Introduction

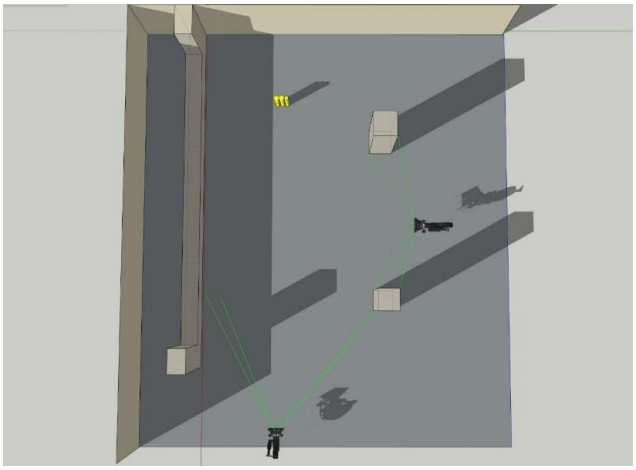
Leg Before Wicket (LBW) is one of the ways in which the batsmen can be dismissed in cricket and has been a subject of controversy historically as there was a death of proper technology. At present, a computer vision technology termed “The Hawk-Eye System” is used to predict the trajectory of the ball and helps in decision making concerning LBWs. Here, we seek to implement an LBW prediction system by predicting the path of the ball towards the stumps from the frames of a video. We first pursue object tracking using simple digital image processing methodologies and then use certain python libraries and fundamental concepts of physics to predict the path of the cricket ball onto the stumps. This methodology has been found to work quite well in our local setting and has given us very favorable results.

Objective/Aim

In this project, the aim is to predict the trajectory of the ball and conclude whether an LBW (leg before wicket) has occurred using this predicted path. For this, we first have to detect the object(in this case a red cricket ball) and isolate it from the background by some means. Then, we find an appropriate way to characterize the center of the ball for usage in the last step. The last step involves the path prediction algorithm which takes into consideration the array of centers of the ball at each time step and predicts the trajectory for future time steps.

Methodology and Results

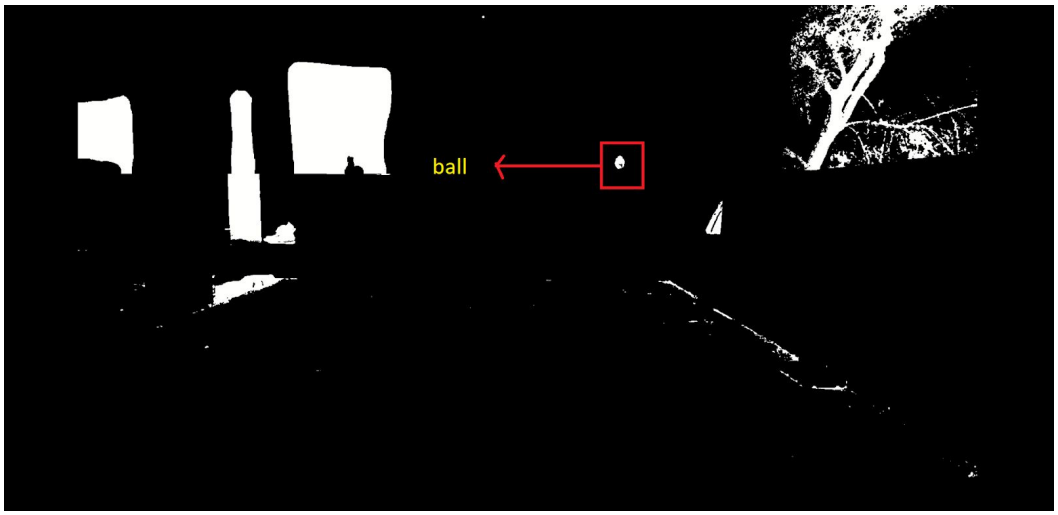
An appropriate database containing around twenty videos of the ball being bowled towards the stumps is taken. These are videos taken by us in a local setting keeping in mind the contrast, brightness, frames per second (fps), etc. The implementation can be broadly categorized into three stages. In all these stages we shall present an example of a single frame to be worked upon and see the results side by side along with the methodology. The frame we have taken is given below along with the camera setup:



First Stage

Here, we deal with detection of the ball frame by frame. The steps are as follows:

