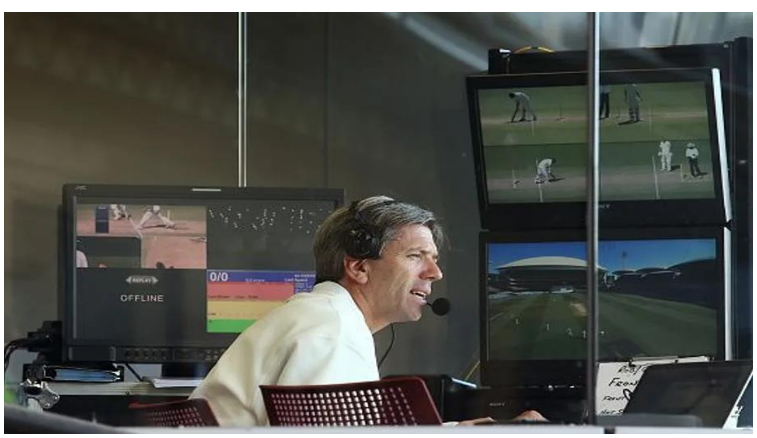

Fig.3.2 Third umpire making Decision

3.3 LBW IN UDRS

LBW is the hardest decision making for an in-field umpire. So, most of LBW decisions will be called for DRS. The third umpire checks for No-ball, whether the ball pitches in-field and uses Hawk-Eye method. The Fig. 3.3 shows Hawk-eye method.

Hawk-eye or virtual-Eye: ball-tracking technology that plots the trajectory of a bowling delivery that has been interrupted through the batsman, frequently by way of the pad, and might expect whether or not it would have hit the stumps. it is based at the precept of triangulation the usage of the visible pix and timing data provided by using high-pace video cameras located at exclusive places and angles across the area of play.

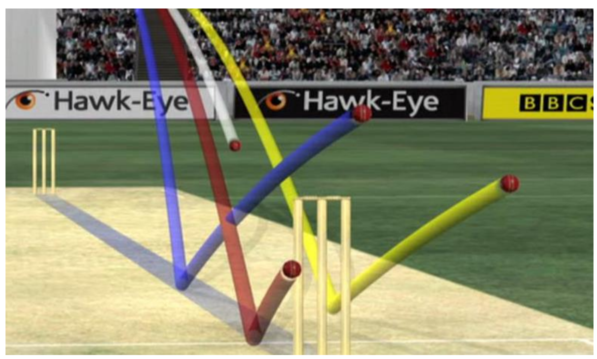

Fig.3.3 Hawk-Eye method

3.4 DRAWBACKS IN HAWK-EYE

The drawbacks in Hawk-eye method are explained below.

More Expensive:

There are number of high-speed cameras needed to implement the Hawk-Eye method which will be expensive.

The professional Hawk-eye method for a Standard Tennis court takes 60,000 to 70,000 USD (without including Storage and computational expenses). Assuming for a large cricket stadium could cost much higher which will be a great amount.

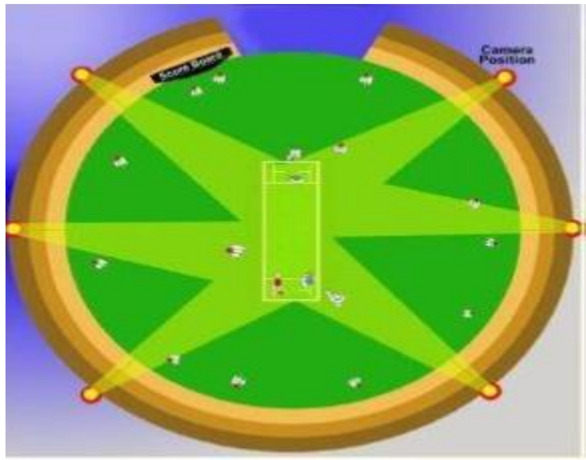

Fig.3.4 Hawk eye Camera position

- As seen in the figure, minimum of 6 high-speed cameras are needed to make decisions. So, it will be more expensive.

