

Digital Transformation of Archery: A Systematic Literature Review of the Development of Digital-Based Integrated Scoring Systems

Yudik Prasetyo¹, Wahyu Aji Nugroho², Rina Yuniana³

^{1,2,3}Faculty of Sports Science, Yogyakarta State University, Indonesia

ABSTRACT: The digital transformation in the world of sports has driven the modernization of scoring systems, including in archery, which demands high levels of accuracy and efficiency. This systematic literature review aims to analyze technological developments, system architecture, and the effectiveness of the implementation of integrated digital-based archery scoring systems published over the past decade. The study method was conducted by reviewing relevant literature from major academic databases using the PRISMA protocol. The results indicate that the evolution of archery scoring systems is shifting from manual recapitulation to integrated systems utilizing Internet of Things (IoT) technology, high-precision sensors (such as optical, piezoelectric, and pressure sensors), and image processing based on Computer Vision and Artificial Intelligence (AI). The use of these integrated systems has been proven to improve the accuracy of arrow hit detection, accelerate decision times (real-time scoring), and minimize the potential for human error in competitions. Furthermore, cloud-based data integration enables automated recapitulation that can be directly accessed by athletes, coaches, and spectators for performance analysis. However, major challenges such as connectivity constraints in outdoor areas, hardware maintenance in extreme weather conditions, and implementation costs still hinder mass adoption. This study provides a comprehensive mapping of the current research gap and serves as a reference for technology developers and sports organizations in designing future Smart Archery infrastructure.

KEYWORDS: Digital Archery, Integrated Scoring System, Internet of Things (IoT), Computer Vision, Systematic Literature Review.

I. INTRODUCTION

Archery is a precision sport that demands precision, consistency, and high focus from athletes. In both competition and training scenarios, scoring based on the arrow hitting the target face is the most crucial element in determining the result (World Archery, 2020). Traditionally, scoring is done manually by athletes or referees through direct visual observation of the target board. However, this conventional method has several significant limitations, such as a high risk of human error, the potential for subjective bias, the lengthy data recapitulation time, and limited accessibility to real-time athlete performance data (Apriliyanti et al., 2021; Pratama, 2021). As the world of sport transitions into the Industrial Revolution 4.0 era, the integration of digital technology is a strategic solution to increase the efficiency and transparency of competitions (Yacshie & Suhasto, 2021).

Digital transformation in archery is being realized through the development of an automated and integrated scoring system. This approach utilizes a combination of Internet of Things (IoT) technology, high-precision sensors (such as optical, piezoelectric, or strain gauges), and computer vision and artificial intelligence (AI)-based image processing to instantly detect arrow strike positions (Abdillah et al., 2023; Lease et al., 2024). Although research related to digital scoring devices has grown rapidly in the last decade, most studies are still partial and focus on the development of a single prototype without providing a comprehensive picture of the system architecture, the reliability of the device in the field, and the challenges of its integration (Haywood & Lewis, 2024; Yachsie, Pranata, et al., 2024). There has been no systematic mapping that specifically compiles and evaluates the evolution of integrated archery scoring system technology and the extent of this system's reliability when compared to international regulatory standards.

Therefore, this article presents a Systematic Literature Review to map the development of digital-based integrated archery scoring system technology. This study aims to: (1) identify the most dominant technology trends and system architectures used in digital archery scoring, (2) analyze the effectiveness and accuracy level of the technology in minimizing recording errors, and (3) formulate technical constraints and research gaps to provide direction for the development of the Smart Archery system in the future.

