

A Multimodel Sensor Fusion Approach for Real Time Batting Performance Analysis Using IOT-Enabled Cricket Bat

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Abstract

Batting performance is heavily dependent on precise timing, swing mechanism and quality of bat-bowl contact and control. However, training is mostly subjective at the grassroots level, relying on visual judgement by coaches or self-assessment by players. These methods overlook critical micro data, not tracking exactly where the ball hits the bat, how timing fluctuates, or how consistently the swing follows its path. This limitation restricts a player's ability to identify mistakes and improve independently. The paper presents the design and development of an IOT-enabled smart cricket bat that integrates piezoelectric impact sensing, motion detection, and wireless communication to provide real-time batting performance analysis. The system captures multimodal data to assess swing speed, impact location, and timing index. To validate the effectiveness of the cricket bat system, primary data was collected using a pre-post usage survey design involving the same group of users. Initial market research identifies batting challenges while post-usage survey quantifies improvement after implementing the system. The results show immense improvement in timing clarity, sweet spot analysis, error recognition, and performance confidence. The proposed system provides the potential of multi-model sensor fusion to democratize access to objective cricket training analysis and reduce

overall reliance on subjective or virtual coaching feedback. This cricket bat technology is not just a device, but a sports management solution that addresses the biggest structural gap in the Indian ecosystem—unequal access to accessible training tools.

Keywords: Smart Cricket Bat, Inertial Measurement Unit (Imu), Piezoelectric Sensor, Measurement, Sports Analysis, Internet Of Things (Iot)

Introduction

There was an inability to identify reasons for incorrect timing of shots, unawareness of sweet spot usage, uncertain methods of swing consistency, and heavy dependence on coaches for corrective lessons. Moreover, present technological systems for batting analysis are not only cost-prohibitive but narrow in design, aiming to provide data for swing actions alone, without pertaining to bat-ball collision dynamics. The lack of affordable, objective, and bat-connected performance analysis systems leads to an immense gap between professional-level training equipment and grassroots development of cricket. Without any retrievable data, players cannot possibly improve on incorrectly executed actions, repeating the same errors without any clue as to what exactly is going wrong. The advent of Internet of Things (IOT) technology and sensor fusion can possibly fill this gap. The incorporation of vibration sensors for bat impacts along with Inertial Motion Sensing allows analysts to ascertain bat actions along with the exact points of contact of the ball to the bat. When paired with immediate data processing and user-friendly feedback mechanisms, such tools have the potential to turn opinionated batting analysis into an objective, data-oriented technique. Such subjectivity in training has been widely reported in engineering literature, where limited access to objective performance metrics restricts consistent skill development.

Review of Literature

Prior research relevant to this study spans across sports analytics, instrumented sporting equipment, and sensor-based analytics in batting performance analytics.

- **Alamar, B. and Mehrotra, V. (2011)** — Sports analytics has evolved beyond the moneyball approach to include advanced data-driven models for strategy, performance and decision making. The article highlights how modern analytics supports real-time insights and holistic team optimization across sports.
- **Cui et al. (2019)** — Enhanced the bat algorithm by integrating principal component analysis to improve optimization efficiency in high-dimension problems. Experimental results show better convergence and search performance compared to the standard bat algorithm.
- **Ng et al. (2018)** — Proposed a smart bat algorithm (SBA) to optimize the development of wireless sensor networks in 3D environments by enhancing search efficiency with decision theory. The SBA achieves better balance in coverage, connectivity and robustness compared to other meta-heuristic methods.
- **Knowles, Mather and Brooks (1996)** — Investigated cricket bat design by modelling impact vibration characteristics and validating with experimental tests. The study examines how different material and geometric properties influence bat performance including energy transfer and vibration response; the findings offer insights into optimizing bat design for improved rebound and reduced harmful vibration.
- **Sarkar (2014)** — Used triaxial accelerometer sensors to analyze cricket bat swing dynamics, showing that low-cost inertial sensors can reliably capture swing features and angles compared with traditional methods. The study validates sensor-based player performance assessment and suggests its usefulness in practice and match conditions.
- **Stretch et al. (2004)** — Analyzed how ball impact location on a cricket bat varies with player skill and stroke type using an instrumented bat and grid system. The study finds significant differences in impact position between batsmen and bowlers and identifies how impact positions relate to stroke execution and performance. This work aids coaches in objectively assessing batting technique and skill levels.
- **James, Davey, and Rice (2004)** — Presented an accelerometer-based sensor platform designed to capture cricket bat swing motion for performance analysis. The study demonstrates how inertial sensors mounted on sporting equipment can provide quantitative swing data useful for training and technique evaluation.