More Computation:

- Hawk-Eye method gets all the recorded videos from several cameras, it needs to work on several images and timing constraints in order to generate a model. This computation will be complex.
- It then, generates a 3D model from the resultant videos and timing data in order to provide output to check whether ball will hit the stump.
- These processes will take more computation and storage, which will also be expensive.

Never work on some Natural conditions:

- **Wind:** When there is wind, it will affect the projection of the ball. Since, Hawk-eye method decides by predicting the projection of the ball, it will result in error.
- **Pitch Conditions:** When the pitch have patches/cracks, there will be change in projection after the ball pitches. The ball may skid a bit more than normal or hit a crack, bit of grass, or worn patch of the pitch. This will be a problem.
- **Illumination:** Hawk-eye method requires more illumination or light source in order to make accurate decisions. But more illumination will disturb the players eye-sight. It introduces more issues.

Not Accurate:

- Since, Hawk-eye method computes the projection of the ball (prediction), there may be some deviations of the ball on actual scenario. Hence, it would not be much accurate.
- It is accepted that there will be 5mm to 15mm error deviation in detection. This could even change the victory of a team.

Since, Hawk-eye method computes the projection of the ball (prediction), there may be some deviations of the ball on actual scenario. Hence, it would not be much accurate. It is accepted that there will be 5mm to 15mm error deviation in detection. This could even change the victory of the teams.

CHAPTER 4

PROPOSED SYSTEM

The proposed system is built on the Computer vision package "OpenCV". OpenCV (Open-Source Computer Vision Library) is an open-source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products.

In order to make LBW decisions, it is necessary to check for the intersection of the ball and pad or leg. If it intersects, it is a LBW out. Else, it is not out. The first step is to detect the ball and pad or leg and then applying some logic to find whether the detected ball and pad intersects.

4.1 FLOW CHART

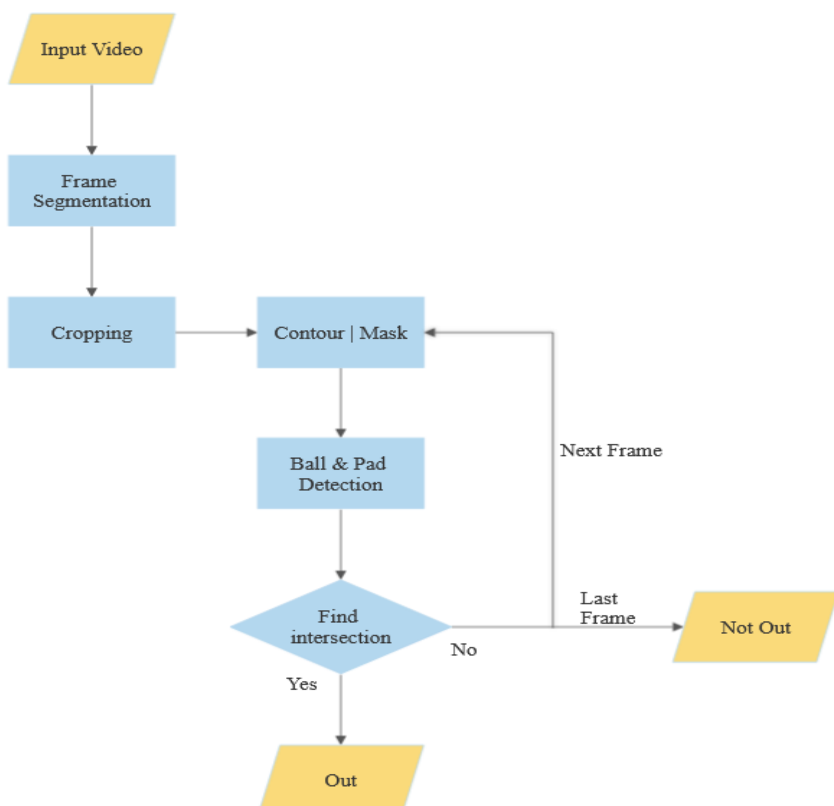

Fig.4.1 Flow Chart

The proposed method consists of 4 main modules, Frame Segmentation and Cropping module, Ball detection module, Pad detection module and Decision-making module. Fig 4.1 shows the flow chart.

