

LBW Dismissal Umpire Decision Prediction CAPTCHA using Backwards Induction & Rational Game Theory (Umpire's Call CAPTCHA)

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Abstract— A CAPTCHA (Completely Automated Public Turing test to Tell Computers and Humans Apart) should be as convenient as easy for human and almost impossible for bots. User should not be irritated by solving AI problems; it must be very easy going with fun. Proposed system is able to serve hard AI problem that can be easily solved by human but almost impossible for bots. This system is based on umpire's call where user is to take decision as a cricket umpire whether batsman is out or not. It has been reviewed that cricket LBW trajectory can only be more precise with hawk eye cameras that mount over the roof of cricket stadium. Even hawk eye trajectory cannot be applied in image processing if a normal camera's coordinates have been captured. It can be done at real time when co-ordinates have been attained from hawk eye and projected at that time. Cricket ball trajectory requires ball speed, angle, position and path; that can only possible with high speed camera. A normal camera is not able to identify the speed of the ball and some co-ordinates also.

Keywords— CAPTCHA, Web Security, DRS, Cricket, LBW, Hawk eye, Camera, Game Theory.

I. INTRODUCTION

Leg before wicket (LBW) is one of the ways in which a batsman can be dismissed in the sport of cricket. Following an appeal by the fielding side, the umpire may rule a batter out LBW if the ball would have struck the wicket, but was instead intercepted by any part of the batter's body (except the hand holding the bat). The umpire's decision will depend on a number of criteria, including where the ball pitched,

whether the ball hit in line with the wickets, and whether the batter was attempting to hit the ball [1].

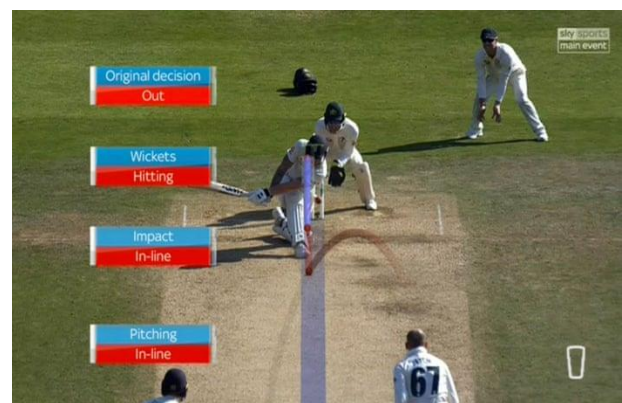


Fig. 1 LBW Dismissal Trajectory [2]

Leg before wicket first appeared in the laws of cricket in 1774, as batsmen began to use their pads to prevent the ball hitting their wicket. Over several years, refinements were made to clarify where the ball should pitch and to remove the element of interpreting the batsman's intentions. The 1839 version of the law used a wording that remained in place for nearly 100 years. However, from the latter part of the 19th century, batsmen became increasingly expert at "pad-play" to reduce the risk of their dismissal. Following a number of failed proposals for reform, in 1935 the law was expanded, such that batsmen could be dismissed LBW even

if the ball pitched outside the line of off stump. Critics felt this change made the game unattractive as it encouraged negative tactics at the expense of leg spin bowling [1].LBW is a pretty weird concept, an almost philosophical method of dismissal. It involves the element of conjecture, a leap of faith, a stroll down the road not taken, a counterfactual reading of what would have happened, but didn't. Even Hawk-Eye's ball-tracking technology, which we like to tell ourselves is a faithful, infallible projection of truth, is really just a best guess. There's nothing to say the ball wouldn't have swung, or dipped, or been caught by a sudden gust of wind, before hitting the stumps [3]. LBW dismissal is very common among in all generations; they knew some common criteria which have been followed for dismissal. Before getting the rules, we should understand the pitch architecture.

