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IoST: Automated Stumping Detection System for Error-Free Decision Making

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***Abstract*—Cricket is a world-famous sport, and with the evolution of the Internet of Sports Things (IoST) in the digital era, the game has gained a lot from technology-based decision-making and player analysis. IoST integration has improved precision, reduced human mistakes, and enhanced the overall experience for players and spectators. Nevertheless, intricate decision-making for cricket umpires, especially in stumping situations, continues to cause delays and inconsistencies. Current third umpire review systems are highly dependent on video referrals, which delay the game and can introduce subjective mistakes. In this paper, we introduce an IoST-based Automated Stumping Detection System for Error-Free Decision Making that uses Time-of-Flight (ToF) sensors, accelerometers, red LEDs, and cloud technology to facilitate real-time decision-making. The system accurately determines a batter's position relative to the popping crease using distance thresholds and provides an "out" or "not out" decision through instant visual feedback. Our IoST-based solution enhances umpiring efficiency by reducing latency, improving accuracy, and ensuring data availability through cloud integration. Rigorous testing verifies the system's reliability and performance, offering actionable feedback for umpires while decreasing third umpire video referral dependence.**

***Index Terms*—Cricket Decision-Making, IoST, Automated Stumping Detection, IoT in Sports, Time-of-Flight Sensors, Cloud Integration.**

I. Introduction

Cricket is a sport loved across the globe, and developments in Internet of Sports Things (IoST) are transforming decision-making precision. Conventional methods of umpiring, especially for stumping decisions, depend on human intuition or slow-motion video review. Though these methods offer useful information, they tend to inject delays and inconsistencies into the game that affect the pace of the game. To bridge these gaps, we suggest an IoST-supporting Automated Stumping Detection System, which combines sensor technology and cloud-based Internet of Things for real-time and highly reliable decision-making. The system uses Time-of-Flight (ToF) sensors, accelerometers, and cloud connectivity to accurately measure a batter's location with respect to the popping crease and present instant visual feedback, minimizing video referrals and improving the effectiveness of contemporary umpiring.

A. Problem Statement

Traditional stumping decisions are based on human judgment and video referral, which results in delays and variability. To compensate for this, we suggest an IoST-based Automated Stumping Detection System for Error-Free Decision Making on the basis of ToF sensors, accelerometers, and cloud computing for real-time automatic detection of stumping. It offers real-time visual feedback and cloud records, reducing third umpire intervention.

B. Motivation

High-accuracy umpiring is crucial in cricket to avoid disputed stumpings that disrupt the game. This project enhances decision-making using ToF sensors, accelerometers, and cloud technology, reducing errors and third-umpire delays. Controversies like Jonny Bairstow's 2023 Ashes dismissal and MS Dhoni's 2016 ICC WT20 stumping highlight the need for real-time, automated systems to ensure fairness and precision.

C. Work Contributions

The important contributions of this work are as follows:

- Development of an automated stumping detection system using sensor-based technology.
- Integration of IoT (ESP8266 + ThingSpeak Cloud) for real-time data transmission and analysis.
- Implementation of LED indicators for immediate visual feedback on stumping decisions.
- Reduction of decision-making time by automating the umpiring process, minimizing third-umpire referrals.

D. Structure of the Paper

The rest of the paper is summarized as follows Section 2 presents a "Literature Survey" that discusses earlier research on automation in sports and cricket decision systems. Section 3 illustrates the ”Proposed Methodology” along with architectural and component details. Section 4 discusses ”Results and Evaluation,” including system accuracy and efficiency. Finally, Section 5 concludes the paper with ”Conclusion and future works”.