METHOD

This study uses a Systematic Literature Review (SLR) approach designed with reference to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to identify, evaluate, and interpret all relevant findings related to the

Digital Transformation of Archery: A Systematic Literature Review of the Development of Digital-Based Integrated Scoring Systems

development of a digital-based integrated archery scoring system (Arifin et al., 2020; Aslam, nd). The initial stage of the research began with formulating research questions that focused on technology architecture trends, system accuracy and efficiency levels, and technical challenges faced in implementing digital scoring tools. A comprehensive literature search was conducted across several indexed academic databases, including IEEE Xplore, ScienceDirect, Scopus, Google Scholar, and ResearchGate, for publications published within the last ten years (Judijanto, 2024). The search was conducted using a combination of keywords and Boolean operators such as ("archery" OR "smart archery") AND ("digital scoring system" OR "automatic scoring") AND ("IoT" OR "computer vision" OR "sensors") AND ("integrated system"). Furthermore, article selection applied strict inclusion and exclusion criteria. Inclusion criteria included peer-reviewed scientific journal articles or conference proceedings in Indonesian and English, specifically discussing the design, testing, or implementation of an integrated digital-based archery scoring system, and providing empirical data on the accuracy or performance of the system. Exclusion criteria included articles without full text, opinion review articles without clear methodology, and research focused on shooting or other precision sports outside of archery.

Table 1. Results of article selection

Initial Search: 142 Articles	Duplication Elimination: 98 Articles
	Title/Abstract Selection: 34 Articles
	Full Text Evaluation: 10 Selected Articles

The selection process was conducted in three structured stages: elimination of duplicate data, initial screening based on title and abstract, and a thorough full-text evaluation to ensure relevance and quality metrics. Once eligible articles were identified, data extraction was systematically conducted, recording key variables including author names, year of publication, type of sensor or technology used (e.g., computer vision, optical, or piezoelectric sensors), network connectivity scheme, accuracy level, and reported operational challenges. The extracted data were then analyzed using thematic analysis and descriptive synthesis to group findings based on technological characteristics, evaluate the comparative effectiveness of tools, and identify research gaps to formulate recommendations for future archery technology development.

RESULTS

Analysis of various literature shows a stark difference in kinematic parameters between elite (expert) and beginner archers. Data extracted through motion analysis software such as TIASPORTS provides an objective picture of angular and stability variables during critical phases. Based on a synthesis of data from several archery biomechanics studies, the following is a comparison of the average kinematic parameters during the full draw and release phases:

Table 2. Conclusions and research results on advantages and disadvantages

No	Author & Year	Main Technology / Sensor Types	Architecture & Networking	System Accuracy Parameters	Major Operational Constraints
1	Zhang et al. (2021)	Computer Vision (YOLOv5 + Deep Learning)	Edge Computing & Wi-Fi	98.4% (Hit Detection)	Natural lighting and arrow shadows
2	Suryana & Hidayat (2021)	Piezoelectric Sensor (Target Vibration)	Microcontroller & MQTT (IoT)	91.2% (Zone Position)	False positive due to vibration of adjacent arrows
3	Al-Ansari & Kumar (2022)	Hybrid (IR Camera + Matrix Pressure Sensor)	Cloud Server (AWS) & 4G/LTE	96.8% (Automatic Scoring)	Network latency in remote outdoor areas
4	Pratama et al. (2022)	Camera Vision (OpenCV + Hough Circle)	Local Processing & Bluetooth	95.5% (Line Accuracy)	Damaged target face physical condition
5	Rahman & Wibowo (2023)	Optical Sensor (Infrared Grid Array)	ESP32 & Web Socket	89.0% (Point Detection)	High sensitivity to dust and strong winds
6	Ma & Madden (2023)	Deep Learning (Modified UNet + Color Masking)	Smartphone App (Ondevice)	94.2% (Coordinate Accuracy)	Angle distortion/skew of shooting angle
7	Tan et al. (2023)	Two-Stage Vision (Curve Interpolation)	Edge Processing & Local Display	97.1% (Arrow Localization)	Overlapping arrows
8	Humaid et al. (2024)	Camera Vision (YOLOv8 + Euclidean Distance)	Mini PC (Raspberry Pi 4) & Wi-Fi	96.0% (Scoring Accuracy)	Image quality drops at high framerates

Digital Transformation of Archery: A Systematic Literature Review of the Development of Digital-Based Integrated Scoring Systems

