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Image Processing Techniques: Application on Penalties taken in Football

[1]Tushar Sharma, [2]Ambarish Ravindran, [3]Prashanth Rajaram

[1, 2, 3] B.Tech Students
[1, 2, 3] Department of Computer Science and Engineering, Amrita Vishwa Vidhyapeetham, Bangalore, India

***Abstract*: The objective of the prediction system is to identify exactly where the shooter is going to kick the ball while taking a penalty, right before he actually does so. This involves close analysis of the player's features and characteristic behaviour that he portrays in the seconds prior to the actual kicking. Computers can derive different predictions based on machine learning techniques such as neural networks and fuzzy logic which will be seen as we proceed. In this proposed project, we analyze videos of particular players by first extracting frames and then, performing operations on them. We draw out features such as angle of leg movement, trajectory of path, etc. and train our system in detecting these aspects. After these features have been appropriately drawn out, the system makes a decision on which direction the player is going to shoot based on certain rules (fuzzy logic) that have been assigned based on behaviour. We shall also see in the sections below, the different ways each feature has been extracted.**

***Keywords:* Feature Analysis, Frame Extraction, Fuzzy Inference Systems, Machine Learning.**

I. INTRODUCTION

The Football Penalty Shootout Prediction System is a project that is aimed at creating a significant impact in the sports world, the game of football, in particular. The project is mainly focused on guiding the goalkeeper of a football game to help improve his performance, that is, to help him save as many goals as possible. The simulation tool is a great aid that helps the goalkeeper practice, well ahead of the game, and can therefore form an essential part of strategizing his game. The analysis provided by the system helps to identify the direction in which the shooter (of the football) will be kicking the ball. This helps the goalkeeper prepare himself to the direction of the kick and this is of major importance to the goalkeeper as he has to save the goal.

As most part of the project revolves around analysis and prediction of the direction of the kick in a football game, the project is mainly attributed to work in a football penalty shootout scene. However, as the broader idea involves analysis of distances and trajectory, the project can be easily extended to be compatible for analysis of features in many other sports.

In a game of football, the penalty is one of the major components that can have a significant impact on the game. The impact is so significant, that it can turn the game on its head, and can decide which team will eventually take home the trophy. On careful analysis, it is observed that the probability that the ball will reach the goal is a mere chance of 50-50, which is a mundane probability that it will either go left or right with equal chance. This is one of the major points of focus in the project. The project aims to increase this probability significantly in one of the two directions that is either left or right thus asserting with accuracy where the shooter is going to kick the ball. The project has been a manifestation of significant efforts by our team who are all focused to help one of the actors of the football scene, the goalkeeper. Our simulation system proves to be a tool to help the goalkeeper make better decisions about his movement when the ball approaches him, thus saving the goal, and in consequence, helping his team taste victory. This system, when used by the goalkeeper, could, as promised before, turn the game on its head.

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II. SCOPE

The Football Penalty Shootout Prediction System is mainly focused on acting as an aid to help the goalkeeper of a football game. However, the analysis and the processes involved can be of a broader use and can help permeate through a wider range of sports. The prediction system gives as output, the direction of the kick of the shooter.

Thus, in a penalty scene in a football match, this system helps the goalkeeper decide where the shooter is going to kick prior to his kicking the ball. The scope of the project is clearly confined to the football penalty scene but the methods and the processes used can be of great aid to extend this to other sports as well.

III. RELATED WORK

Motion recognition of soccer players in a video scene is essential for analysis [1]. The inherent motion of a moving character's arms and legs and neighbouring position of the object, such as a ball, closely influences the motion of the soccer player.

It is important choose the features for recognizing a player's motion by human knowledge and describe correlation between objects. They propose an approach to motion recognition by statistical weights [2]. Knowing the locations of players and the ball in a ground field is the key for soccer game analysis [3]. Given an image sequence, the authors may address three main problems

1) Ground field extraction,

2) Player and ball tracking and team identification and

3) Player positioning.