Frame segmentation module is used to extract the frames from the video and cropping is applied and the processed frames are stored. Ball detection is used to find the edges of the ball and Pad detection provides the edges of the pad and leg. Based on the detection of ball detection and pad detection, decision making module finds the intersection of detected ball and pad.

If there is any intersection, the decision-making module provides immediate output as Out. Else if there is no intersection, then the next frame's ball and pad detection is given to decision making module and intersection will be found out. If there is no intersection till the last frame, then it will be given as Not Out.

4.2. FRAME SEGMENTATION AND CROPPING

The particular video segment of the match is taken as input. The input video is first given to frame segmentation and cropping module.

Video is the consequent collection of images (frames) taken at particular interval of time. In frame segmentation, the frames contained in the video will be stored in-order to process the images to do object detection. This has been illustrated in Fig.4.2 Video Representation. These stored frames will be accessed by Ball detection and Pad detection modules.

Cropping is the elimination of unwanted outer regions from a photographic or illustrated image. This technique removes some of the peripheral regions of an image to put off extraneous trash from the picture, to enhance its framing, isolate the subject rely from its background. As an image is a matrix, it can be cropped by way of limiting the index values of row and column. The cropping will be a constant one throughout the process of segmentation.

The cropping of segmented frames will be done focusing the pitch and the batsman. The median blur is applied in order to remove the unwanted noise added to the image for better detection.

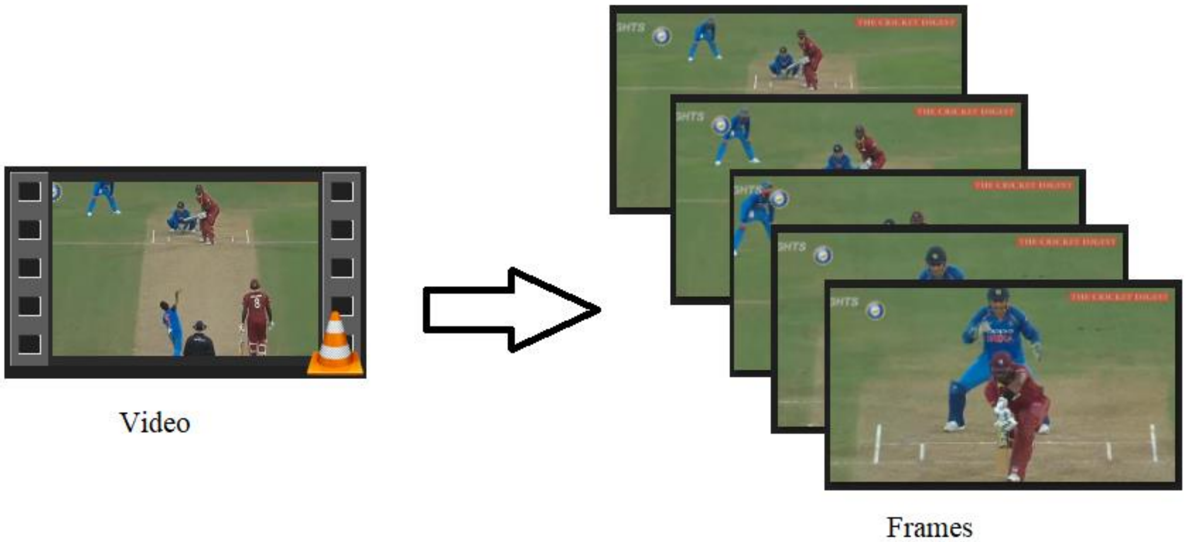

Fig.4.2 Video Representation

4.3. BALL DETECTION

Ball detection is done using edge detection algorithm such as Canny Edge detection and Contour, to detect the edges and Minimum enclosing circle method to find the circle in the detected edges.