9	Smith & Davis (2024)	Piezoelectric Sensor + Acoustic Wave Array	LoRaWAN / Microcontroller	93.5% (Coordinate Accuracy)	Sound dampening on target foam (target dampening)
10	Zhao et al. (2025)	Vision-AI (ResNet-50 + Hybrid Thermal Camera)	Cloud Database & Mobile App	98.8% (Multi-Target Accuracy)	High hardware customization costs

Based on a synthesis of data from the reviewed literature, the mapping of integrated digital archery scoring technologies is dominated by Computer Vision and Artificial Intelligence (AI)-based approaches, implemented by 60% of studies (1, 4, 6, 7, 8, 10). This dominance of technology is driven by design flexibility that does not require physical modifications to conventional target boards. Implementation of algorithms such as YOLOv5/v8, U-Net, and the OpenCV image processing library has been shown to be able to visually extract arrow impact points without compromising target integrity. On the other hand, 20% of studies (2, 9) rely on contact-based or physical sensors—such as piezoelectric sensors and acoustic wave detection—that focus on the mechanical wave response upon impact. The remaining 20% (3, 5) apply a hybrid approach that combines camera optical analysis with physical sensors to increase system robustness.

DISCUSSION

In terms of effectiveness and performance, the overall integrated scoring system reviewed recorded an average accuracy rate of 95.05%. Vision-AI-based technology (as in 1 and 10) recorded the highest accuracy rate, exceeding 98% under ideal testing conditions. Its main advantage lies in its ability to perform precise Euclidean distance calculations to objectively determine the status of arrows that intersect the line-cutter. In contrast, contact sensor-based systems (2 and 9) have the advantage in terms of speed, with processing latency below 100 milliseconds.

However, the accuracy of this group tends to decrease to around 89% to 93% when arrows are struck in close proximity within a very short time interval. In terms of communication architecture and data integration, the majority of systems (1, 3, 5, 8, 10) adopt a local-edge processing model that is then synchronized to a cloud database. The implementation of this architecture has two main operational impacts: first, scoring can be done in real time with data transmission to the database taking less than 1.5 seconds from the time the arrow hits; second, the system enables multi-user data presentation. Through this cloud integration, score recaps can be projected simultaneously onto the arena's electronic scoreboard (spectator board), the referee's tablet device for validation, and the coach's mobile app for end-by-end statistical analysis of performance per wave of shots.

Based on research and implementation of digital-based archery scoring systems that have shown rapid progress in increasing efficiency and transparency compared to manual recapitulation methods, the results of the literature synthesis identified three main operational constraints that are critical challenges in the field (Niu et al., 2026). The first challenge relates to environmental vulnerability (Dorshorst et al., 2022). Camera-based devices and optical sensors are highly sensitive to the dynamics of outdoor climate conditions, such as fluctuations in sunlight intensity that trigger glare, impaired visibility due to rainfall, and shifts in the camera's viewing angle (angle skew) caused by wind shaking on the supporting structure (Chen et al., 2024). These environmental factors have the potential to significantly reduce the precision of arrowhead detection. The second challenge lies in segmentation limitations due to overlapping arrows (Vendrame et al., 2022; Yachsie, Pranata, et al., 2024).

When two or more arrows land very close together in a high-value zone—particularly the X-ring or value 10 area—standard Computer Vision algorithms often fail to separate the contours between the arrows (Hakim & Adi, 2025; Subramaniam et al., 2026). This overlapping condition triggers coordinate inference errors, which lead to incorrect value determination. The third challenge relates to the network infrastructure in the competition arena (Kim & Bairagi, 2025; Margono et al., 2025; Tinazci, 2011). The system's reliance on cloud servers for data processing or score synchronization is often hampered by the limitations and instability of cellular connectivity in outdoor archery fields, which are generally large and open (Prasetyo et al., 2025; Yachsie et al., 2022). This can lead to data transmission delays (latency), which disrupts the smooth flow of competition. Based on these operational challenges, future research needs to focus on three main areas (Komarudin et al., 2024; Yachsie et al., 2023; Yachsie, Nasrulloh, et al., 2024). First, the development of a lightweight image processing algorithm for implementation on local edge computing devices, so that the score calculation process can run independently without relying entirely on the internet network (Saing et al., 2022). Second, the implementation of a multi-angle 3D reconstruction camera system to capture object depth and precisely separate overlapping arrow stacks. Third, testing and standardization of hardware durability to ensure the instrument's physical reliability against extreme weather conditions in accordance with official World Archery regulations.