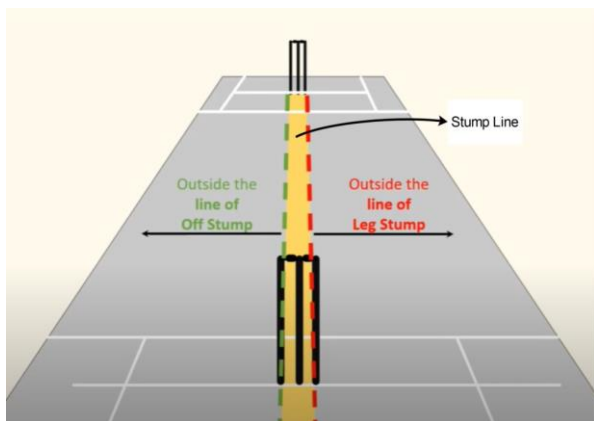


Fig. 2 Pitch Overview [4]

Fig. 2 shows the pitch architecture where yellow bar shows the stumps line between wicket to wicket, green line shows the off stump line and red line shows the leg stump line.

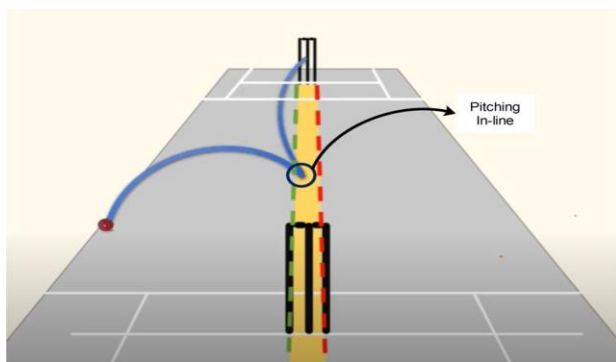


Fig. 3 Pitching [4]

Table I Impact Rules

		Striker's attempt to play stroke	
		Genuine	Not Genuine
Impact	In the Stumps Line	Out	Out
	Outside of off stump line	Not out	Out
	Outside of leg stump line	Not out	Not out

LBW dismissal is not so confusing at all for human but it's very complicated for system to project the actual trajectory by computing its actual speed and angle by normal camera rather than hawk eyes. Hawk eyes can acquire the frames at 340 frames per second whereas normal camera acquires 30 frames per second. Normal camera is not able to calculate the actual speed of the ball because of slower frame rate and if speed is not to be calculated the angle will not be assumed that it will hit the stump or not. It's better to predict either by human or hawk eyes. Hawk eye is owned by Sony Company and they charge millions of dollar for mounting their camera in an international cricket match. So, no tactics can be applied for actual assumption even by image processing. The term CAPTCHA (Completely Automated Public Turing Test To Tell Computers and Humans Apart) was coined in 2000 by Luis von Ahn, Manuel Blum, Nicholas Hopper and John Langford of Carnegie Mellon University. A CAPTCHA is a program that protects websites against bots by generating and grading tests that humans can pass but current computer programs cannot. For example, it has been consider that humans can read distorted text as the one shown below, but current computer programs can't [6].



Fig.4 Conventional CAPTCHA [6]

II. RELATED WORKS

Tao Zhang et al. [11] analyzes the characteristics of simple segmentation CAPTCHA and indivisible verification code, and puts forward the CAPTCHA recognition algorithm based on convolution neural network. It designs the training network structure for different CAPTCHA and makes full use of the self-learning characteristics of convolution neural network, simplifies the traditional CAPTCHA recognition in the character segmentation, de-noising another human intervention, making the training network model itself has anti-noise, anti-rotation and other excellent features. And finally can reach the correct rate of 90 or so, recursive neural network. This system is based on character recognition that is designed with auto-generated strings along with self-learning feature for segmentation and verification. But character recognition based CAPTCHA can be manipulated by some image processing tools and machine learning approaches. This paper reported our investigation of using visual reasoning in the CAPTCHA design. Haipeng Wang et al. [12] proposed a CAPTCHA where it is required for users to locate particular object(s) in an image according to the requirement of a text query. Author uses synthetic images with 3D shapes (e.g., geometric shapes, numbers, English letters, etc) for image