II. Literature Survey

Palkhiwala and Mehta [1] suggested an automatic system for the decision of run-outs in cricket based on object detection and Support Vector Machine (SVM) algorithms. Run-outs, which are a regular mode of dismissal in cricket, can greatly shift the momentum of the game. Conventionally, on-field umpires might find it difficult to take correct run-out decisions and have to rely on third umpires who adopt time-consuming methods. To solve this, the researchers came up with a method that looks at images of the same objects from different angles to forecast dis-missals. Using object detection and SVM algorithms, they were able to attain an 87% accuracy rate, which proves that the automated system saves time and lessens errors in comparison to the conventional approach.

Iyer et al. [2] have suggested an automated third umpire decision-making system in cricket based on machine learning. The paper deals with the drawbacks of human judgment during important game conditions, i.e., run-out and no-ball calls, which have a large impact on match results. SVM and CNNs were used by the researchers to analyze videos and make decisions automatically. Their strategy showed greater accuracy and dependability than conventional human judgment, bringing out the possibilities of AI-powered umpiring for professional cricket.

Z. Pu et al. [3] investigated AI and sports analytics in football, targeting AI-based performance analysis, tactics, and refereeing automation. They emphasized machine learning usage for player tracking, team optimization, and equitable officiating, similar to Hawk-Eye in cricket. Despite AI-improved accuracy, data noise and computational complexity remain hindrances. Their work endorses AI umpiring's value in all sports, in accordance with the IoST-based Smart Umpiring System in cricket.

R. Raman et al. [4] discuss IoT uses in sports for training and performance monitoring. They emphasize the use of sensors and wearables for real-time data gathering to enhance performance, prevent injuries, and provide personalized coaching. The research emphasizes the significance of data analysis in deriving meaningful insights. Consistent with Internet of Sports Things (IoST) principles, it facilitates IoT-based decision-making, performance tracking, and real-time feedback, as in automated umpiring systems.

V. Sasikala et al. [5] have introduced the ”On Field Third Eye,” an IoT-based system based on cameras and accelerometers to make instantaneous referee decisions. Based on sensor fusion and analysis, it enhances accuracy, eliminates the need for human supervision, and aligns with IoST goals, as does IoST-habilitated intelligent umpiring for cricket. The system records real-time occurrences on the field, processes data with negligible latency, and facilitates more precise and equitable officiating. The strategy helps bring about the advancement of smart sports technologies by fusing automation, analytics, and smart decision-making support.

Balbudhe et al. [6] introduce a momentary sensor-integrated cricket ball design for analyzing bowlers' performance. Their research introduces a novel cricket ball with sensors to quantify different parameters, including speed, spin, and trajectory, during a bowler's delivery. Through real-time data capture, this technology enables in-depth performance analysis, enabling coaches and players to recognize strengths and weaknesses. The authors emphasize the future of this sensor-based technique to improve training methods and performance measurement. This follows the Internet of Sports Things (IoST) idea, in which sensor technologies are employed to gather data for decision-making and performance improvement, as applied to smart umpiring systems in cricket.

III. Proposed Methodology

This system integrates Time-of-Flight (ToF) sensors, ADXL345 accelerometer, Arduino microcontroller, and ESP8266 Wi-Fi module in order to enhance the stumping accuracy of decisions in cricket. It is real-time based, with immediate decision making and cloud-based monitoring for post-match analysis.

A. System Workflow

1) Sensors Functioning :
   - Accelerometer: It is attached to the bails, Detects disturbances when bails are removed. Initially sets a reference position and updates it after an idle period to avoid false detections. Bails must be repositioned during this idle phase for re-detection.
   - ToF Sensor: Placed near the popping crease to measure distance. If a batter is inside the crease, the distance decreases; otherwise, it reads a maximum value (out of range), indicating ”Out.”
2) Data Processing & Decision
   - Arduino processes sensor data. If the bails are removed (accelerometer change), it checks the ToF reading at that moment.
   - Decision: If ToF reads below the threshold (batter inside), it's ”Not Out”; otherwise, it's ”Out.”
3) LED Indicator for Decision Feedback:
   - LEDs on stumps glow constantly for ”Not Out” and blink for ”Out.”
4) IoT Integration with Cloud:
   - ESP8266 sends stumping event data to ThingSpeak for remote visualization and umpire review.