Objectives

1. To recognize and measure important issues pertaining to batting for amateur cricketers from data collected before using the system.
2. To assess variation in player understanding, error awareness, and performance perception regarding the proposed system through pre-post analysis.
3. To determine the effectiveness of metric-driven feedback by quantifying the qualitative responses of users into quantifiable data through the use of Likert scales.

Hypothesis

H1: Error Awareness & Confidence

- Null Hypothesis (H0.1): The use of the proposed system has no effect on the players' ability to spot errors or their confidence level regarding the execution of shots.
- Alternative Hypothesis (H1.1): Application of the proposed system remarkably enhances the awareness of errors and confidence levels among the players.

H2: Effectiveness of Metrics-Driven Feedback

- Null Hypothesis (H0.2): The use of numeric and metric measures of feedback cannot greatly improve one's perceived batting skill over and above the benefits of receiving verbal feedback alone.
- Alternative Hypothesis (H1.2): The use of numeric and metric measures of feedback can greatly improve one's perceived batting skill over and above the benefits of receiving verbal feedback alone.

Methodology

- **Primary Market Assessment** — To determine the most common problems faced in amateur cricket batting, 106 subjects completed a formal attendance-based pre-use questionnaire that explored views related to timing clarity, sweet-spot awareness, the nature of swings, mistakes identified, their confidence level with the information provided, and excitement to receive data-driven feedback. Responses were recorded on a five-point frequency scale (1–dissatisfied, 5–satisfied) using descriptive statistics as the method of evaluation. Average scores below the neutral level indicated the need for training assistance based on metrics identified.
- **Pre-Post System Evaluation** — To validate metric-based feedback, a matched pre-test and post-test study was conducted with 30 amateur players at a coaching centre located in the Dadar area of Mumbai. The location of this study represents a typical urban training environment where group or batch training is predominantly utilized without much individual attention provided to each player. Players in the study completed matched pre-use and post-use questionnaires to assess altered perception specifically regarding their level of awareness of timing, impacts, swinging motions, recognizing mistakes being made, and confidence based on feedback received, with five potential responses for each item.
- **Data Aggregation and Visualization** — For each data point, the mean Likert scale score was computed per participant at both pre-use and post-use points of the evaluation. Data points were graphed into grouped bar charts to illustrate changes in player perception and understanding following use of the system. This shows the overall positive change seen in these constructs through the practical application of the research objective. Likert-scale based pre-post evaluation has been widely used in applied sports technology and human validation to quantify changes in user perception and understanding.

Result and Analysis

Baseline Results

Overall, analysis of the 106 participants' pre-use responses indicated a low mean for most of the key batting components evaluated, and the majority of the participants did not realize that they were having difficulty with timing clarity, impact awareness, swing consistency, and overall confidence in themselves.

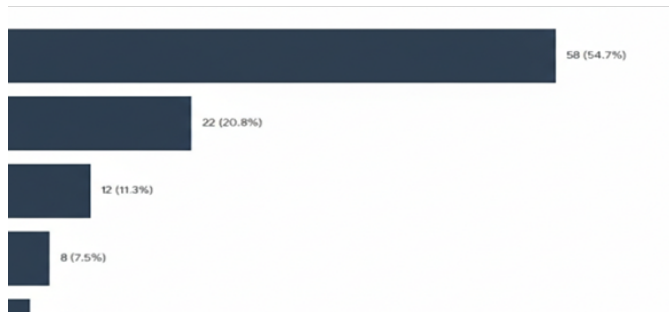


Figure 1 Comparison of pre-use mean scores across batting components (n=106).

Comparison of Pre-Use and Post-Use Mean Scores

A comparison of the pre-use and post-use mean scores from the evaluated 30 participants illustrated improvements on the following constructs: timing awareness, sweet spot recognition, swing understanding, data aggregation and visualization, and shot execution confidence.

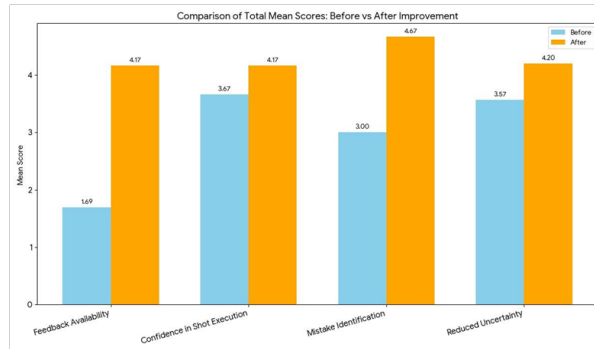


Figure 2 Pre-use vs. post-use mean scores across performance constructs (n=30).