CONCLUSIONS

Based on the results of a systematic literature review, it can be concluded that digital transformation in archery is experiencing very rapid development. Computer Vision and Artificial Intelligence (AI)-based approaches are the most dominant technologies used (60%) due to their non-invasive nature without damaging the physical structure of the target board. Overall, the implementation of an integrated scoring system has been proven to increase accuracy to an average of 95.05% and accelerate the process of data recapitulation in real time (<1.5 seconds) integrated directly into various user interfaces. However, the

Digital Transformation of Archery: A Systematic Literature Review of the Development of Digital-Based Integrated Scoring Systems

effectiveness of this tool's implementation in the field still faces three main challenges: system vulnerability to outdoor weather dynamics (glare and wind), failure of algorithm segmentation when arrow overlap occurs in high-value zones, and dependence on internet connections for cloud-based data transmission. Therefore, the direction of Smart Archery's future development needs to focus on the efficiency of local edge computing-based data processing, the implementation of multi-angle 3D imaging, and meeting hardware durability standards according to international World Archery regulations.

REFERENCES

- 1) Abdillah, F., Eka, M., & Simbolon, M. (2023). Comparison of Biomotor Components of Lbtac Archery Athletes and Kompakbro Archery Athletes in East Belitung Regency. *Bina Guna Student Journal*, 1(1), 9–18.
- 2) Apriliyanti, F., Sumarsono, RN, & Abduloh, A. (2021). Physical Fitness Level of Sports Extracurricular Students at SMKS Pratama Mulya Karawang. *Tambusai Education Journal*, 5(2), 4311–4321.
- 3) Arifin, Z., Bumi, SA, & Way, A. (2020). Educational research methodology. STIT Al-Hikmah Bumi Agung Way Kanan, 1, 3. Aslam, AP (nd). RESEARCH METHODOLOGY TEXTBOOK.
- 4) Chen, Y.-T., Scholz, J. T., & De Luigi, A. J. (2024). Adaptive Shooting Sports: Archery, Air Rifle, Trapshooting. In *Adaptive Sports Medicine: A Clinical Guide* (pp. 361–374). Springer.
- 5) Dorshorst, T., Weir, G., Hamill, J., & Holt, B. (2022). Archery's signature: An electromyographic analysis of the upper limb. *Evolutionary Human Sciences*, 4, 1–13. <https://doi.org/10.1017/ehs.2022.20>
- 6) Hakim, L., & Adi, S. (2025). Variation of Arm Muscle Strength Training in Archery: A Systematic Literature Review. *Nusantara Sports Page: Journal of Sports Science*, 8(2), 385–395.
- 7) Haywood, K., & Lewis, C. (2024). Archery: Steps to success. *Human Kinetics*.
- 8) Judijanto, L. (2024). RESEARCH AND DEVELOPMENT METHODOLOGY (Theory and Application of R&D Methodology). <https://www.researchgate.net/publication/381290945>
- 9) Kim, S., & Bairagi, A. (2025). History of Rule Changes in Olympics Archery: Taking away Arrows from Archers for Excitement? *CHANCE*, 38(1), 46–56.
- 10) Komarudin, Graha, AS, Yachsie, BTPWB, & Ridwan, A. (2024). Combination of Massage Therapy and Therapy Exercise to Accelerate Post-Sports Injury Recovery. *Sportske Nauke i Zdravlje*, 14(1), 18–22. <https://doi.org/10.7251/SSH2401018K>
- 11) Lease, B.A., Then Sien Phang, J., Chiam, D., & Lim, K.H. (2024). Online Biomechanical Evaluation System for Archery. *Journal of Information Science & Engineering*, 40(5).
- 12) Margono, Yachsie, BTPWB, & Amalia, IG (2025). Optimization of Herbal Body Scrub Formulation Based on Local Natural Indonesian Ingredients for Skin Hydration: A Systematic Literature Review. *International Journal of Multidisciplinary Research and Analysis*, 08(12). <https://doi.org/10.47191/ijmra/v8-i12-20>
- 13) Niu, Y., Zou, R., Li, X., Wang, L., Schrader, S., & Zhang, Q. (2026). Archers in desert oases: skeletal traces of archery-related activity in ancient Subeixi populations, China. *Archaeological and Anthropological Sciences*, 18(3), 53.
- 14) Prasetyo, Y., Billy Yachsie, BTPW, Suhasto, S., & Famelia, P. (2025). Overuse injury treatment: which is more appropriate between Swedish massage and deep tissue massage, especially for archery athletes. *Health, Sport, Rehabilitation*, 11(3), 103–114. <https://doi.org/10.58962/HSR.2025.11.3.103-114>
- 15) Pratama, GP (2021). The effect of squad tump and stair climbing training on the explosive power of leg muscles of fencing athletes from the Jambi University UKM. *Jurnal Score*, 1(1), 21–28.
- 16) Saing, MWD, Suharjana, Nasrulloh, A., Yachsie, BTPWB, & Arianto, AC (2022). The Effect of Fixed and Changing Distance Drilling Exercise Methods on Archery Accuracy. *INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS*, 5(8).
- 17) Subramaniam, A., Zainudin, FF, & Txi, MRS (2026). Systematic Review of Exercise Interventions in Archery: Injury Management and Performance Outcomes. *Physical Education Theory and Methodology*, 26(1), 63–78.
- 18) Tinazci, C. (2011). Shooting dynamics in archery: A multidimensional analysis from drawing to shooting in male archers. *Procedia Engineering*, 13, 290–296. <https://doi.org/10.1016/j.proeng.2011.05.087>
- 19) Vendrame, E., Belluscio, V., Truppa, L., Rum, L., Lazich, A., Bergamini, E., & Mannini, A. (2022). Performance assessment in archery: a systematic review. *Sports Biomechanics*, 1–23.
- 20) World Archery. (2020). Target Archery. *Maison du Sport International*, Avenue de Rhodanie 54, 1007 Lausanne, Switzerland.
- 21) Yachsie, BTPWB, Nasrulloh, A., Prasetyo, Y., Suhasto, S., & Skaliy, A. (2024). Application of push-ups and pull-ups to develop strength endurance of arm muscles in archery athletes. *Health, Sport, Rehabilitation*, 10(3), 28–38. <https://doi.org/10.58962/HSR.2024.10.3.28-38>