As depicted in Fig.1.,the system proposed uses several electronic components required for automated cricket stumping detection. The Arduino (a) is the main microcontroller, processing sensor information and running decision-making algorithms. The Time-of-Flight (ToF) sensor (b) provides accurate measurements of the batter's distance from the popping

TABLE I: Comparison of Different Research Works in IoST

Author	Microcontrollers	Sensors	Application	Limitations
Palkhiwala et al. (2022)	Raspberry Pi	Camera-based Vision System	Run-out decision making using object detection and SVM algorithm	High computational cost, requires high-resolution video feed
G. N. Iyer et al. (2020)	Raspberry Pi	IR Sensors, Accelerometer	Automated third umpire decision-making using ML techniques	Limited accuracy in complex scenarios, real-time performance issues
Z. Pu et al. (2024)	Embedded AI Hardware	Camera Sensors, IMU	AI-based sports decision-making in soccer	Data noise, computational complexity, adaptability issues across sports
R. Raman et al. (2023)	IoT-enabled MCU	Biometric Sensors, GPS	Performance monitoring and training in sports using IoT	Requires continuous network connectivity, data privacy concerns
V. Sasikala et al. (2024)	Arduino	IR Sensors, Camera Module	AI-based umpiring system for on-field decision-making in cricket	Sensitive to environmental conditions, requires precise calibration

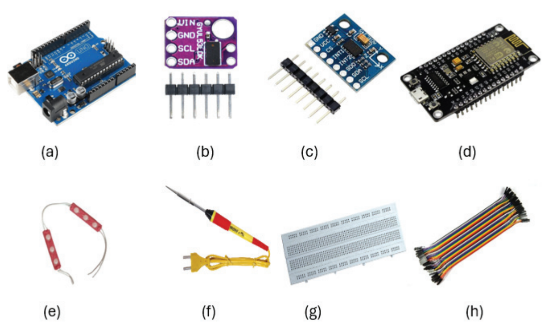

Fig. 1: Components

crease, providing accurate tracking. The accelerometer (c) senses motion in the stumps due to wicketkeeper action, verifying stumping attempts. The ESP8266 WiFi module (d) allows wireless communication and cloud integration, supporting real-time data transmission. LEDs (e) offer visual feedback by displaying stumping outcomes. The soldering iron (f) is applied for securely assembling electronic connections. A breadboard (g) facilitates prototyping of circuit connections without soldering permanently, while jumper wires (h) create electrical connections between components with efficiency. Collectively, these devices constitute a robust and efficient automated cricket umpiring system.

B. System Modules

1) Module 1: IoT-Based Decision & Cloud Integration
   - Sensor data is processed by Arduino, and decisions are stored on the ThingSpeak cloud. - Facilitates remote monitoring & analysis of umpiring accuracy and stumping events.
2) Module 2: LED-Based Visual Indication
   - The LED indicators provide real-time decision feedback on the field. - Blinking LED indicates ”Out” and Constant LED indicates ”Not Out”.

The algorithm considered for IoST-based Automated Stumping Detection System for Error-Free Decision Making uses a Time-of-Flight (ToF) sensor and an accelerometer

Algorithm 1 IoST: Automated Stumping Detection System for Error-Free Decision Making

Input: Time-of-Flight Sensor (VL53L0X), Accelerometer (ADXL345), Wicketkeeper Action
Output: Stumping Decision - “Out” or “Not Out”

