Advanced Digital Cricket Simulator with Integrated Performance and Fitness Analysis

Dr.Vaniprabha, Gokulakannan S, Jeyaraman S
Electronics and Communication Engineering, SNS College of Engineering Coimbatore, India

***Abstract*— This project introduces a next-generation cricket simulator designed to transform traditional training methods through advanced technology integration. The system combines a digitally programmable bowling machine, an LED-based bowler animation display, and a machine vision video replay system to create a realistic, data-driven, and immersive training environment tailored for professional cricketers and coaches. The programmable bowling machine is capable of delivering a wide variety of deliveries with precision, enabling customized training sessions that simulate match conditions. The LED-based bowler animation display projects full-scale, high-fidelity visuals of real bowlers to provide a lifelike experience, improving a batsman's timing, anticipation, and decision-making under pressure. At the heart of the simulator is a machine vision-based video analysis system, employing high-speed cameras to capture detailed footage of player movements. This system enables post-session analysis of key performance and fitness parameters such as head position, footwork, balance, shot execution, and body alignment. By providing slow-motion replays and annotated breakdowns, it facilitates biomechanical assessment and technical feedback without the need for wearables or intrusive sensors. The simulator's real-time feedback and data analytics offer coaches and athletes deep insights into individual performance, helping to refine technique, enhance physical conditioning, and reduce injury risks. This evidence-based approach to training supports precise intervention and continuous improvement. With its integrated use of intelligent technology, realistic simulation, and analytical depth, this cricket simulator represents a significant leap forward in modern sports training.**

***Keywords*—Machine vision, Cricket Simulator, IR sensor frame, Skill development, Image Processing, Ball throwing machine.**

I. INTRODUCTION

Cricket is a dynamic sport that demands a harmonious blend of technical skill, mental resilience, physical conditioning, and instantaneous decision-making. From the nuanced wrist movement of a spinner to the split-second reflexes of a batsman facing a 150 km/h delivery, the game challenges players at both physiological and psychological levels. As the competitive landscape of professional cricket intensifies, the need for precise, efficient, and data-informed training methodologies has become increasingly critical.

Traditionally, cricket training has relied on net sessions, one-on-one coaching, and match simulations to improve technique and decision-making. While effective to a degree, these methods are inherently limited by their dependence on human observation, variability in training conditions, and the lack of quantifiable feedback. Even with modern coaching tools, real-time insights into a player’s biomechanics, posture, and overall fitness remain elusive. Moreover, subjective assessments often fail to detect subtle technical flaws or early signs of physical fatigue, both of which can significantly impact performance and injury risk. In recent years, the integration of technology into sports training has created new possibilities. Vision-based systems, in particular, have emerged as powerful tools for non-invasive performance and fitness monitoring. High-speed cameras, paired with intelligent video processing algorithms, can capture and analyze complex movements in fine detail—frame by frame—without interrupting the natural flow of practice. Unlike wearable sensors, which may affect a player’s comfort and movement, vision-based systems allow for continuous monitoring of posture, footwork, balance, and head position under realistic training conditions. Building on this technological potential, this project proposes a next-generation cricket simulator that integrates three core components:

Digitally Programmable Bowling Machine – This system is capable of delivering a wide variety of bowling styles with high accuracy and repeatability. Speed, spin, swing, bounce, and line/length can be programmatically controlled, enabling the creation of custom training sequences tailored to specific match scenarios or skill development goals.

LED-Based Bowler Animation Display – To simulate the presence of a real bowler, a full-scale LED screen displays synchronized high-definition animations of actual bowlers during their run-up and delivery. This immersive visual cue system improves batsman anticipation, timing, and reaction, replicating the psychological challenges faced during live matches.