4.3.1 CANNY EDGE DETECTION

Canny edge detection is a technique to extract useful structural data from specific gadgets and dramatically lessen the quantity of statistics to be processed. it has been broadly carried out in numerous computer vision systems. Canny has observed that the requirements for the utility of edge detection on diverse vision systems are fantastically comparable. hence, an aspect detection method to cope with these requirements may be applied in a wide variety of situations. the general standards for edge detection include:

1. Detection of edge with low error, which means that the detection should accurate as many edges shown in the image.

2. The edge point detected from the operator should accurately localize on the center of the edge.
3. Image noise should not create false edges.

The Process of Canny edge detection algorithm can be broken down to 5 different steps:

1. Apply Gaussian filter to smooth the image in order to remove the noise
2. Find the intensity gradients of the image
3. Apply gradient magnitude thresholding or lower bound cut-off suppression to get rid of spurious response to edge detection
4. Apply double threshold to determine potential edges
5. Track edge by hysteresis: Finalize the detection of edges by suppressing all the other edges that are weak and not connected to strong edges.

Gaussian Filter: As a result of edge, detection is affected by noise, it is essential to perform filtering in order to avoid false detection. The image is smoothened by convolving it with a Gaussian filter. The Gaussian filter equation for the size of the kernel (2k+1) × (2k+1) is given by the equation (1).

$$\mathrm{H_{ij}} = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{\left(\mathrm{i}-(\mathrm{k}+1)\right)^2+\left(\mathrm{j}-(\mathrm{k}+1)\right)^2}{2\sigma^2}\right); 1 \leq \mathrm{i}, \mathrm{j} \leq (2\mathrm{k}+1) \qquad (1)$$

the choice of the dimensions of the kernel is vital in determining the performance of the filter. As the dimensions of the kernel is growing, the detector becomes less sensitive for noise detection with an boom in localization mistakes.

Determination of intensity gradient:

To come across edges found in an image in all instructions, the Canny facet detector makes use of 4 filters for detecting horizontal, vertical, and diagonal instructions. the brink gradient may be decided as in the equation (2).

$$\mathbf{G} = \sqrt{\mathbf{G_x^2} + \mathbf{G_y^2}} \text{ and } \boldsymbol{\theta} = \mathbf{arctan}\,(\mathbf{G_x}, \mathbf{G_y}) \qquad (2)$$

Where G_x and G_y are the first-order derivatives in the horizontal and vertical directions. The edge direction angle is rounded to one of four angles representing vertical, horizontal, and the two diagonals (0°, 45°, 90° and 135°).

Non-Maximum Suppression: This is used to determine the largest edge. The algorithm is, For every pixel:

- Compare the edge strength with that of them in the positive and negative directions.
- The value of the present pixel is retained if its comparison is the largest among the compared values. Otherwise, it is neglected.

Double Threshold: After nonmaximal suppression, the ensuing pixels are actual part pixels. along with those pixels, some greater pixels because of noise and colour variations can also be gift. those are in addition decided on by putting a low and an excessive threshold. If the edge gradient fee is higher than the high threshold its miles retained and if it is much less than the low threshold, its miles discarded.

Edge tracking: The susceptible area pixels can be resulted from a robust pixel or because of noise or shade versions. this can similarly be diagnosed via blob evaluation which identifies the connectivity of a weak pixel to a strong pixel. If there may be a strong facet pixel recognized in a blob then that susceptible pixel is taken into consideration otherwise its miles left out.

4.3.2 CONTOUR

Active contour models (additionally known as “deformable contours” or “snakes”) are broadly used for systematically refining object contours. The basic concept is to attain a complete and correct define of an object that may be ill-defined in locations, whether through lack of contrast, or noise or fuzzy edges.

Contour is the technique of identifying structural outlines of items in an image which in turn can assist us figuring out shape of the object. It's a curve becoming a member of all of the continuous points (alongside the boundary), having same color or depth. The contour is a beneficial device for form analysis and item detection and reputation. by way of applying contour, all the rims inside the given photograph can be decided.