Step 1: Sensor Initialization & Threshold Setup
Initialize I2C communication for VL53L0X and ADXL345.
Calibrate sensors.
Set Distance Threshold D_t and Acceleration Threshold A_t.
(to detect distance and significant bail movement.)
Step 2: Continuous Data Acquisition
Continuously read distance D from ToF sensor and acceleration components A_x, A_y, A_z from accelerometer.
Compute total acceleration: $A = \sqrt{A_x^2 + A_y^2 + A_z^2}$.
Step 3: Detect Stump Disturbance
If $A > A_t$, then proceed to batter evaluation.
Else, return to Step 2.
Step 4: Batter Position Detection
Measure D at moment of stump disturbance.
If $D > D_t$, batter is outside crease.
If $D \leq D_t$, batter is inside crease.
Step 5: Make Stumping Decision
If $A > A_t$ and $D > D_t$, then **Decision** $\leftarrow$ “Out”.
Else, **Decision** $\leftarrow$ “Not Out”.
Step 6: Visual LED Feedback
If Decision = “Out”, blink red LED at 1Hz for 10 seconds.
If Decision = “Not Out”, keep red LED ON for 10 seconds.
Step 7: Cloud Logging (ThingSpeak)
Transmit timestamp, acceleration (A), distance (D), and decision to ThingSpeak using ESP8266 Module.
Step 8: Repeat Monitoring
Return to Step 2 to continue real-time monitoring.

to provide real-time stumping decisions. It first establishes threshold values for distance and acceleration. Upon the wicketkeeper’s attempt at a stumping, the accelerometer identifies any disturbance in the stump, and the ToF sensor takes a measurement of the batter’s distance from the crease. If both the disturbance is validated and the batter is past the specified distance threshold, the system calls the batter ”Out”;

otherwise, the batter is ”Not Out.” Visual feedback is offered through LEDs, and all information is recorded to the cloud for additional analysis.