generation. The text queries involve many aspects of visual reasoning, such as object identification, comparison, spatial relationships, etc. Author has carried out both controlled and online experiments to ensure the usability of this design. A simulated attacking experiment was also conducted to verify the CAPTCHA security. In addition, we have tried neural style transfer to generate new images, and its effectiveness was also confirmed in the experiment. Jesudoss A. et al. [13] proposed a hard independent authentication scheme where user is required to input secret OTP (One Time Password). But author does not insist that the proposed work is superior to the popular Kerberos Protocol or SSL Protocol. There is no doubt that these popular protocols are far superior and beyond comparison. This work is not a replacement for these protocols but can be used as a pre-authentication module to produce fruitful results. This work may be further extended by including protection against SQL Injection attack and single-sign on feature. Yu Hu et al. [14] proposed a CAPTCHA which is based on convolutional neural network. According to the CAPTCHA of images character distortion and adhesion, and all characters in the image can be recognized without segmentation. Multi task joint training model is introduced to improve network learning rate and model generalization ability, and the network structure is modularized, which can recognize the different character length of the CAPTCHA image with slight modification. Experimental results show that the proposed method has a good recognition effect, and the recognition accuracy reaches to 96.5%. In the future work, Chinese characters CAPTCHAs recognition will be added. S.Ezhilarasi et al. [15] proposed a CAPTCHA which is based on image recognition user is required to identify the object over an image that is puzzled with noise. In this Decision-Making CAPTCHA where human interpretation resulted 85% of participants felt easy in solving the CAPTCHA and obtained success rate of 97% in login access. Background complexity is low. This system has explored the space of systematic distortions as a means of making automated image matching and recognition a very hard AI problem. Shotaro Usuzaki et al. [16] proposed a CAPTCHA scheme for resisting relay and automated attacks. In this CAPTCHA, the user tracks a target object from an randomly appearing decoy objects with his or her mouse cursor. This method focuses on delay time that occurs between the bot and the remote human-solvers during relay attack, which makes it difficult to successfully break the CAPTCHA. It is necessary to determine appropriate parameters to obfuscate our CAPTCHA while not affecting usability. Muhammad A. Shah et al. [17] proposed a CAPTCHA scheme that is based on voice recognition namely called vCAPTCHA. Author analyzed that speech-based vCAPTCHA system would more effectively secured web resources from bots while minimizing the inconvenience of legitimate, human, users. Author uses Pocketsphinx for speech recognition that is pre-built model where training is not performed manually. But Google voice recognizer is not getting more powerful and able to recognize various voice commands and voice based system is always considered as weak authentication protocol and not a trustworthy approach. Zhouhang Cheng et al. [18]

proposed an image based CAPTCHA that has been developed using Neural Style Transfer. In this study, author proposed Grid-CAPTCHA and Font-CAPTCHA, two types of novel image-based CAPTCHAs. Author demonstrates that the proposals meet both the usability and security measures for good CAPTCHA design. These proposed CAPTCHAs both provide challenges that are straight forward for humans to solve but remain difficult for machines. The results suggest that neural style transfer can clearly decrease the success rate of classification, localization, and recognition for machine attacks. In conclusion, when implementing neural style transfer on common CAPTCHAs, the difficulty in breaking the CAPTCHA for machines rises, while the difficulty for human remains the same. We hope this research provides a new meaning to neural style transfer and will also inspire more extensive and exciting works in this research area to promote the development of CAPTCHA. This technique offers a new direction in designing CAPTCHAs and increases security. Monther Aldwairi et al. [19] proposed flash based gaming CAPTCHA. The server presents the user with a client puzzle to solve in order to gain access to the service or website. The puzzle should be hard enough for computers, but easy for humans to solve. Several methods have been suggested including the popular image-based, as well as video-based, and text-based CAPTCHAs. In this paper, authors present a Flash-based gaming CAPTCHA to differentiate bots from humans. They propose a drag and drop client puzzle where the user will play a simple game to answer a visual question. This method turns out to be convenient, easy for users but not very much challenging for bots because author uses mini games where answer is just based on recognizing any object or dragging an object towards the target. Jamie Plenderleith et al. [20] proposed curious way to determine whether you're human or bot during a CAPTCHA test — by testing your understanding of physics. Jamie Plenderleith is an inventor of this CAPTCHA and filed a patent application for a new CAPTCHA method which would show you a 3D simulation of something about to happen to a person or object on behalf of Amazon Technologies, Inc. That something would involve Newtonian physics — perhaps an item is about to fall on someone, or a ball is about to roll down a slope. The test would then show you several "after" scenarios and, if you pick the correct option, you've passed the test. A method, comprising; generating, via at least one computing device, a user interface comprising a challenge, the challenge comprising a first image associated with a scene in which an object is placed; generating, via the at least one computing device, a correct response associated with the scene and at least one incorrect response associated with the scene, wherein the correct response comprises a second image associated after an observable change to the object within the scene and the at least one incorrect response comprises at least one respective image after a respective incorrect observable change to the object within the scene; and determining, via the at least one computing device, whether to grant access to a resource based a selection of one of the correct response or the at least one incorrect response.