Machine Vision-Based Video Replay and Fitness Analysis System – This component leverages high-speed, multi-angle cameras and advanced computer vision algorithms to record and analyze player movements in real time. Key performance indicators such as body alignment, foot placement, balance at the crease, bat-lift consistency, and follow-through dynamics are extracted and reviewed using annotated slow-motion replays. Additionally, the system provides fitness-related analytics, including fatigue indicators (e.g., loss of balance, head lag, irregular footwork), asymmetrical motion detection, and micro-level posture analysis. This enables early detection of biomechanical inefficiencies and injury-prone movement patterns.

By combining real-time performance metrics with fitness and fatigue assessments, the simulator supports holistic player development. Coaches are empowered with objective, data-rich insights that allow for precise feedback, targeted corrections, and personalized training programs. Players, in turn, gain a deeper understanding of their techniques and physical readiness, leading to improved performance, enhanced consistency, and reduced injury risk.

II. LITERATURE SURVEY

The integration of technology into sports training has seen rapid growth in recent years, particularly with the advent of machine learning, computer vision, and immersive simulation tools. Cricket, as a technically demanding sport, presents a fertile ground for innovation, especially in areas such as skill enhancement, injury prevention, and performance analytics. This literature survey reviews existing research and developments related to programmable bowling systems, visual simulation, video-based motion analysis, and intelligent training environments relevant to the proposed next-generation cricket simulator. Mishra et al. highlighted Programmable bowling machines have become increasingly sophisticated, with digital controls allowing precise replication of delivery types. The importance of delivery variability in cricket training and explored control algorithms for programmable machines that replicate line, length, speed, and spin [1]. However, these machines often lack synchronized visual input, limiting realism and anticipatory training. Muller and Abernethy et al. The use of visual cues in athlete performance has been emphasized in several studies. demonstrated that batsmen use kinematic cues from bowlers' movements to anticipate deliveries, and that removing such cues can significantly impair performance [2]. This supports the inclusion of life-sized LED-based bowler animations in simulators to enhance visual realism and cognitive response during training.

Stenros et al. reviewed Emerging technologies such as virtual reality (VR) and augmented reality (AR) have been adopted in sports training to provide immersive, game-like experiences. VR applications in sports and found strong potential for improving spatial awareness, timing, and reaction under controlled environments [3]. Although VR has limitations in replicating real ball interactions, hybrid systems with physical elements (like actual ball deliveries) and visual feedback are gaining prominence. Pandey et al. discussed Video-based performance analysis using machine vision has become a cornerstone in sports biomechanics. the application of high-speed cameras in cricket for assessing batting techniques, noting their effectiveness in tracking body movement, bat trajectory, and timing with frame-by-frame precision [4]. This method provides non-intrusive, high-resolution data essential for accurate skill assessment. Glazier et al. emphasized The role of biomechanical evaluation in injury prevention is widely acknowledged. that improper batting postures and repetitive stress on joints can lead to overuse injuries, and highlighted the value of biomechanical analysis in mitigating such risks [5]. A video-based approach, as proposed in this simulator, offers a viable alternative to sensor-based systems, reducing discomfort while maintaining data accuracy. Carson et al. who found The effectiveness of real-time coaching tools has been explored that instant video replay and data-driven feedback significantly improve learning curves in sports training [6]. Incorporating immediate replay and analytics enables coaches to intervene during sessions, reinforcing correct techniques and addressing faults on the spot. Yoon et al. developed a sports like baseball and tennis, training simulators that combine ball delivery systems with visual displays and analytics are becoming common. For instance, baseball batting simulator using synchronized pitch delivery and virtual pitcher projection, resulting in improved player timing and perception [7]. These cross-sport parallels validate the core elements of the proposed cricket simulator. Rathore and Singh et al. highlighted While systems like Hawk-Eye and PitchVision offer excellent post-match analytics, they are primarily used in professional game contexts rather than training environments. There remains a gap in real-time, immersive systems that combine programmable bowling, visual replication of bowlers, and machine vision analytics in one integrated training platform [8].