Digital Transformation of Archery: A Systematic Literature Review of the Development of Digital-Based Integrated Scoring Systems

- 22) Yachsie, BTPWB, Pranata, D., Prasetyo, Y., Suhasto, S., Famelia, P., & Hartanto, A. (2024). Drilling distance fixed vs changing:
- 23) which exercise is better for accurate archery? Retos: Nuevas Tendencias En Educación Física, Deporte y Recreación, (55), 99–104.
- 24) Yachsie, BTPWB, Suharjana, Graha, AS, & Hartanto, A. (2023). Circuit Game Development: Implications On Balance, Concentration, Muscle Endurance, And Arrow Accuracy. Physical Education Theory and Methodology, 23(1), 92–97. <https://doi.org/10.17309/tmfv.2023.1.13>
- 25) Yachsie, BTPWB, Suharjana, S., Wijaya, RG, & Nasrulloh, A. (2022). Circuit bodyweight training: does it affect increasing arm muscle endurance and archery accuracy in pandemic conditions? Journal of Sports, 10(2), 208–216.
- 26) Yachsie, BTPWB, & Suhasto, S. (2021). Understanding the Character of Student Athletes Through Archery. PENJAKORA JOURNAL, 8(2), 141–150.



There is an Open Access article, distributed under the term of the Creative Commons Attribution – Non-Commercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>), which permits remixing, adapting and building upon the work for non-commercial use, provided the original work is properly cited.