A starting approximation is made, both via instituting a huge contour that can be shrunk to length, or a small contour that may be elevated definitely, until its shape fits that of the item. In principle, the initial boundary can be as an alternative arbitrary, whether or not basically out-side or in the object in question. Then, its shape is made to conform concern to an energy minimization manner: on the one hand, it is desired to reduce the external electricity similar to imperfections within the degree of match; on the other hand, it is desired to minimize the internal power, so that the form of the snake does no longer come to be unnecessarily elaborate, e.g., through taking on any of the traits of photo noise.

There also are version constraints that are represented in the formulation as contributions to the external energy: common of such constraints is that of stopping the snake from getting into prohibited areas, including past the image boundary, or, for a moving car, off the vicinity of the street. The snake's internal strength includes elastic power which might be needed to amplify or compress it, and bending strength. If no bending power terms have been covered, sharp corners and spikes within the snake would be unfastened to arise and not using a restrict. similarly, if no elastic strength phrases were covered, the snake might be accepted to grow or shrink without penalty.

The photo statistics is generally taken to interact with the snake via three major styles of photograph characteristic - lines, edges, and terminations (the latter can be line terminations or corners). numerous weights can be given to these capabilities in line with the conduct required of the snake.

As compared to classical characteristic extraction strategies, snakes have more than one advantages:

• They autonomously and adaptively search for the minimum state.
• Outside forces act upon the snake in an intuitive manner.
• Incorporating Gaussian smoothing inside the photograph electricity function introduces scale sensitivity.
• They may be used to find dynamic objects.

4.3.3 MINIMUM ENCLOSING CIRCLE

Minimum enclosing circle method is used in-order to get the center pixel position of the ball (circle) and its radius.

The smallest-circle problem (also known as minimum covering circle problem, bounding circle problem, smallest enclosing circle problem) is a mathematical problem of computing the smallest circle that contains all of a given set of points in the Euclidean plane. The corresponding problem in *n*-dimensional space, the smallest bounding sphere problem, is to compute the smallest *n*-sphere that contains all of a given set of points.

A bounding circle will be drawn over the edges of the enclosing circle with a green color of thickness 2 pixels uniform around the circle. Instead of using bounding boxes, bounding circle is used to make accurate predictions.

4.4. PAD DETECTION

Pad detection module will provide the mask of the pad detected from the input image.

4.4.1 COLOR MASK

The process of partitioning a digital image into multiple segments is defined as image segmentation. Segmentation aims to divide an image into regions that can be more representative and easier to analyze. Such regions may correspond to individual surfaces, objects, or natural parts of objects. Typically, image segmentation is the process used to locate objects and boundaries (e.g., lines or curves) in images.

Color image segmentation that is based on the color feature of image pixels assumes that homogeneous colors in the image correspond to separate clusters and hence meaningful objects in the image. In other words, each cluster defines a class of pixels that share similar color properties.

Color masking means to edit random colors by applying mask and thus limiting the range of displayed colors to specific shades. Color masking gives us a fine control of updating pixel values on the screen. By limiting the color channels that are written by each drawing command, a graphic designer can use each channel, for example, to store a different grayscale image. By applying color masking, it can be accurately to detect the objects needed in an image.

Based on the track pant and cricket pad of the batsman, it is possible to extract its segment using color masking. Depending on the lower boundary and upper boundary shades of that color, to get the proper shape of the pad and leg. Since, it is also a LBW out, even the ball touches the batsman. So, by color masking it is possible to extract both same. Here the pad and track pant are in red color so generating a mask which covers the least intensity of red and an equal red color according to the batsman's pad. The regions other than the pad and the leg will be black. The output will be mask. Thus, by applying the mask, it can eliminate the detection of bat, stump, crease line and other unwanted objects.

4.4.2 MEDIAN BLUR

The median filter is a non-linear digital filtering technique, regularly used to take away noise from an image or sign. Such noise discount is a standard pre-processing step to improve the results of later processing (as an example, edge detection on an picture). Median filtering may be very broadly used in digital photograph processing because, under positive situations, it preserves edges whilst casting off noise, also having applications in sign processing.