Sports video analysis has received special attention from researchers due to its high popularity and general interest on semantic analysis [4]. Hence, soccer videos represent an interesting field for research allowing many types of applications: indexing, summarization, players' behaviour recognition and so forth. It is essential to provide a hierarchy and classify approaches into this hierarchy based on their analysis level, i.e., low, middle, and high levels. Automatic summarization generation of sports video content has been object of great interest for many years.

Most of the work that has been done on the field of sports videos is too specific to finding only certain characteristics of the videos without necessarily taking into account the final applications of these approaches. So far, little work has been done to practically apply these features to make useful conclusions from actual sports videos. Our approach does precisely this. It is a manifestation of a number of approaches and ultimately applies these techniques to make accurate predictions. This unique feature of application of methods to elicit results in a real time scenario is what sets the work apart from the rest.

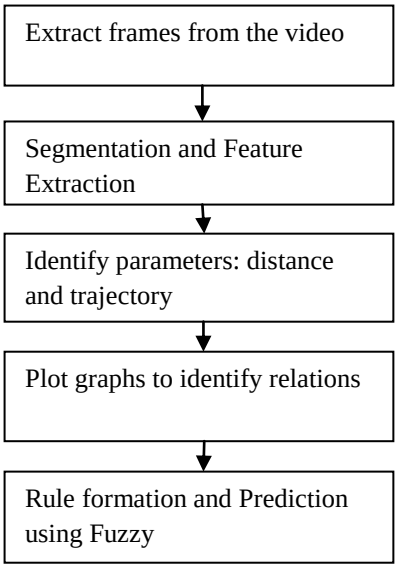

Fig. 1: Proposed Model

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IV. PROPOSED MODEL

The proposed model as described above follows a procedural approach and the sequence of steps have been carried out as represented. The system takes in as input football videos that have to be provided by the end-user. These videos involve a shooter kicking the ball towards the left, right or to the centre of the goal. This would be analyzed and the output would be provided before the shooter kicks the ball. The major portions of the analysis are done before the shooter kicks the ball as this is the aim of the system. Once the football videos are input by the user, it is necessary to extract separate frames from these videos. This frame extraction code involves identifying individual frames from the video, extraction based on certain parameters, and finally storing these individual frames onto a folder. During the process of frame extraction, segmentation and feature enhancement also take place. This is performed to mainly remove any noises that could be present in the frames thus obtaining clearer frames for further analysis. The feature enhancement techniques used in our project are erosion and dilation. On obtaining clearer frames, we then perform the critical step of feature extraction which involves extracting two important features namely- Trajectory and the distance between the legs (angle). On obtaining these parameters, separate graphs for each feature is plotted to make further analysis. These graphs prove to be extremely useful to make certain conclusions about the direction of the kick. Once these graphs are plotted, we identified the variations between the points on the graph. Taking this into consideration, we then used the FIS (Fuzzy Inference System) which is a Mat lab tool, to form rules. These rules form the basis for concluding whether the shooter kicks the ball towards the right, left or centre. The final step involves the prediction, which is done with the help of the defined rules and the output is accordingly presented to the user.

A. Frame Extraction from Football Videos:

A video or movie frame is a single picture or still shot, that is shown as part of a larger video or movie. Many single pictures are run in succession to produce what appears to be a seamless piece of film or videotape. Each frame can be selected on its own to print out a single photograph.

Several methods use automatic key-frame extraction for the purpose of developing computerized algorithms. A visual storyboard is the simplest and the most common method as a video surrogate. The technique uses automatic detection of shot changes and automatic extraction of key frames at each shot (fade in and out, dissolve, wipe, etc.). This method prevails in the Internet environment primarily due to both its cost-efficiency and easy implementation.

The shot detection based key-frame selection may contain redundancies because similar content may exist in several shots; In order to decrease the redundancy, we can group shots into logical scenes, and then select a key-frame for each scene. However, video programs have no strict boundaries of logical scenes. Therefore, automatically segmenting a video into such higher-level units will always be difficult. This is one of the reasons why we chose to use all the extracted, available frames for further processing and relevant analysis. These frames are then converted accordingly from colour RGB images to gray scale and then the intensity image is converted to a binary image by computing a global threshold value for each image.