III. PROBLEM STATEMENT

There are several researches made over hard AI problem that challenges bots and stated that they are not able to solve it because of intellectual efforts; but it can only be solved by human. S.Ezhilarasi et al. [15] implemented an image recognition and annotation model which is based on user's decision. The images are random tiled from an image database of images of nature, animals, flowers, everyday objects, fruits, vegetables, vehicles etc and image pre-processing techniques are performed such as color quantization, luminosity, image dithering, rescaling, morphological operations and image transparency. After processing the image; system added some noise over an image for turning it more complicated that cannot easily recognized. Authors deliberately corrupting a picture with noise to check the resistance of an image process operator to noise and assess the performance of varied noise filters. Either this kind of CAPTCHA might be complicated even for human also or it can be detected by using Tensorflow. Google's tensorflow is a method of object recognition and classification that can work very effectively and can detect distorted and noisy image too.



Fig. 5 Noise generation and Annotation based Decision-Making [15]

IV. METHODOLOGY

As computers become more powerful and as artificial intelligence becomes more advanced, there is a continuing need to evolve the tests employed by CAPTCHAs, as computers programmed with artificial intelligence or other text and image recognition algorithms can defeat certain weak CAPTCHA algorithms. Every decision based CAPTCHA is related to challenge response test where user is required to understand the challenge and respond with a decision. Let's understand how a bot cannot solve the Umpire's call or LBW decision challenge. A normal camera captures a video up to 60 frames per second (fps) for full HD resolution but for LBW decision it requires much more frame rate that only hawk eye provides. Hawk eye provides 340 fps and can capture the ball's path precisely up to 3.6 mm. It means that technology is inaccurate when the margin is less than 3.6 mm. To predict the ball's trajectory; there are six hawk eye cameras mount over the roof of the cricket stadium at distinct angles [21].



Fig. 6 Hawk Eye Camera Mount in Cricket Stadium [21]

Hawk eye camera has been owned by Sony Company that has been originally developed by Paul Hawkins. Sony has all rights and patents to use this technology and not to be sold or developed by other company. The technologies also have not disclosed that are used in hawk eye camera and its trajectory. But hawk eye technology is also not accurate and system cannot predict the actual position, path, speed and angle of the ball. It can be inaccurate if margin is less than 3.6 mm [22]. If the technology predicts that less than half of the ball is hitting the stump then there is good chance that the ball might miss the stump. So, if a high speed camera and its trajectory cannot predict the actual position of the ball and there is no any other technique in image processing that can do so. So, it is impossible to obtain the correct decision by the systems. So that is why it is the hardest AI problem for bots by capturing the video of LBW dismissal and predicts the actual trajectory whereas decision requires whether a ball is pitching in-line or outside of off side or over the leg stump but not outside the leg stump, impact should be in-line and ball might be projected that it is hitting the stump. It can be either observed by umpire or by people whom are watching the telecast. Humans have greater tendency to predict the decision more accurately and cricket is very much popular among all. Everyone is well aware about the rules of cricket and LBW out. If it can be adapted as CAPTCHA then it gives the best security in the field of turing test [21]. In this gaming CAPTCHA you are the umpire in cricket matches instead of being one of the players. You need to make correct LBW decisions and continue your streak of correct decisions. Predict the swing movement of the ball in the air and the spin movement on the ground besides knowing the LBW laws of cricket. User will get a short video of real cricket data for LBW and asked for taking decision on the basis of that video. User can replay the video 5 times and appeal for DRS only once. Everyone is very much familiar with cricket rules and all most everyone can predict the decision more precisely. There are only three major factors of LBW i.e. pitching,