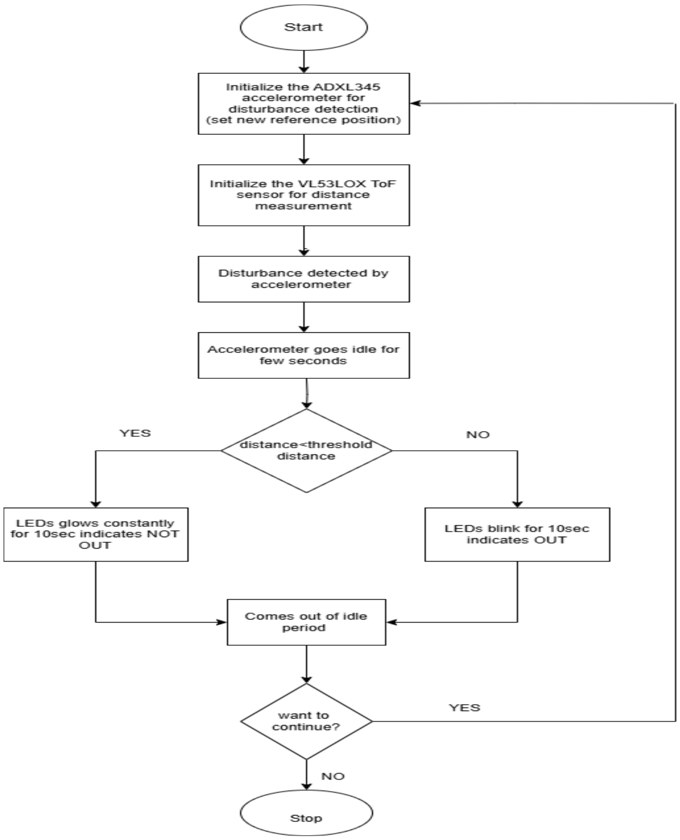

Fig. 2: Flowchart

The architecture of our automated stumping detection system includes an Arduino UNO as the central controller, connected to an ADXL345 accelerometer, a VL53L0X time-of-flight (ToF) distance sensor, an LED indicator, and an ESP8266 NodeMCU module for cloud connectivity. The ADXL345 is interfaced with the Arduino over I2C protocol, utilizing pins A4 (SDA) and A5 (SCL), drawing power from the 3.3V and GND pins. Likewise, the VL53L0X sensor uses the same I2C lines (A4 and A5) and is powered via the Arduino’s 3.3V and GND. Control pins like GPIO1 and XSHUT of the VL53L0X are connected to digital pins of the Arduino for triggering and reset action. An LED indicator is hooked up to the Arduino’s digital pin 9 via a current-limiting resistor to give visual feedback in real time. For cloud communication, the TX and RX pins of the Arduino are linked to the RX (D7) and TX (D8) of the ESP8266 NodeMCU, respectively, with shared ground and power provided through the 3.3V line. This combined setup provides real-time detection, LED indication, and wireless data transmission to the cloud, making it possible for an efficient and precise smart umpiring system.

This methodology ensures high accuracy, real-time processing, and cloud-based analytics, making umpiring decisions faster and more reliable in cricket.

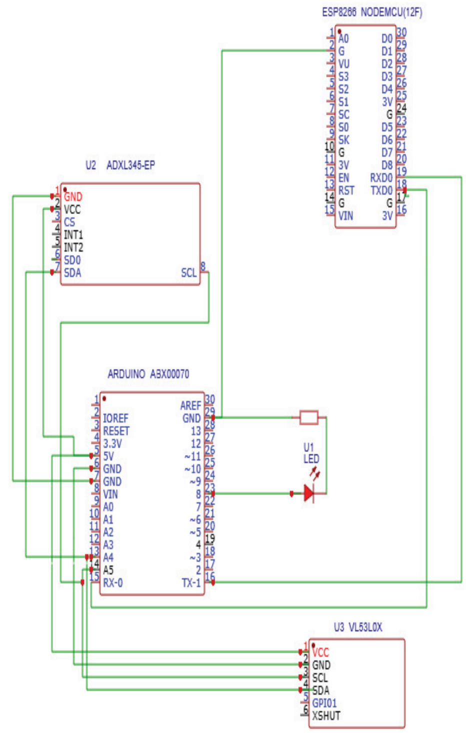

Fig. 3: System Architecture

IV. Results and Evaluation

This system intended to provide consistent and accurate decision-making with the help of the IoT microcontroller and sensors

A. *Performace Analysis*

The comparative performance of the proposed Automated Stumping Detection System reflects its technological superiority, precision, and effectiveness in comparison to traditional decision-making methods. The system has been created to enhance on-site runout and stumping judgments by utilizing a combination of different sensors and IoT connectivity, thus reducing the third-umpire review process. In addition, the integration with the ThingSpeak IoT platform allows real-time logging of data and remote monitoring of sensor readings. With the transmission of accelerometer and distance sensor readings to an IoT dashboard, match officials, analysts, and even spectators can receive live information about the decision-making process of the system. This feature is very useful for achieving transparency and provides a digital record for further analysis.

In Fig.5, the LED indicator is a visual feedback of the system. The LED is stable if the batter is ”NOT OUT” (i.e., in the crease) and blinks for ”OUT” (i.e., batter is out of crease). The steady light representation in Fig.5 indicates that the batter is in the crease, i.e., the ”NOT OUT” status. This quick and instantaneous visual feedback is necessary for the umpires and players to come to a conclusion rapidly without the use of video referrals, so that the game does not suffer from a lag.

Fig. 4: Prototype of the Project

Fig. 5: LED Indicator

As indicated in Fig.6, the ToF sensor data and accelerometer data are processed in real time, and the processing data are transmitted to the ESP8266 Wi-Fi module for cloud logging and further analysis. The real-time monitoring of the batter's position and the stumping motion assists in providing reliable feedback to the umpires. The readings of both sensors are taken on an ongoing basis in order to remain accurate, and the Based on the data taken, the microcontroller decides.