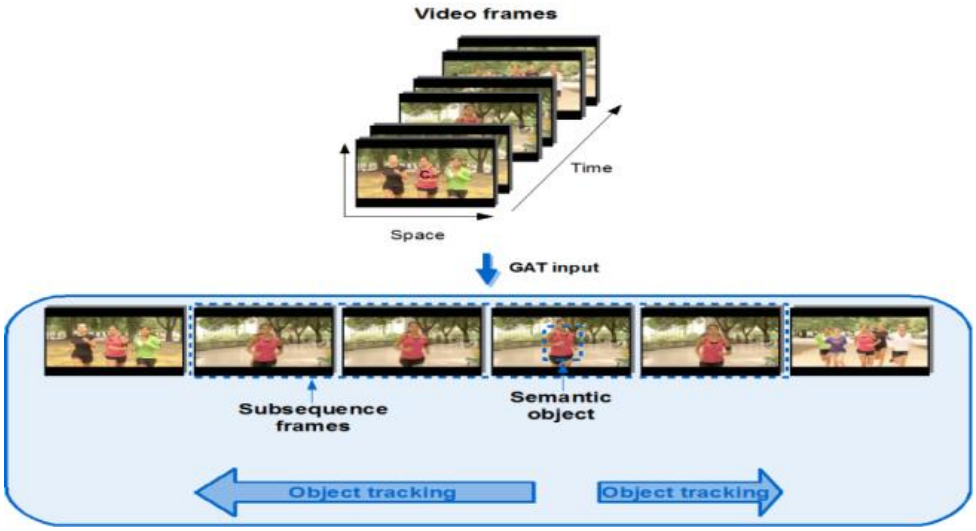

Fig. 2: Frame Extraction

B. Segmentation:

Image segmentation is the process of dividing an image into multiple parts. This is typically used to identify objects or other relevant information in digital images. There are many different ways to perform image segmentation, including: Thresholding methods such as Otsu's Method, Colour-based Segmentation such as K-means clustering, Transform methods such as watershed segmentation. An effective approach to performing image segmentation includes using algorithms, tools, and a comprehensive environment for data analysis, visualization, and algorithm development. In this paper, we will discuss Otsu's Method of thresholding and its relevant applications to our work. Otsu's method of thresholding automatically performs clustering-based image thresholding, or, the reduction of a gray level image to a binary image. The algorithm assumes that the image contains two classes of pixels following bi-modal histogram (foreground pixels and background pixels), it then calculates the optimum threshold separating the two classes so that their combined spread (intra-class variance) is minimal, or equivalently (because the sum of pair wise squared distances is constant), so that their inter-class variance is maximal. Accordingly, we have used Otsu's method to perform segmentation to our video frames. On performing the process of segmentation, we observe the contrast between the foreground and the background. This contrast helps us to identify the distinct features that separate the two layers and helps obtain the specific characteristics that are required for further analysis. Here, the shooter of the football and his movement towards kicking the ball are of major importance and the rest of the image is not required for further analysis. Thus, the time between the shooter's initial movement towards the football and the point of contact between the shooter's leg and the ball is the main source of interest and all other features are considered noise and removed. The segmentation mainly focuses on extracting the shooter of the goal and the relevant features associated with him as only these are required for further analysis.

Fig. 3: Frame after performing segmentation for a shooter kicking the football right

Fig. 4: Frame after performing segmentation for a shooter kicking the football left

C. Frame enhancement:

Frame enhancement is a technique widely used in image processing to make frames derived from videos more 'clear' and easy to interpret by removing noise and unnecessary details from the image. We use frame enhancement in our product to make sure the images are clear and sharp before further analysis can take place.

Frame enhancement uses many techniques, two of which are –

• Erosion - Erosion is one of two fundamental operations (the other being dilation) in morphological image processing from which all other morphological operations are based. It was originally defined for binary images, later being extended to gray scale images, and subsequently to complete lattices. It is used mainly to remove noisy data that could exist as speckles or white dots in the background of an image which reduces clarity. Erosion works in the following way –

1. It takes two pieces of data as inputs, first is the image to be eroded and next is a structuring element, which is a small set of coordinate points.
2. Suppose that X is the set of Euclidean coordinates corresponding to the input binary image, and that K is the set of coordinates for the structuring element.
3. Let K_x denote the translation of K so that its origin is at x.
4. Then the erosion of X by K is simply the set of all points x such that K_x is a subset of X.