impact and hitting wicket. User can get a hint for pitching and impact by appealing for DRS review at once but user is required to predict whether ball will hit the stump or not. Human has great tendency to predict the angle and projection of the ball. In cricket every audience is an umpire and always predicts the decision before the third umpire and most of the time audience is correct. But system is not able to predict the decision correctly because of many challenges. Umpires decision is complicated by itself but it becomes easy for television audience where ball is more visible to predict decision precisely. There is no system developed rather than hawk eye till now that can project the trajectory of cricket ball even hawk eye can work only at the time of cricket match where live data is acquiring from hawk eye camera. Later it requires hawk eye's original co-ordinates to project the trajectory of the system. Even by projecting the trajectory, a decision is still taken either by ground Umpires or third or Television Umpire. System does not take decision automatically. So, why can't it be a part of CAPTCHA as a hard AI problem. It could be the hardest AI problem in the field of CAPTCHA that can be easily solved by human but almost impossible for bots. Here we have estimated the design of the Umpire's call CAPTCHA for LBW dismissal as in the fig given below.

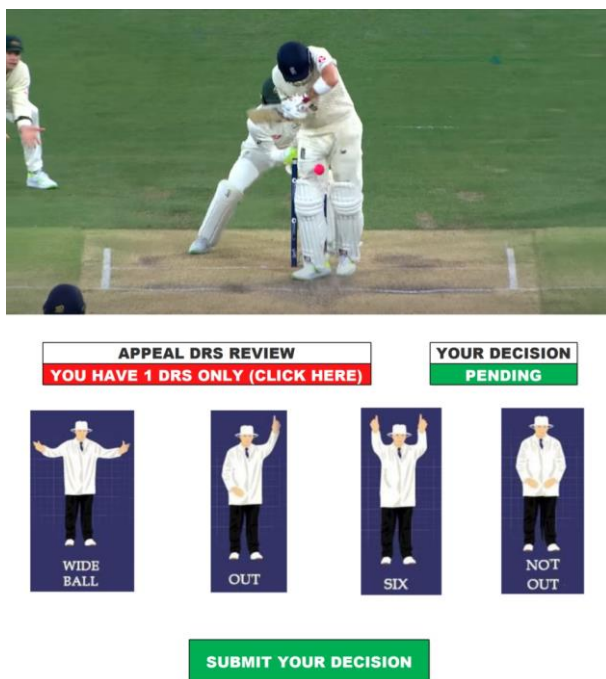


Fig. 7 Expected Proposed Work Preview

As fig 7, user is will get a real cricket video with replay option and user will get a chance to replay the video 5 times and appeal for DRS review for once. User is required to identify whether batsman is out or not by observing whether the ball is pitching –in line, outside off stump, outside leg stump and impact is in line or outside along with whether ball will hit the stump or not at that particular angle. This approach is entertaining and challenging for human to take correct decision and prove himself where they are human or bots. When user appeal for DRS then he will get a hint for

correct pitching and impact but still user will have to identify whether ball will hit the stump or not by itself. Fig shows the DRS review for the respected video.