- Convert the RGB image into grayscale for ease of detection in later steps
- Using the grayscale image I have used the binary inverse thresholding function to convert any pixel having an intensity of less than 70 (on a 255 scale) to white (or intensity value of 255) and anything having an intensity of more than 70 to black (or intensity value of 0).
- Since the ball is of dark red colour the grayscale image would lend it an intensity value closer to 0 than to 255. So, when we apply thresholding, the black colour of the ball changes to white in the output. The relatively lighter colour of the background is thresholded to an intensity value of 0 (black)

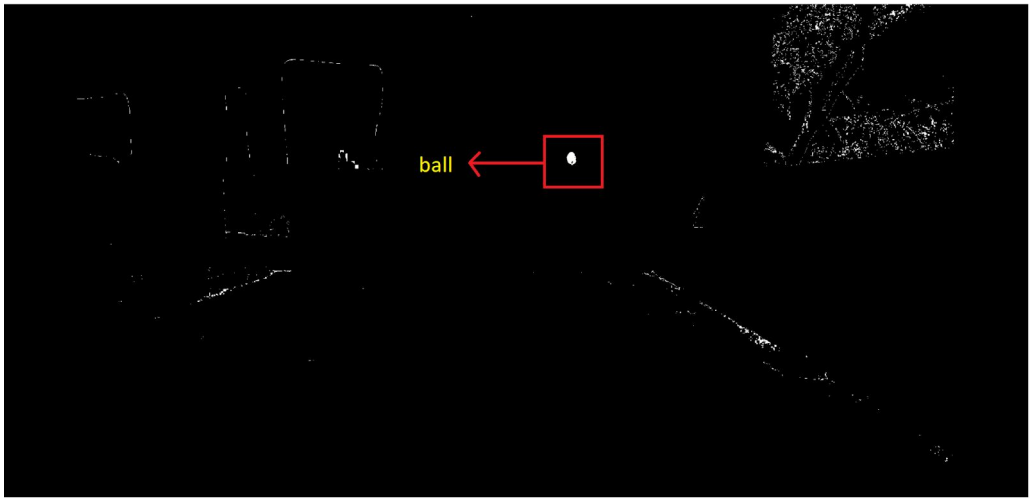


Second stage

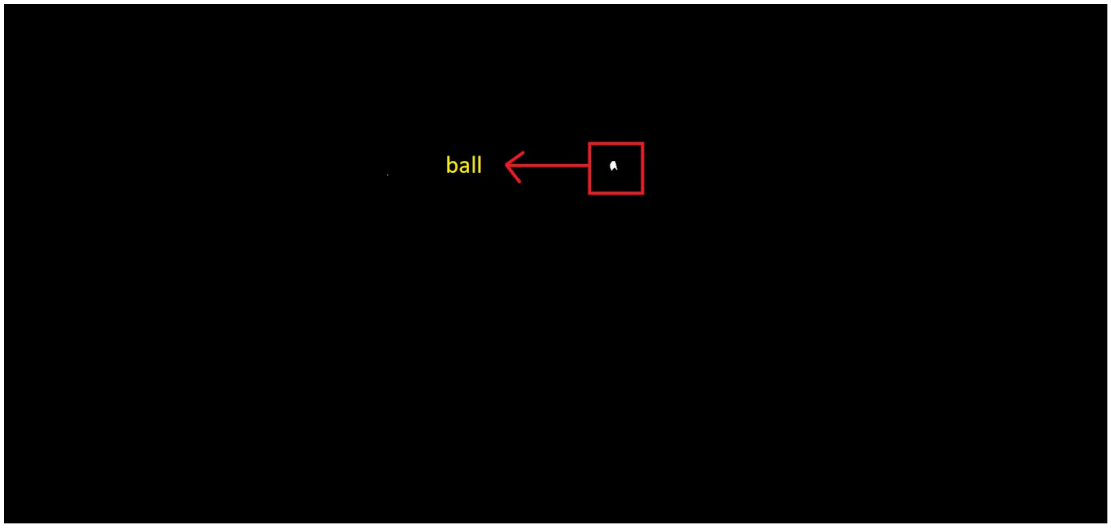
- In the thresholding operation, I found that many background elements have also been set to white indicating that we need some kind of motion-based elimination method by which the ball is identified while the rest of the background entities are removed
- For this, we employ a pixel-based operation where the pixels from the very first frame are compared to the pixels in the current frame based on the truth table below

f_o	f_i	f_i'
0	0	0
0	1	1
1	0	0
1	1	0

- f0 - the first frame, fi - the current frame, and fi' - resultant for whether there is an object in motion or not.
- Therefore, if by this algorithm, the pixel is judged to not be a part of a moving object, then its intensity is set to 0 (black)
- The image after this operation is shown below:



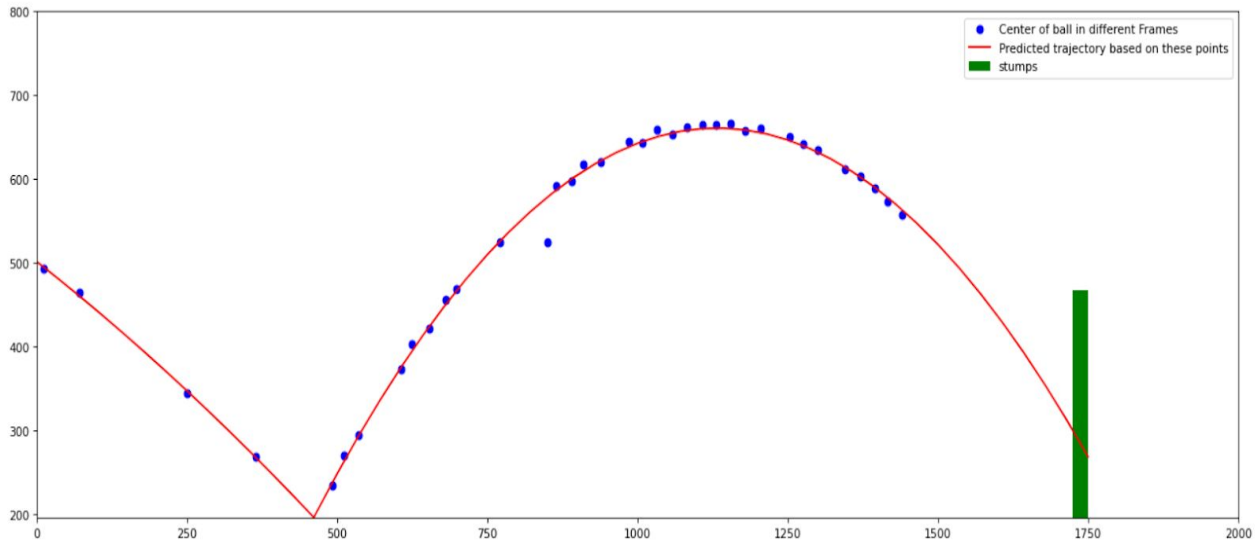
- We can still see some small white pixel components coming from the background elements as these may have moved a bit during the previous operation
- This is characterized as salt noise and we can proceed to remove it by using the median filtering technique with a filter size of 5x5
- Then we use OpenCV methods to find contours in the frame. Contours represent a curve joining the continuous points along the boundary, having the same color or intensity of pixels
- The result of the previous two steps are shown below:



- Some of the edge details of the ball are lost due to the median filtering step but the center part of the ball still remains intact.
- We then need the co-ordinate information about the ball for use in the third stage. We get a very good approximation of the center of the ball by taking the center of mass of the white pixels as follows: $x\_com = \frac{\sum(\text{distance of } i^{th} \text{ white pixels along } x)}{\text{total white pixels}}$ $y\_com = \frac{\sum(\text{distance of } i^{th} \text{ white pixels along } y)}{\text{total white pixels}}$

Third Stage

- In this stage, we hope to predict the path of the ball by approximating it to that of a polynomial of degree two. Newton's equations have hinted that projectile motions such as these can be characterized by second-degree polynomial equations so this approximation is very close to the true path.
- We have used python libraries such as NumPy and matplotlib to plot the positions of the ball at each frame and then predict the trajectory.
- The program takes in the listen of coordinates of the center of masses as calculated in the previous stage for each frame. A second-degree polynomial curve is made to fit these points by optimizing for minimum least square error and thus gives us the result as shown below (The labels for the different parts of the graph are given on the top-right):



- We can see that even after the blue dots, the path is predicted.

Discussion and Conclusion

We have done the above procedure with 20 different videos and have achieved favorable results. The techniques implemented in the project involve digital image processing methods. Some ways in which this method may not work and improvement is needed are:

- There may be some outliers or noisy points when we start detecting the centers of the ball in each frame and this may cause minor disturbances
- A camera with high frames per second (fps) capturing capability is preferred as we would want to capture the fast-moving ball. (In the above results a phone camera was used. Nevertheless, we achieved favorable results)
- Dark moving objects in the background may be mistaken to be the ball and the results will not pan out as expected

In conclusion, we have built a program that does well as long as some conditions are taken care of. More advanced works have been carried out in the field which give very good results and are being used in cricket matches today.

References

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