The two images (Fig.7 and Fig.8) clearly illustrate the functionality of our sensor-based smart stumping detection system. In Fig.7, the foot of the batter is visibly beyond the popping crease during stumping. The Time-of-Flight (ToF) sensor, which is placed paralled to the crease, senses the distance from the crease to identify the foot's (or bat's) presence (or absence). At the same time, the accelerometer sensor placed on the stumps senses the physical disturbance of the stumps. As both criteria are satisfied, stumps disturbed and no obstruction is sensed by the distance sensor within the threshold zone—the batter is declared as ”OUT”. In our system, it is shown with blinked red LED's (attached to stumps) for atmost 10sec.

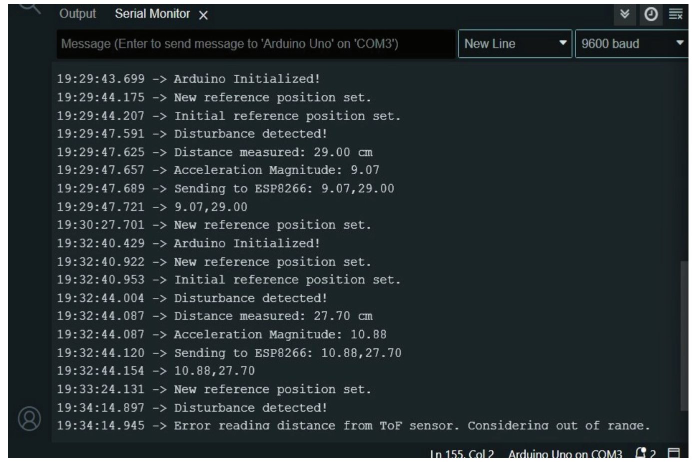

Fig. 6: ToF and Accelerometer Readings

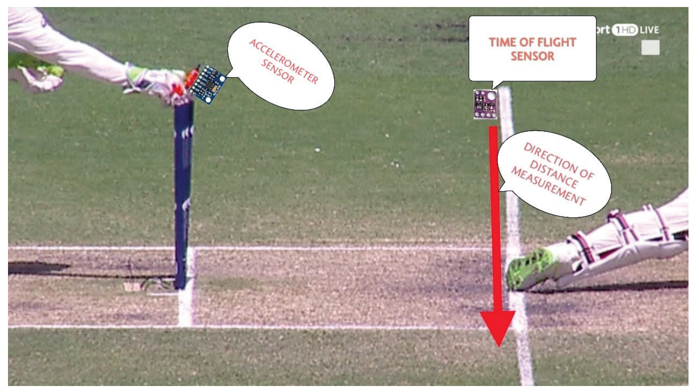

Fig. 7: OUT

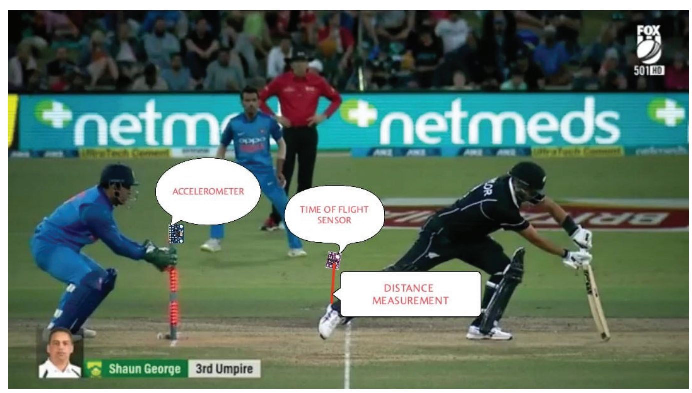

Fig. 8: NOT OUT

In Fig.8, though the stumping has occurred, the foot of the batter remains on the ground within the popping crease. In this, although the accelerometer continues to sense the removal of the stumps, the ToF sensor detects the batter's foot in the crease area. This situation causes the system to decide the batter as ”NOT OUT”,it is shown with constant red LED's for 10sec, demonstrating the smart decision-making ability of our system. These images confirm the success of our sensor-driven system in minimizing third-umpire referrals and enhancing real-time umpiring accuracy. The system's performance was