III. EXISTING SYSTEM

Current cricket training environments predominantly rely on conventional bowling machines and manual coaching methods, which, despite their widespread use, exhibit several notable limitations. Traditional bowling machines are mechanically restricted and lack digital programmability, making it difficult to simulate the diverse range of deliveries encountered in competitive matches. Furthermore, they are unable to replicate bowler-specific actions, such as unique run-ups or wrist movements, which diminishes the realism and tactical depth of practice sessions. Another key limitation is the absence of visual cues. In real match scenarios, bowlers provide critical visual information—including body posture, arm action, and momentum—which batsmen use to anticipate the ball. The lack of such cues in standard machines hinders perceptual and cognitive training.

Coaching feedback in current systems is largely subjective, relying heavily on the coach's observational expertise. While experienced coaches offer valuable advice, this feedback is often qualitative and lacks consistency due to the absence of objective measurement tools. In addition, any video analysis conducted is typically post-session, requiring manual review and annotation, which delays the feedback process and reduces the opportunity for immediate skill correction. Lastly, existing training setups generally do not integrate biomechanical analysis, making it challenging to assess key physical components such as body balance, stride alignment, bat swing, and overall posture in a scientific and data-driven manner. These gaps underscore the need for a more advanced, integrated training solution that combines mechanical precision with visual realism and analytical depth.

IV. PROPOSED SYSTEM

The proposed next-generation cricket simulator presents an integrated solution designed to overcome the limitations of conventional training systems. At the heart of this innovation is a digitally programmable bowling machine, capable of delivering a comprehensive range of ball trajectories with high precision. This includes variations in line, length, speed, and spin, all digitally controlled to replicate real match conditions and tailored to suit individual player needs. By enabling consistent and programmable delivery patterns, the machine facilitates more structured and effective practice sessions.

To enhance the realism and cognitive engagement of the training experience, the simulator incorporates a high-resolution LED-based bowler animation display. Positioned directly behind the bowling machine, this display projects life-size visuals of bowlers executing their run-up and delivery actions. These animations are precisely synchronized with the physical ball release, providing critical visual cues that improve the batsman's anticipation, timing, and decision-making—thereby creating an immersive and match-like environment.

Complementing the physical and perceptual elements is a sophisticated machine vision-based video replay and analysis system. High-speed cameras capture each training session from multiple angles, while advanced computer vision algorithms analyze the batsman's biomechanics, including head positioning, footwork, balance, bat swing, and posture. Unlike wearable sensors, this non-intrusive system delivers rich biomechanical insights through visual tracking and slow-motion playback, offering a scientifically grounded approach to technique evaluation.

The system further supports both real-time and post-session analytics through an interactive dashboard interface. Coaches and players receive immediate feedback via annotated video replays and statistical summaries, allowing for on-the-spot correction and long-term performance monitoring. Critical training moments can be tagged, and fitness indicators tracked over time to evaluate progress and mitigate injury risks.

Overall, this simulator offers a highly immersive training environment that bridges the gap between practice and actual gameplay. It enables objective performance evaluation through precise machine vision analysis, fosters technical and cognitive skill development, and provides valuable data for injury prevention and fitness monitoring. By combining mechanical accuracy with perceptual realism and data-driven feedback, the system represents a transformative step forward in cricket training methodology.

A. BLOCK DIAGRAM

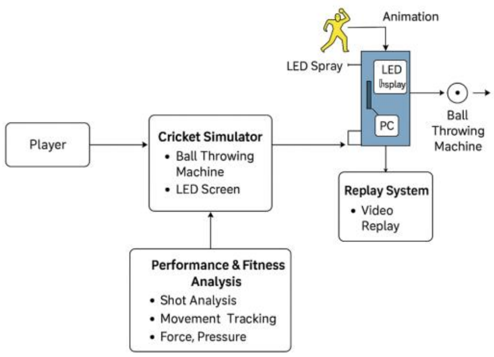

Fig.1 Architectural Block Diagram of proposed System

The proposed system is a digitally programmable cricket bowling machine integrated with advanced visualization, user interface, and biomechanical analysis components to enhance the training experience for players. At the core of the system is a motorized bowling unit powered by brushless DC motors and linear actuators, enabling precise control over delivery styles such as fast bowling, spin, inswing, outswing, yorkers, and bouncers. These elements are dynamically adjusted in terms of seam position, release angle, and height. The control is handled by a high-performance STM32F407VGT6 microcontroller, which executes pre-set delivery parameters received via serial or wireless communication. Real-time feedback is obtained through speed and spin sensors to ensure consistency and repeatability in deliveries.