Median filtering is one type of smoothing technique, as is linear Gaussian filtering. All smoothing strategies are effective at doing away with noise in smooth patches or smooth regions of a sign, however adversely affect edges. regularly although, at the equal time as lowering the noise in a sign, it's miles critical to keep the edges. Edges are of essential importance to the visual look of photographs, for example. For small to slight degrees of Gaussian noise, the median filter is demonstrably better than Gaussian blur at removing noise even as retaining edges for a given, fixed window length.

But its overall performance isn't that a whole lot better than Gaussian blur for excessive ranges of noise, whereas, for speckle noise and salt-and-pepper noise (impulsive noise), it is specifically effective. because of this, median filtering may be very broadly utilized in virtual photograph processing.

The Median blur operation is much like other averaging methods. right here, the principal detail of the picture is replaced with the aid of the median of all of the pixels within the kernel area. This operation approaches the edges while getting rid of the noise.

After color mask, the other pixels or noise may consist of values within the boundaries. In order to remove that apply median blur. Also, it removes the unwanted edges/ spikes if pixels near the pad. By this, a better outline of the obtained leg and pad segments is obtained.

4.4.3 THRESHOLDING

Thresholding is a type of image segmentation, in which limiting the pixels of an image to make the image less difficult to analyze. In thresholding, it converts an image from coloration or grayscale right into a binary photograph or complete-shade photograph, i.e., one that is truly black and white. That is typically done with a view to separate "item" or foreground pixels from historical past pixels to useful resource in photograph processing. The following figure shows the graphic model of thresholding.

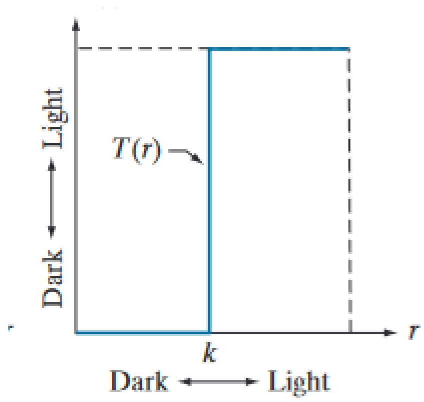

Fig.4.3 Thresholding

Where k is the threshold value below which every pixel is set to be 0 (Black) and above the threshold value is set as 255 (White). Thus, a binary or black and white image mask is obtained.

The blurred pixels or noise in the previous image can be removed by applying thresholding. Thresholding removes the weak pixels obtained from blurring and enhances the final image.

4.5 DECISION MAKING

Decision Making module is the last and important module in order to make decision based on intersection of detected ball from Ball detection module and detected pad from Pad detection module.

From ball detection module, the detection of ball is represented by bounding circle and from pad detection module, mask of the pad is obtained. The AND logic is used to find the intersection of detected ball and detected pad.

4.5.1 COLOR MASKING ON BALL DETECTION

The first step on finding intersection is applying color mask on ball detection. The bounding circles will be on radiant green color or the color not in the whole surrounding, and the color mask is applied to get the exact bounding circle's color. Thus, a mask of the bounding circle representing the edges of the ball.

4.5.2 FINDING INTERSECTION

Thus, the two masks representing the detected ball and pad. The masks are applied with pixel wise AND operation. Both the pixels in the pad's mask and ball's mask should be 255 or logic 1, so that the edges of the ball and pad intersects.

The resultant mask obtained on pixel wise AND logic, shows the intersection area. If there will be any pixel's value is 255 or logic 1, then there is intersection and returns out. Else, the decision making of next frame will be continued as discussed in 4.1 Flow chart.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 OPENCV

OpenCV (Open-Source Computer Vision Library) is an open-source computer vision and machine learning software library. OpenCV-Python is a library of Python bindings designed to solve computer vision problems.

OpenCV-Python makes use of Numpy (Numerical Python), which is a highly optimized library for numerical operations with a MATLAB-style syntax. All the OpenCV array structures are converted to and from Numpy arrays

Tkinter is used to make use of GUI (Graphical User Interfaces) to show Out or Not Out through a window. Tkinter allows us to create a GUI window and create an application using Python.