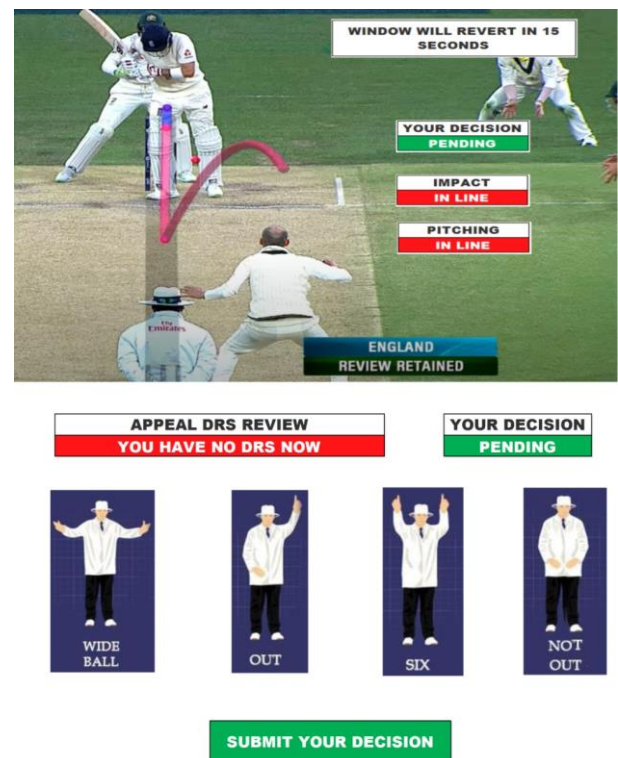


Fig. 8 Expected DRS Preview

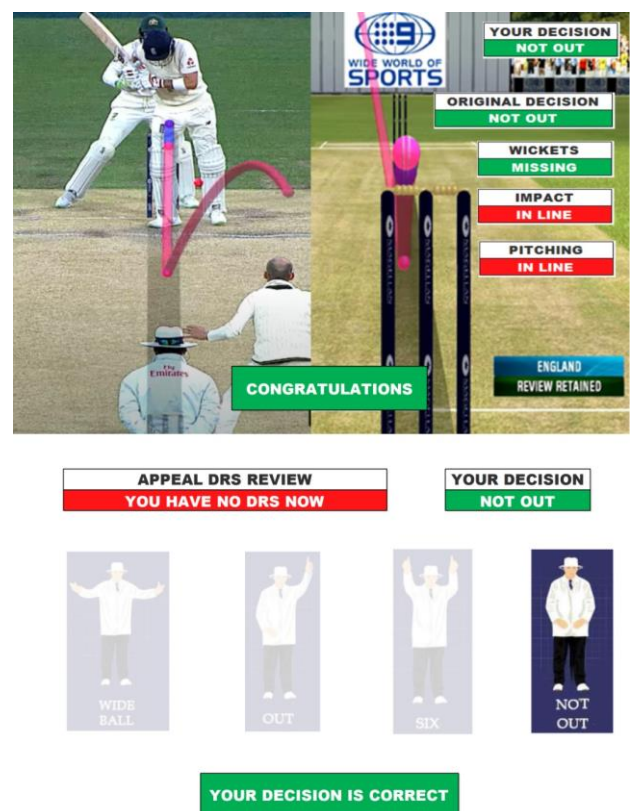


Fig. 9 Expected Final Decision Preview

User can get only one review for a single video and after 15 seconds it will revert back to the original video where user is required to choose the correct answer or he can reload the CAPTCHA for other challenge. Once the user predicts the answer and submits it then system will verify the user by projecting the actual trajectory and if user decision becomes match with the correct decision the system will allow the user and successfully verified the user as legitimate or human. As in fig. 8 shows the decision is correct and system successfully verify the user whether he is robot or a human.

A. Game Theory

Game theory is the study of mathematical models of strategic interaction among rational decision-makers. It has applications in all fields of social science, as well as in logic, systems science and computer science. Individual decision problems with stochastic outcomes are sometimes considered "one-player games". They may be modeled using similar tools within the related disciplines of decision theory, operations research, and areas of artificial intelligence, particularly AI planning (with uncertainty) and multi-agent system.