Interpretation

- **Most significant growth** — Feedback availability experienced the most significant growth, increasing from the lowest mean of 1.69 to 4.17, suggesting a significant change/improvement in data or communication available to players.
- **Highest final score** — Error recognition had the highest post mean of 4.67, indicating a significantly improved ability of players to identify errors in their own execution of technique.
- **Overall** — All four categories had positive trends, with all post-use means greater than a score of 4.0.

Statistical Observations

- Participants expressed increased clarity regarding their batting errors and increased confidence in their ability to accurately assess their own batting performance after exposure to metric-based feedback from the evaluation.

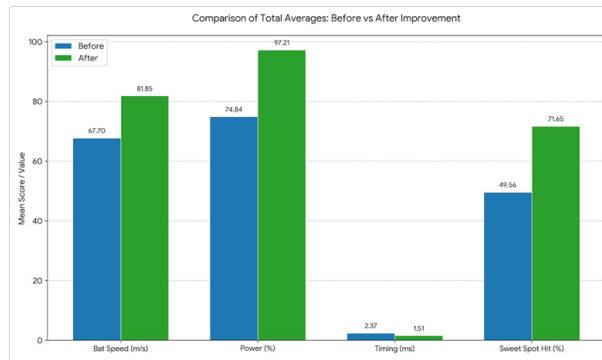


Figure 3 Objective performance metrics: pre-use vs. post-use comparison.

Interpretation

- **Most significant growth** — The average sweet spot hit saw the largest percentage increase, jumping from roughly 50% to 72%.
- **Timing Efficiency** — Timing improved by nearly 36%, with the average contact time dropping from 2.37ms to 1.51ms.
- **Power & Speed** — Both bat speed and power reached high performance levels, with power nearing a 100% average.

Hypothesis Testing

Hypothesis testing was conducted using a paired pre-post comparative approach, as the same participants provided both sets of data. Qualitative user perception data was converted to a quantitative methodology using a 5-point Likert scale, indicating degree of agreement and improvement from the experience of using the hypothesized system. H1 mean Likert scale scores related to error awareness and confidence in shot execution were compared pre and post the user experience.

The results from the analysis show that all post-use mean scores are significantly greater than pre-use means, indicating improved ability to recognize errors in shooting technique as well as increased confidence following implementation of the system. Thus, the null hypothesis H0.1 was rejected and the alternative hypothesis H1.1 was accepted.

H2 metrics (clarity, usefulness, and perceived improvement) were analysed through Likert-scale feedback on three criteria: clarity, usefulness, and improvement.

Table 1 Hypothesis Decision Table

Hypothesis	Hypothesis Statement	Basis of Testing	Findings from Analysis	Decision
H0.1	The proposed system has no effect on players' ability to spot errors or on their confidence in shot execution.	Paired pre-post comparison of Likert-scale mean scores (error awareness and confidence).	Post-use mean scores were significantly higher than pre-use means; participants reported greater clarity in identifying errors and higher confidence.	Rejected
H1.1	The proposed system remarkably enhances error awareness and confidence levels among players.	Likert-scale analysis + user perception feedback.	Error recognition recorded the highest post mean score (4.67); all constructs exceeded a mean of 4.0 post-use.	Accepted

H0.2	Numeric and metric-based feedback cannot greatly improve perceived batting skill beyond verbal feedback alone.	Likert-scale feedback on clarity, usefulness, and perceived improvement (H2 metrics).	Significant perceived improvement reported; sweet spot hit increased from ~50% to 72%, timing improved by 36%, power and confidence improved.	Rejected
H1.2	Numeric and metric-based feedback can greatly improve perceived batting skill beyond verbal feedback alone.	Likert-scale analysis + performance metrics.	Participants reported higher clarity, usefulness, and improvement; objective performance indicators also showed strong gains.	Accepted

Discussion

Overall, this research supports the finding that objectively assessed metrics led to a better understanding of batting by improving awareness of errors and improving perceived performance level. Similar limitations in grassroots coaching have been documented in sports technology studies, emphasizing the absence of accessible and data-supported feedback mechanisms.

The research illustrates significant weaknesses in amateur-level cricket coaching settings, which primarily rely on verbal and observational feedback. The research indicates that prior to using the methodology employed in this study, players struggled to comprehend timing errors, quality of impact, and swing consistency due to the lack of objective metrics data. In addition, most situations where players were coached in groups by one coach resulted in less effective outcomes per individual than in the example used for this study, where every player received their own specific time to review metrics and received greater individual engagement.

Conclusion

This paper has shown that the use of metrics-driven feedback is effective in increasing player understanding and perceived performance in cricket training settings where the dominant form of instruction is verbal. The proposed system ensures improvement in understanding, confidence, and corrective capabilities of players in coaching, owing to subjective coaching feedback being quantified using the proposed metrics system. The proposed system is validated in a practical setting, and the results indicate the value of sensor analytics in existing coaching systems.

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