To augment realism and help players better anticipate the ball, a life-sized LED-based bowler animation display is integrated into the system. This module employs a high-definition LED panel (25–50 inches) synchronized with the physical ball release using a playback module such as a Raspberry Pi or Jetson Nano. Pre-recorded animations representing various bowling styles and actions are stored locally and triggered in perfect sync with the bowling machine, enhancing perceptual realism during training.

Complementing the delivery mechanism is a machine vision-based video replay and fitness analysis system. High-speed cameras (≥80 fps) are positioned to capture the batsman's response in high detail. Using vision processing algorithms such as OpenPose or MediaPipe, the system tracks key biomechanical markers including head position, footwork, stride alignment, bat swing, and reaction time. Annotated replays and posture assessments are generated for each session, and long-term data trends are analyzed to detect form drift or physical fatigue over time.

All system components are coordinated by a central control and processing unit comprising an STM32 microcontroller for real-time actuation and a mini PC (Intel Celeron-based) for high-level logic execution, vision processing, and user interface management. This unit handles user inputs from a connected tablet or laptop, dispatches delivery commands to the bowling machine, synchronizes animation playback, and logs session data. Wireless communication (via Wi-Fi or Bluetooth) enables seamless connectivity and data exchange across all subsystems.
The user interface is presented through a web or app-based dashboard accessible via tablets or laptops. It allows users to configure delivery profiles, monitor real-time session metrics, visualize performance data through annotated videos and graphs, and manage player-specific training records. The system also incorporates robust power and safety subsystems including surge-protected power supply units, emergency stop mechanisms, voltage/current monitoring circuits, and protective shields for cameras to ensure operational safety and equipment durability.

Together, these modules form an intelligent, immersive cricket training platform that combines mechanical precision, visual realism, and data-driven performance analytics, offering players a comprehensive tool for skill development and coaching support.

B. SIMULATOR SETUP

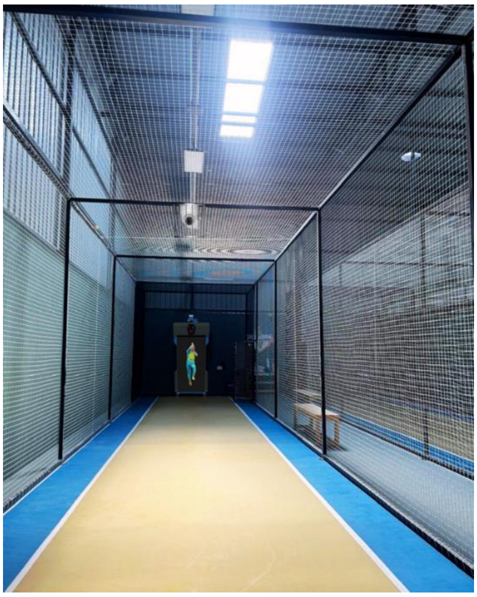

Fig.2 Simulator Setup

Fig.2 shows, the realtime simulator setup arena for practice and performance development. The simulator arena is fully covered with net and an indoor arena with LED screen ball throwing machine. Fig. 3 shows the 3D representation of batting cage with infrared sensors and the simulator placement etc., the machine area is completely closed for better display and the infrared sensors places both side of the cages, when the shot hit by a batsmen the sensors scan the ball speed and angle too to measure the reaction time of the batsmen. Here S1, S2 are distance between sensors.