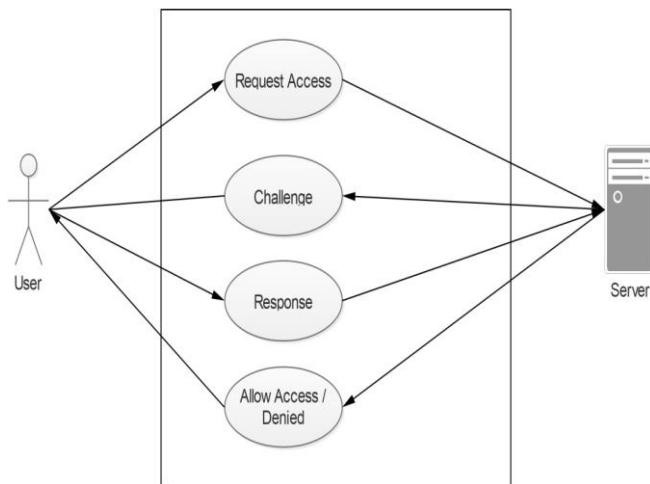


Fig. 10 Use Case

Although these fields may have different motivators, the mathematics involved are substantially the same, e.g. using Markov decision processes (MDP). Game theory has come to play an increasingly important role in logic and in computer science. Several logical theories have a basis in game semantics. In addition, computer scientists have used games to model interactive computations [23]. Also, game theory provides a theoretical basis to the field of multi-agent systems.

A. Decisive Game Theory

Game designers need to not only understand how decisions create a computer gaming experience, but also need to be able to create an experience that includes lots of unique, difficult decisions with strong feedback. Creating good decision-based games requires three abilities: The ability to recognize a decision point, the ability to evaluate how fun a decision is, and the ability to design fun decision-making play without compromising other aspects of the game (i.e.

without requiring lots of new assets or making the game too complex and difficult to learn) [24].

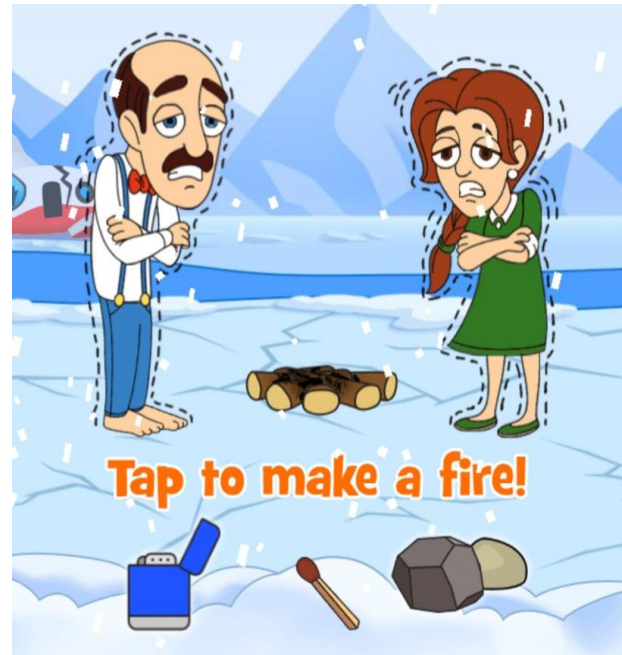


Fig. 11 Decisive Game (Gardenscapes Game) [25]

B. Backward Induction

Backward induction is the process of reasoning backwards in time, from the end of a problem or situation, to determine a sequence of optimal actions. It proceeds by first considering the last time a decision might be made and choosing what to do in any situation at that time. Using this information, one can then determine what to do at the second-to-last time of decision. This process continues backwards until one has determined the best action for every possible situation (i.e. for every possible information set) at every point in time. In the mathematical optimization method of dynamic programming, backward induction is one of the main methods for solving the Bellman equation. In game theory, backward induction is a method used to compute subgame perfect equilibria in sequential games. The only difference is that optimization involves just one decision maker, who chooses what to do at each point of time, whereas game theory analyzes how the decisions of several players interact. That is, by anticipating what the last player will do in each situation, it is possible to determine what the second-to-last player will do, and so on. In the related fields of automated planning and scheduling and automated theorem proving, the method is called backward search or backward chaining. In chess it is called retrograde analysis. Backward induction has been used to solve games as long as the field of game theory has existed [26]. Then system will continuously validate the timer and if user took more than 5 minutes then system declared that user is either bot or he is not proficient to solve the CAPTCHA anymore. When user started analyzing the query and predicts the decision then user will have a DRS option for reviewing the impact and pitching of the ball and get a hint for best decision making. But user will get only one chance to review the system and screen will be reverted within 15

seconds to the main screen where user is required to take decision on the basis of hints. Once user submit his decision then system will validate whether user's decision is correct or not by projecting the trajectory of the ball and display the correct decision and if decisions are matching then system declared that user is not a robot and privilege the user with access. User will also have reload option where another challenge will be served.