It erodes the boundaries of inner regions and makes small holes bigger, thus completely removing the noise.

• Dilation - Dilation is one of the basic operations in mathematical morphology. Originally developed for binary images, it has been expanded first to gray scale images, and then to complete lattices. The dilation operation usually uses a structuring element for probing and expanding the shapes contained in the input image. It is used to remove or 'smoothen' the noise that is created in the object of an image. Any white speckles present in objects are smoothed over by overlapping the nearby pixels over it.

Dilation works in the following way -

1. It takes two pieces of data as inputs, first is the image to be eroded and next is a structuring element, which is a small set of coordinate points.
2. Suppose that X is the set of Euclidean coordinates corresponding to the input binary image, and that K is the set of coordinates for the structuring element.
3. Let K_x denote the translation of K so that its origin is at x.
4. Then the dilation of X by K is simply the set of all points x such that the intersection of K_x with X is non-empty.

D. Feature Extraction:

In machine learning, pattern recognition and in image processing, feature extraction starts from an initial set of measured data and builds derived values (features) intended to be informative, non-redundant, facilitating the subsequent learning and generalization steps, in some cases leading to better human interpretations. Feature extraction is related to dimensionality reduction. Dimensionality reduction is a linear, discriminative, supervised technique for reducing feature vectors extracted from image data to a lower-dimensional representation [6]. When the input data to an algorithm is too large to be processed and it is suspected to be redundant (e.g. the same measurement in both feet and meters, or the repetitiveness of images presented as pixels), then it can be transformed into a reduced set of features (also named features vector). This process is called feature extraction. The extracted features are expected to contain the relevant information from the input data, so that the desired task can be performed by using this reduced representation instead of the complete initial data. We use feature extraction in our project to extract –

• Trajectory of the player before he kicks the ball - Each player shows a characteristic 'way' of running when he kicks in a certain direction and we have capitalized on analysis of that. The way a player runs betrays where he is going to exactly kick the ball. Analysis of the way he runs over a certain period of time gives rise to patterns. Recording and overlapping of the patterns gives rise to a distinct structure for each variation [5].

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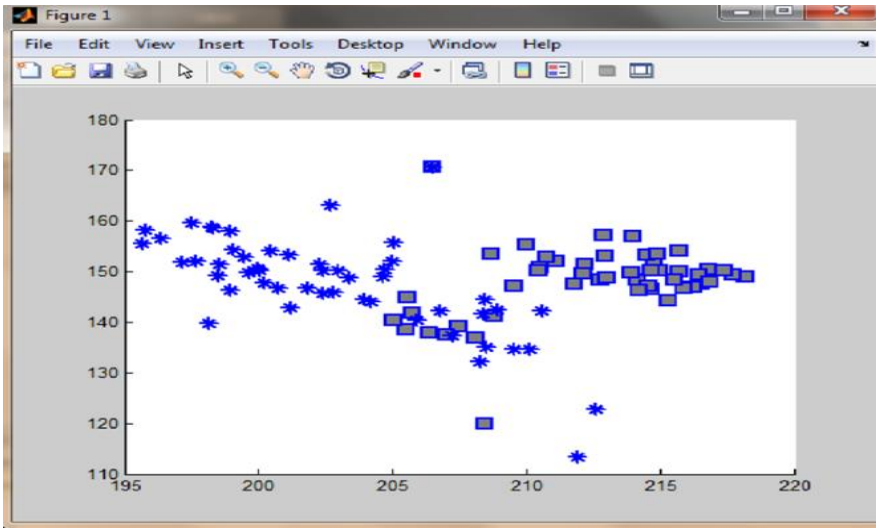

Fig. 5: System results - Graph showing that difference between trajectory of a person kicking left and right

In the graph, there is a distinct difference between the trajectories of a person kicking left (star) and a person kicking right (square). Each player follows a different trend in trajectory is can be used in a large way to pick where the person is going to kick the ball.