5.1.1 RESULTS OF FRAME SEGMENTATION AND CROPPING

Fig.5.1 Cropped image

The particular segment of video is provided as the input to this module and this module extract the frames. The frames will be cropped focusing the ball and the pad of the batsman removing the unwanted objects into the frame/image and stored one by one.

As frame segmentation and cropping, extracts the frames from the input video, crops and stores in the specified location as shown in the Fig. Frames stored in a specified location

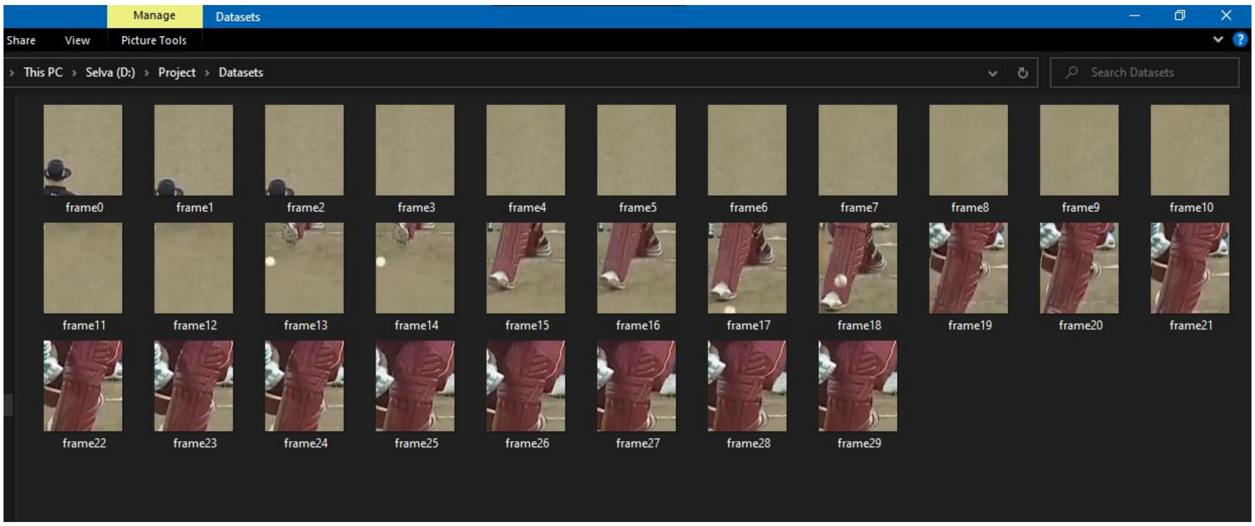

Fig.5.2 Frames stored in a specified location

5.1.2 RESULTS OF BALL DETECTION

Fig.5.3 Ball Detection

The Fig 5.3 shows the result of Ball detection. A green color bounding circle over the detected ball of thickness 2 - 3 pixels is used to represent the circle enclosing. Based on the accuracy requirement the thickness can be varied.

In order avoid unnecessary detection of small or larger circles, it can also select the detected circles based on their radius. In this case, the radius of the ball varies from 5 to 10 pixels. So, it allowed to detect the circles with pixel radius of only 5 to 10 to make sure of ball detection and removing other circle detections.

This ball detection output is given to the Decision-making module for further process.

5.1.3 RESULTS OF PAD DETECTION

Fig.5.4 Color Mask

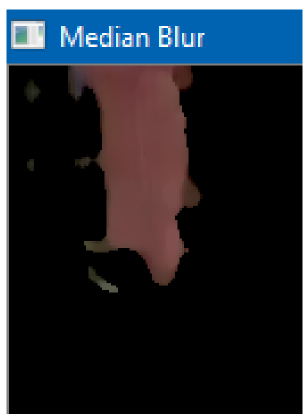

Fig.5.5 Blurred image

Fig.5.6 Final Image

Fig. 5.4 shows the result after applying color mask. In this result, the pad is detected and some noises and pixels of same values is added. The other pixels/regions are set to black.

Fig.5.5 shows the result after applying median blur. The noises were removed and the edges of the pad was enhanced further.

Fig.5.6 shows the final result of pad detection. Thresholding is applied in-order to get the exact outline of pad after blurring.