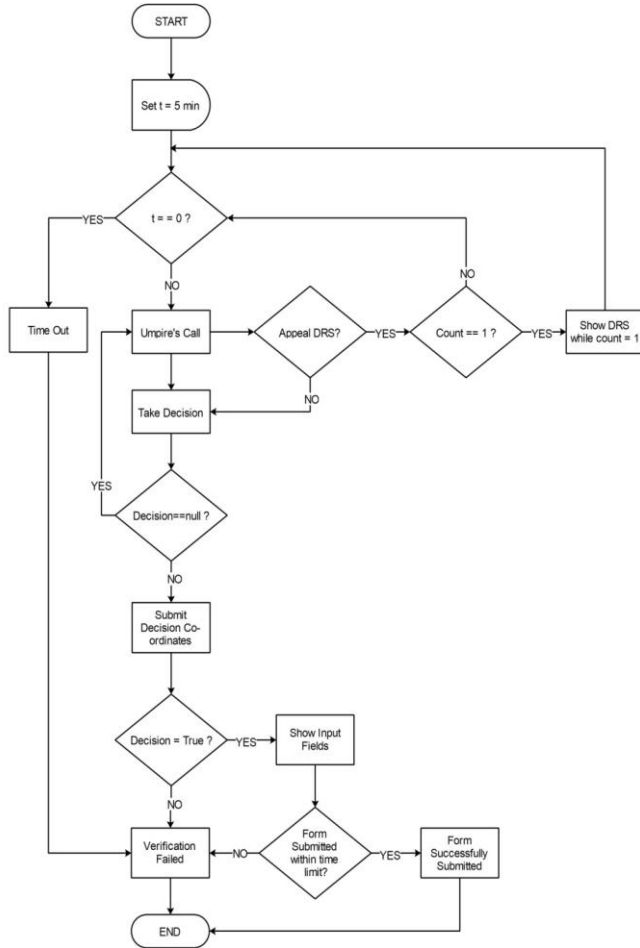


Fig. 12.Flow Chart

V. RESULT ANALYSIS

Result will be based on recorded response time, success rate, failure rate and overall frequencies. It can be analyzed using mean value, standard deviation and variance for recorded dataset.

$$\text{Standard Deviation } (\sigma) = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2}$$

Where μ is mean, N is total no. of dataset,
 x_i is an individual value
 variance (S) = σ^2

$$S = \frac{1}{N} \sum_{i=1}^N (x_i - \mu)^2$$

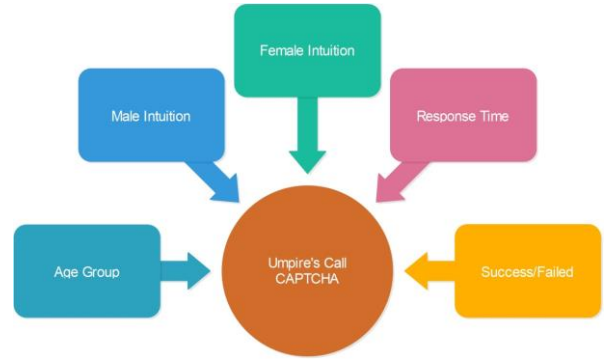


Fig. 13.Result Attributes

VI. CONCLUSION & FUTURE SCOPE

Thus the New Technique for Generation of CAPTCHA based on Gaming Methodology provides most effective CAPTCHA till now that is better able to differentiate human and robot. This is the next generation CAPTCHA where users enjoy it along with best security motives. No attacks can affect the security premises of proposed system, thus the system is enough suitable for proposing enhanced level of protection in the field of gaming CAPTCHA. The current proposed concept of Cricket Umpire's call CAPTCHA can be enhanced in future with more intellectual efforts and different spots can be used for umpire intuition that can be easily solved by human but almost impossible for bots. The CAPTCHA can be implemented in future with the more intellectual problem or Umpire's skills test that can be solved within few seconds which may be fewer than the proposed one. Time and space complexity can be reduced in future for better outcomes. Proposed CAPTCHA is applicable in various fields such as- digital transaction where human latency is often important, big data optimization and many more.

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