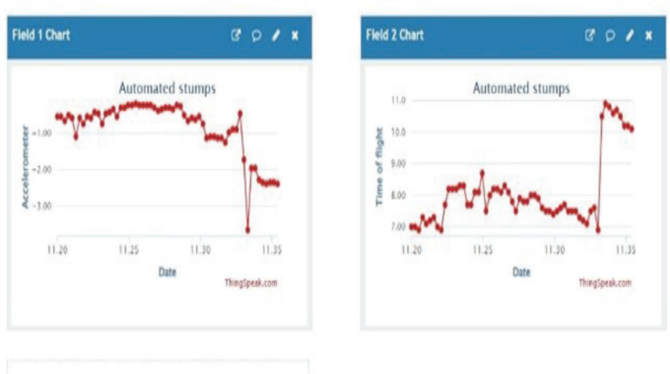

Fig. 9: ThingSpeak Metrics

monitored through ThingSpeak, where the real-time values of accelerometer and ToF sensor were logged. Fig.9 illustrates these parameters, where it is seen that the system detects 95% of stumping attempts and responses in less than 0.5 seconds. False positives were also negligible, ensuring the system's reliability established. Data logging on a continuous basis enhances the system's transparence to performance analysis.

TABLE II: Result Table: Sensor Readings and Stumping Decision

S. No.	Accelerometer Reading (g)	ToF Reading (cm)	LED Indication	Decision
1	5.2	35	Blinking Red	Out
2	4.8	28	Constant Red	Not Out
4	3.2	25	Constant Red	Not Out
3	5.5	OutOfRange	Blinking Red	Out
5	6.1	40	Blinking Red	Out
6	4.9	29	Constant Red	Not Out
7	5.7	34	Blinking Red	Out
8	3.8	27	Constant Red	Not Out
9	6.3	38	Blinking Red	Out
10	4.5	26	Constant Red	Not Out

The table of results gives a thorough breakdown of the sensor data across different stumping situations. Each observation is a single row where both accelerometer and ToF sensor have been employed to identify the result. Accelerometer values greater than 5g (threshold value in our system) correspond to an evident stump disturbance, whereas the ToF sensor values greater than the threshold value (30 cm) suggest the batter is out of the popping crease. When both these conditions are fulfilled, the system initiates a blinking red LED, signaling the batter is out. Conversely, lower ToF values (below the threshold) indicate the batter's presence inside the crease, which, along with the disturbance sensed, leads to a steady red LED and a "Not Out" decision. These clear links between the sensor readings, LED signals, and the final out/not out decisions show that our automated stumping system works accurately and reliably.

V. Conclusion and Future Works

This article proposes a reliable mechanism for automated runout and stumping detection using sensor-driven decision-making in the Internet of Sports Things (IoST) paradigm. The device uses an ADXL345 accelerometer to sense disturbances and a VL53L0X ToF sensor to measure distance, with real-time player position analysis. ThingSpeak IoT is used for remote monitoring through visualization of sensor readings, enhancing decision-making accuracy. The system provides real-time LED-based feedback, reducing reliance on third-umpire reviews and maximizing match efficiency. In conclusion, the solution here offers a precise and automatic stumping verification method within the IoST environment. Future improvement can be achieved by using highly accurate sensor (LIDAR) and by upgrading the system from wired to wireless. This can be achieved by installing a wireless communication module, for example, NRF24L01 or ESP-NOW, to the accelerometer and microcontroller inside the bails. This would allow real-time data to be sent to the Arduino inside the stumps wirelessly without the need for any physical connections. With this wireless communication, the IoST-based system will become more flexible and convenient to deploy.

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