• Angle between the legs when he stretches to kick the ball.

The system can make an accurate prediction of where the ball will be kicked based on this feature.Distance is directly proportional to angle; hence distance could as well be used to make an accurate prediction of where the ball is going to be kicked. It should be noted that in this particular feature, there is a large amount of difference in angle between legs when a person is left legged or right legged. Our system takes that into account as well and makes a prediction.A left legged person kicking left and a right legged person kicking right have very less distance between their legs as their legs cross over. Hence their distance is taken to be very low. Similarly, a left legged person kicking left and a right legged person kicking right will have a much wider angle between their legs as they are more spread.

We have taken into consideration two scenarios.

First scenario has a left legged person kicking right and a right legged person kicking left.

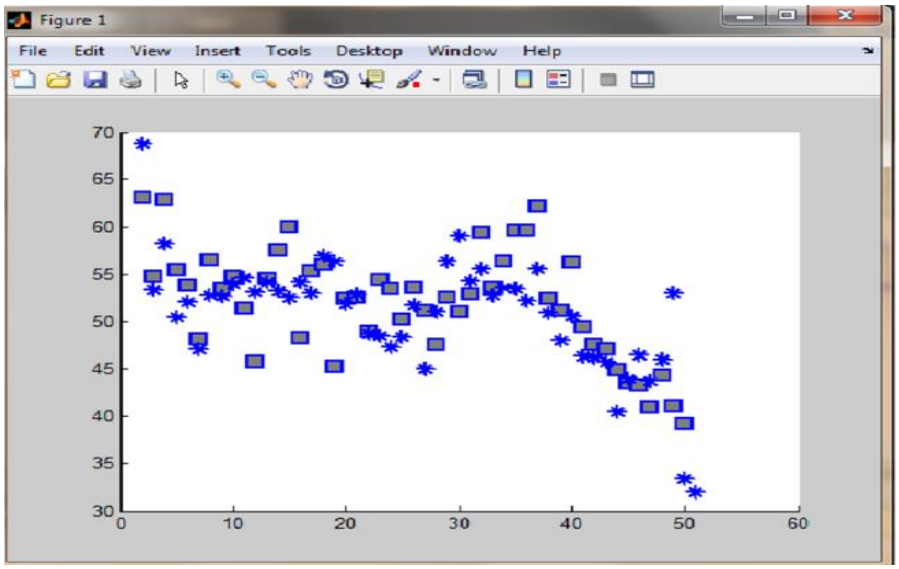

Fig. 6: System results: Star – person kicking left; square – person kicking right

We can see that the graph is pretty uniformly distributed as frames (x-axis) move ahead. In our second scenario, we analyze a situation where a right legged player kicks left and right.

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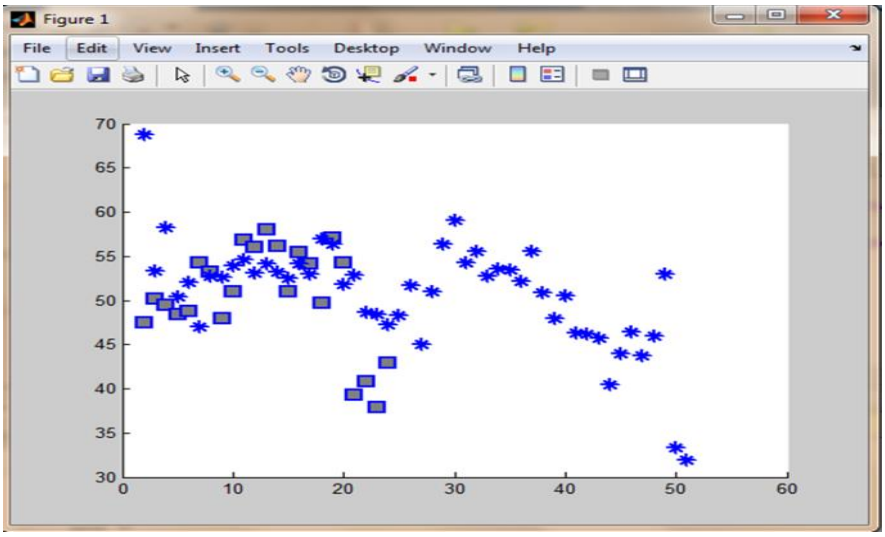

Fig. 7: Star – player kicking right; square – player kicking left.