C. BATTING CAGE WITH SIMULATOR 3D MODEL

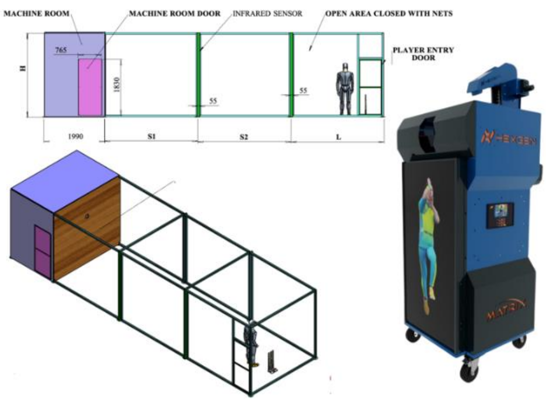

Fig.3 Batting Cage with Simulator 3D model

D. FUCTIONAL WORKFLOW

The functional workflow of the proposed cricket simulator begins with a precisely timed video capture sequence. High-speed cameras operating at a minimum of 80 frames per second are triggered at the exact moment of ball release. This synchronization is achieved by hardware-linking the cameras to the bowling machine's release mechanism, ensuring accurate frame alignment. The footage capture starts milliseconds before the ball is delivered and continues until the batsman completes their shot or movement, allowing for a complete visual analysis of the entire action.

Following capture, the system proceeds with real-time pose estimation using advanced computer vision algorithms such as Open Pose or Media Pipe. These algorithms run on a local edge device, extracting a dynamic skeletal model of the batsman. Each frame is analyzed to map joint positions—including shoulders, elbows, hips, knees, wrists, and ankles—enabling a detailed biomechanical breakdown of the player's movement throughout the delivery.

Subsequent posture and bat swing analysis is conducted primarily from the front camera view. This stage focuses on evaluating spine alignment, head stability, and upper-body orientation during shot execution. It detects forward or backward leaning, excessive torso twisting, and incorrect shoulder positioning. Additionally, the bat swing is closely monitored by tracking the trajectory of the wrists and bat tip, assessing the back-lift and follow-through for optimal technique. The system automatically flags technically flawed actions such as cross-batted or off-balance shots for later review.

Simultaneously, the top camera captures footwork and balance dynamics. It measures stride length, foot placement, pivot mechanics, and weight distribution. By tracking movement speed and changes in stance, the system can identify hesitation, overstepping, or constrained positioning—factors that often lead to mistimed shots or increased injury risk. To enhance clarity, visual overlays such as heatmaps and path tracking diagrams are generated to depict the player's foot movement across the crease.

The final component of this workflow involves the extraction of fitness indicators from the combined analysis. Metrics such as fatigue detection, injury risk assessment, and performance consistency are derived from the session data. Indicators of muscular fatigue—such as diminishing foot speed or increased bodily sway—are automatically highlighted. Similarly, joint misalignment and over-rotation in shoulders or hips can point to potential injury risks. Consistency in technique is also measured through variations in footwork, stance, and bat angle across multiple deliveries. All findings are compiled into a comprehensive session dashboard featuring visual charts and annotated replays, providing players and coaches with actionable insights to improve technique and maintain peak physical conditioning.

V. SIMULATOR OUTPUT AND ANALYSIS REPORT

Session Summary: 100 Deliveries | Mixed Bowling Types | 6 Batsmen

Delivery Type	Count
Off-spin	20
Leg-spin	20
Inswing	20
Outswing	20
Pace (130-140 km/h)	20

Table 1.0 Delivery Breakdown

The performance summary of six players reveals insightful patterns in reaction time, shot execution, and footwork efficiency. Player 1 demonstrated an average reaction time of 580 milliseconds, with a shot perfection rate of 74% and footwork efficiency at 82%. Their best performance came against off-spin deliveries, although a consistent issue was noted in the form of delayed foot movement when facing outswingers. Player 2 recorded a slightly slower reaction time of 620 milliseconds, with shot perfection at 68% and footwork efficiency at 76%. They showed strong front foot drives against leg-spin but exhibited a lag in bat swing when responding to pace bowling.