5.1.4 RESULTS OF DECISION MAKING

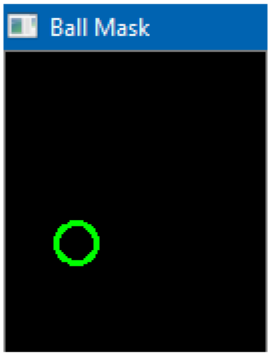

Fig.5.7 Ball Mask

As shown in the Fig 5.7, a mask representing the edges of the ball represented by green bounding circle of thickness 2 pixel used. This mask will be made with pixel wise AND logic with the detected pad mask.

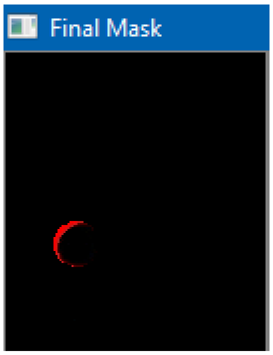

Fig. 5.8 Final Mask

The final mask in Fig.5.8 represents the intersection of the detected ball and pad. The final mask will be checked pixel by pixel to find whether there is any intersection represented by the pixel value 255.

```
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 255 255
 255 255 255 255 255   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 255 255 255
 255 255 255 255 255 255 255   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0 255 255 255 255 255   0
   0   0   0   0   0 255 255 255 255   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0 255 255 255 255   0   0   0
   0   0   0   0   0   0   0 255 255 255   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0]
[  0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0 255 255 255   0   0   0   0   0
   0   0   0   0   0   0   0   0 255 255 255   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
```

Fig 5.9 Intersection Matrix

As shown in Fig 5.9 Intersection Matrix, the 255 represents the intersection of ball and pad and 0 represents there is no intersection. Based on this, the final decision will be made.

5.2 FINAL RESULT

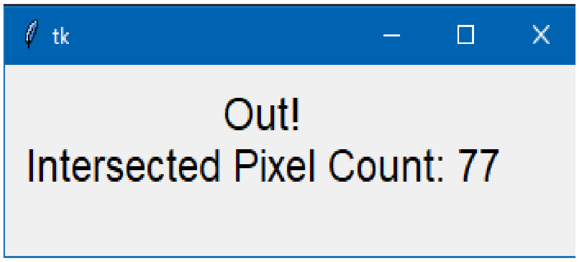

Fig.5.10 Out Decision Window

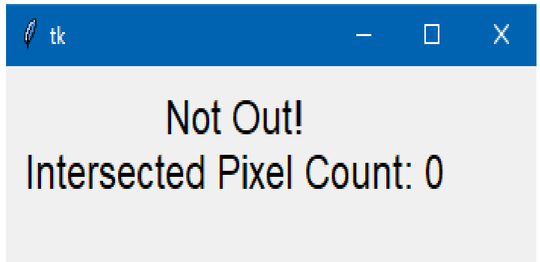

Fig.5.11 Not Out Decision Window

Final result will be shown in a separate window as Decision Window. If there is any pixel in the final mask of value 255, then it represents the intersection of ball and pad. So, it is given immediate Out and the intersected count of the pixels will be displayed as shown in Fig.5.10 Out Decision Window.

If there is no intersection till the last frame of the video, it represents there is no intersection of ball and pad throughout the video segment. So, it is given Not Out with intersected pixel count as shown in Fig. 5.11 Not Out Decision Window.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

CONCLUSION:

The proposed Automatic LBW Decision making system overcomes the drawbacks in the existing method. This method provides more accurate decisions on finding the intersection of ball and pad. It is reliable and fast compared to other methods. The proposed method takes 1 to 5 seconds to make decision and it is cost effective. Automation in decision-making provides un-biased results and makes constant evaluation. This method can be included in automatic scoring board system as well.

FUTURE SCOPE:

Some resources like Snick-o-meter readings can also be included in decision-making to provide clear justification on the decision. This method can also be improved by providing videos of different viewpoints notably front view and anyone of the side view to make more accurate and reliable results/decisions. Depending on the video quality and frames per second, the accuracy can be improved drastically.

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