We can see that when a right legged player kicks left, his legs cross over and angle reduces which our system detects and there's a clear difference between the two cases in this scenario.

E. Fuzzy Inference System:

Fuzzy inference is a computer model based on fuzzy set theory, fuzzy if-then-rules and fuzzy reasoning. Fuzzy Inference System (FIS) is a way of mapping an input space to an output space using fuzzy logic, here the input space is the crisp set and the output space is the fuzzy set. Fuzzy if-then rules or fuzzy conditional statements are expressions of the form

IF A THEN B, where A and B are labels of fuzzy sets.

The antecedent describes to what degree the rule applies, while the conclusion assigns a fuzzy function to each of one or more output variables. The set of rules in a fuzzy expert system is known as knowledge base. [7]

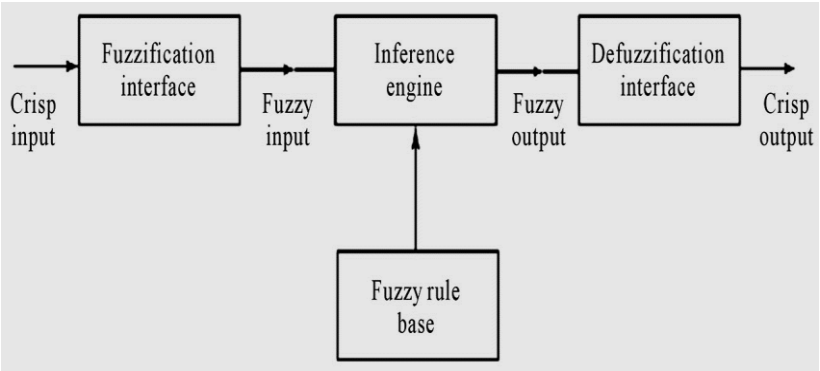

Fig. 8: Block Diagram of FIS

The crisp input is given to the fuzzification interface, here the truth value of each rule is determined and resolves to a degree between 0 to 1.In the inference engine the Truth value for the each rule is computed and applied to the conclusion part of each rule. This results in one fuzzy set to be assigned to each output variable for each rule. The implication function then modifies that fuzzy set to the degree specified by the antecedent. Clipping is commonly used for inferencing rules. Later the aggregation of outputs takes place using maximum operator. On the aggregated output the defuzzification method will be applied to get back the crisp output.In the proposed system FIS is used as a classifier, the extracted features are used as the inputs. Here the features used are the trajectory of the player and the average distance between player's legs. Here the membership function used for the inputs (trajectory and average distance) and output (decision) is the Gaussian function. This is used because the Mean Average Percentage Error was less for Gaussian function when compared to the other functions. The standard deviation of the features for individual events (say left and right) is taken and is given as Gaussian function. Based on the brute force the rules were formed and the accuracy of each rule is determined on the given template videos and the high accuracy rules are used for the system's rule base.