Player 3 stood out with the fastest reaction time of 540 milliseconds, achieving the highest shot perfection (81%) and footwork efficiency (88%) among all players. They handled inswing deliveries particularly well, though occasionally lost balance when facing leg-spin. Player 4 had a reaction time of 605 milliseconds, shot perfection of 65%, and footwork efficiency at 70%. They were effective against off-spin deliveries, especially with pull and sweep shots, but experienced issues with delayed weight transfer on pace deliveries.

Player 5 recorded a reaction time of 550 milliseconds and delivered a shot perfection rate of 79%, with 84% footwork efficiency. Their top performance was against outswing deliveries, where their bat angle and judgment were particularly commendable. However, mistimed flicks against inswingers were a recurring challenge. Finally, Player 6 showed an average reaction time of 575 milliseconds, 72% shot perfection, and 80% footwork efficiency. They faced leg-spin deliveries effectively but had a tendency to adopt a slightly closed stance when playing inswingers.

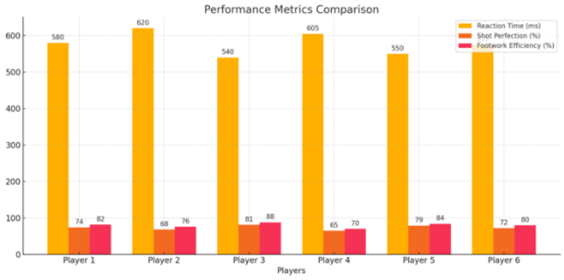

Fig.4 Performance metrics

This comparative bar chart illustrating key performance metrics for six players displays average reaction time (in milliseconds), shot perfection (percentage of ideal shot execution), and footwork efficiency (percentage of optimal movement and balance) for each player. This visualization helps in quickly identifying strengths and areas for improvement, aiding targeted coaching and player development. The biomechanical analysis conducted during training sessions revealed several key insights into player technique and stability. On average, head stability during shot impact was recorded at 83%, indicating a generally strong foundation for shot execution. Players 3 and 5 demonstrated excellent bat control and consistent back-lift, particularly under pace, whereas Players 2 and 4 showed inconsistencies when facing faster deliveries. Stride length was found to be optimal in Players 1 and 3, contributing to better balance and shot execution, while others exhibited either shorter or excessively aggressive steps that compromised their posture and stability. Additionally, shot judgment was consistently accurate against spin deliveries, but several players faced difficulties when responding to in-swinging deliveries, often misjudging the line.

Furthermore, reaction time trends suggest that Player 3 consistently performs under pressure, indicating superior anticipation and reflexes. Footwork efficiency strongly correlated with higher shot perfection scores, reinforcing the value of balanced movement in stroke execution. The analysis also highlighted that fatigue-induced form breakdown became evident after extended sessions, particularly in Players 2 and 4, signaling the need for improved endurance training. Biomechanical variability across sessions underscores the importance of consistent monitoring to detect early signs of performance decline or potential injury. These insights enable coaches to implement more personalized, data-informed training plans, fostering long-term athletic development and competitive readiness.

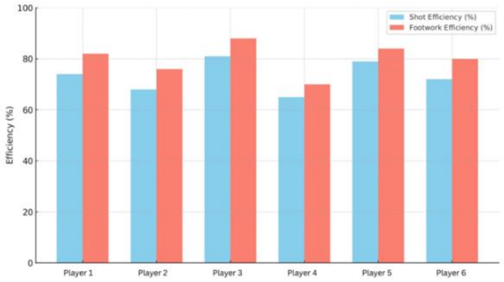

Fig 5. Shot Efficiency and Footwork

The visual comparison of Shot Efficiency and Footwork Efficiency for each player shown above. It clearly shows individual strengths for example, Player 3 leads in both metrics, while Player 4 has room for improvement in both shot and footwork efficiency