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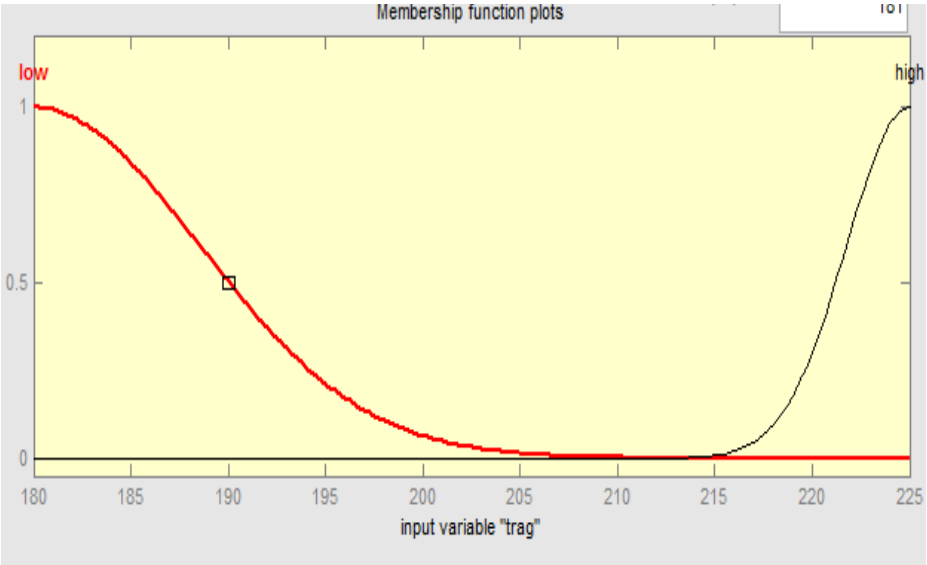

Fig. 9: Input of FIS

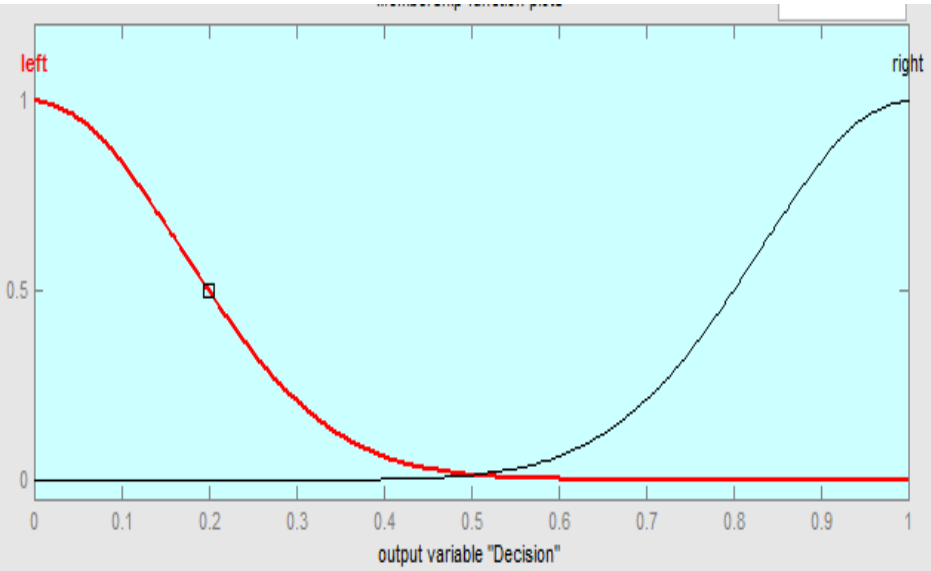

Fig. 10: Output of FIS

The processing system processes the video and gives the average of the individual features, later this is fed to the FIS and based on the rule base the output will be determined. The accuracy of the system was 60% for the given rules.

V. CONCLUSION

In this paper, we use image processing and fuzzy inference systems to device a tool that can aid a goalkeeper to identify the direction in which the shooter of the football will be kicking. Using various image processing tools and In-built functions of MATLAB, we were able to design the system up to expectations to produce the desired results.The parameters that we have used are the trajectory and the distance between the legs and we used these parameters for analyses of the video frames that we extracted. Using these parameters, we were able to identify the various characteristics that define whether the shooter is going to kick the ball in the left direction, or right, or centre.Finally, after obtaining the individual frames and the specific parameters that differentiate videos that determine whether the shooter is kicking in the left or right direction, we used the fuzzy inference system to define rules based on these parameters. Hence, depending on the rules defined, the fuzzy system predicts the direction of the kick and this is our ultimate output.Thus, this simulations system can be used accordingly by the goalkeeper to make predictions and prepare him before a football game. This is majorly advantageous to the goalkeeper as his main aim is to stop the ball from reaching the goal.

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