SOFTWARE HOMESCREEN

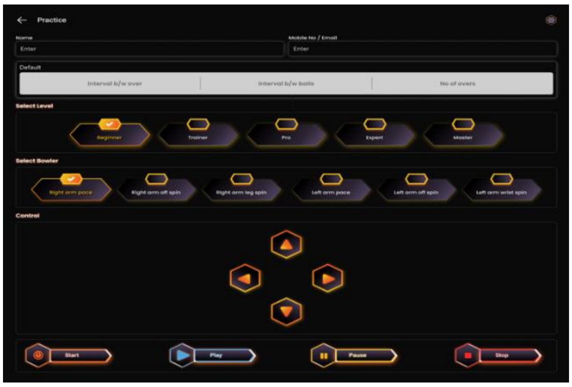

Fig 6. Software Homescreen

The software home screen provides a user-friendly interface for cricket practice session configuration. Users can input their name and contact details to initiate a personalized training session. The platform allows selection of difficulty levels ranging from Beginner to Master, catering to various skill levels. Players can also choose specific bowler types including Right Arm Pace, Off Spin, Leg Spin, and Left Arm variations, enhancing realism and customization. Control arrows offer positional and delivery adjustments, simulating real-time pitch conditions. The user sets intervals between balls and overs, tailoring session pace and intensity. Once configured, the session begins with the Play button, while Pause and Stop controls manage session flow. The Start button activates session recording, ensuring performance data is stored. This intuitive layout supports both casual learners and advanced players, making it suitable for individual practice or structured training. The visual design, with highlighted controls and glowing effects, ensures clarity and ease of use. Overall, the software provides an efficient and engaging platform for cricket skill development.

VI. CONCLUSION

The seamless integration of the ball release mechanism, bowler animation synchronization, and intelligent video replay significantly elevates the realism and analytical capabilities of cricket training. This advanced system offers players immediate, actionable feedback and provides coaches with comprehensive video and data archives to inform skill development and injury prevention strategies. By leveraging hardware precision, real-time computing, and vision-based analytics, this next-generation simulator represents a transformative leap in sports technology. It turns standard video footage into a powerful source of biomechanical and fitness insights—without the need for intrusive wearables or complex lab setups. Combining both overhead and frontal camera perspectives, the system delivers a holistic assessment of a batsman's posture, movement, and power mechanics. This capability supports personalized training programs, promotes safer playing techniques, and enhances overall performance, making the system an indispensable tool in the future of cricket coaching and athlete development.

REFERENCES

[1] Design and Control of a Programmable Bowling Machine for Cricket Practice - Author: Mishra S, Agarwal P & Verma A - International Journal of Mechanical Engineering and Robotics Research - [2017].

[2] Batting with an Eye on the Ball: Visual Perception in Cricket - Author: Muller S &

Abernethy B -Journal of Sports Sciences - [2006].

[3] Immersive Training with Virtual Reality in Sports A Review - Author: Stenros M, Salin K & Smed J - Sports Technology Journal - [2020].

[4] Machine Vision-Based Biomechanical Analysis in Cricket Batting - Author: Pandey R, Dutta S & Srivastava S - Procedia Computer Science Journal - [2019].

[5] Biomechanics of the Cricket Batting Stroke: Implications for Injury Prevention and Performance - Author: Glazier P.S.- Sports Medicine Journal - [2010].

[6] A Real-Time Feedback and Skill Acquisition: Applications in Sports Coaching - Author: Carson H.J, Collins D & McNamara - International Journal of Sports Science & Coaching - [2018].

[7] Development of an Immersive Baseball Batting Simulator Using Virtual Pitcher Animation and Ball Projection - Author: Yoon J, Kim Y & Lee, H - IEEE Access [2021].

[8] Technological Advancements in Cricket Training: A Review of Existing Tools and Emerging Trends - Author: Rathore A, & Singh J - Journal of Sports Technology and Analytics - [2020].